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REVISED FINAL TECHNICAL MEMORANDA ECOLOGICAL RISK-BASED SURFACE SOIL REMEDIATION EVALUATION FOR IR PROGRAM SITES 06, 10, and 11

Naval Construction Battalion Center Davisville, Rhode Island

Contract No. N62472-92-D-1296
Contract Task Order No. 0032

Prepared for

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Northern Division
Naval Facilities Engineering Command
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1-20-98

James Shultz — Date
CTO Manager

1-20-98

Charles Flynn — Date
Program Manager

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TECHNICAL MEMORANDUM

Ecological Risk-Based Surface Soil Remediation Evaluation For IR Program Site 06

Naval Construction Battalion Center
Davisville, RI

16 January 1998

TECHNICAL MEMORANDUM

TO: Christine Williams, EPA Region I and Richard Gottlieb, RIDEM

FROM: Philip Otis, Navy RPM, NCBC Davisville

SUBJECT: Ecological Risk-Based Soil Remediation Evaluation at IR Site 06

The information provided in this Technical Memorandum serves to document evaluations of ecological risk from surface soil at Site 06. The format has evolved through iterative discussions among the Navy, EPA, and other members of the BCT. In August 1996, the Navy submitted to the BCT a protocol to address the need for remediation of surface soil at IR sites at NCBC (*Use of Ecological Risk Assessment Results to Support Remedial Decision-Making: An Example at the NCBC Davisville*). This protocol employed a stepwise process of balancing ecological risk estimates for surface soil with available toxicological-based screening criteria and background information. The protocol culminates in a judgement regarding the need for remediation of surface soil at a site. After extensive comment by EPA and other reviewers, the Navy prepared and submitted in December 1996 a document, *Technical Memoranda and Responses to Comments on Soil and Related Ecological Risk Evaluations at NCBC Sites 06, 10, and 11* (EA 1996a). In addition to the site-specific soil-remediation evaluations, this document contained the Navy's responses to comments on the August 1996 draft of the protocol, and responses to outstanding comments of the February 1996 *Draft Final Facility-Wide Freshwater/Terrestrial Ecological Risk Assessment* (EA 1996b). Based on review of this document and subsequent discussions among all parties, the Navy submitted in February 1997 several text sections that EPA wanted to have included in the Technical Memos. These text sections concerned additivity of similar chemical constituents, selection of the risk threshold for the soil evaluation, documentation of soil benchmark criteria, and a revised metals screen of NCBC data. These were reviewed, revised, and are incorporated herein for Site 06.

Soil-Based Remediation Evaluation Protocol

The protocol consists of 10 sequential steps directed at identifying and validating chemical risk drivers, selecting Preliminary Remediation Goals (PRGs), and determining the need for, and extent of, remediation of surface soil.

Step 1 Conduct the ERA--for Site 06 and other NCBC sites, the baseline document is the *Facility-Wide Freshwater Terrestrial Ecological Risk Assessment at NCBC Davisville* (EA 1996b).

Step 2 Select a Risk Threshold--A Hazard Quotient (HQ) of 10 is selected as a threshold for terrestrial-based Receptors of Concern (ROC) (robin, hawk, shrew) based on the maximum Constituent of Concern (COC) concentration in surface soil in the watershed containing the IR site (data based on ERA modeling). The robin, hawk, and shrew, unlike other receptors such as the great blue heron and mink, receive their entire chemical dose via surface soil, either through the food web or by direct ingestion. Therefore, basing the soil-remediation evaluation on these receptors is the most conservative approach. (Reader note that the potential for chemical constituents in Site 06 and other IR site soils having been transported to nearby watershed sediment and surface water is evaluated under separate cover in a report, *Watershed Evaluation Report.*)

Step 3 Identify Watershed-Specific Risk Drivers--All COC/ROC HQ combinations in the watershed that exceed the risk threshold are identified (data from ERA Table 6-9).

Step 4 Determine if Risk Drivers Occur at Site Being Evaluated and, if so, Validate Risk Drivers--If none of the risk drivers occur at the site in question (they are at one or more other sites in the watershed), then the process stops here for this site. If risk driver(s) occur at the site in question, then maximum soil concentrations at the site are compared to published benchmark soil concentrations (background, criteria, detection limits). This comparison allows one to evaluate whether the HQ(s) represent unacceptable risk, and is necessitated by the sizable uncertainty associated with the TRVs (Toxicity Reference Values) used in the food-web modeling. If benchmark data and elevated HQs are few, this comparison may be done as a tabulation. If not, visual displays are employed (Step 5).

Step 5 Create Decision Diagram for Ecological Risk-Based Cleanup (DDERC)--If a number of HQs and benchmark data are involved, the risk validation of step 4 is best done graphically.

Step 6 Select an Ecological Risk-Based Preliminary Remediation Goal (PRG)--Using the graphical and/or tabular data, a PRG is identified that will reduce ecological risk to desired level.

Step 7 Identify Sample Locations Exceeding PRG in Site Under Investigation

Step 8 Repeat Steps 4 Through 7 for Each Designated Risk Driver COC

Step 9 Determine Extent of Projected Site-Specific Remediation

Step 10 If Necessary, Reassess PRG Selection in Light of Projected Level of Remediation Effort and Ecological Risk Reduction--The PRG selection and proposed remediation effort are evaluated in light of perceived risk reduction and take into account the areal extent of COCs and other factors.

As indicated above, the EPA and other reviewers raised several issues bearing on earlier drafts of the Technical Memo protocol for ecological risk-based soil-remediation evaluation. They asked that these issues be addressed in the Technical Memoranda. Each of the four issues is addressed below, prior to actually describing the soil protocol-evaluation results for Site 06.

HQ=1 vs. HQ=10 for Risk Management Threshold

The Navy's use of HQ=10 as a threshold for evaluating the necessity for remediation (Step 2 above) was questioned by reviewers. The concern was raised that a real risk could be overlooked by ignoring HQs < 10. The Navy's position on this has to do with the difference between risk assessment and risk management.

A threshold of HQ=1 was used in the ERA document (February 1996) to select COCs and to model ecological risks to terrestrial receptors. Selecting a threshold of HQ=1 is generally appropriate at this stage to avoid false negatives (i.e., concluding there is *de minimus* risk when, in fact, significant risks may exist).

In contrast to the ERA, this Technical Memorandum is a risk management document designed to support remedial decision-making for soils at Site 06. A threshold of HQ=10 is used in this risk management Technical Memorandum to help identify chemical constituents that are risk-drivers. To do this, one must filter some of the "noise" present in the ERA. We have selected a threshold of HQ=10 based, in part, on general guidance offered by Menzie et al. (1993) for interpreting the importance of HQs.

- HQ between 1.0 and 10 suggests some small potential for environmental effects
- HQ between 10 and 100 suggests a significant potential that greater exposures could result in environmental effects
- HQ greater than 100 indicates that effects may be expected

Menzie et al. (1993) suggest that HQs greater than 1.0 do not necessarily indicate that an effect will occur, but only that a lower threshold of toxicity may have been exceeded. This guidance is based on a great deal of data and experience of the authors conducting a variety of ecological risk assessment projects.

By basing the site-specific action/no action remedial decision on a threshold above which there is a *significant potential that greater exposures could result in environmental effects*, an environmentally protective decision has been preserved. In contrast, basing a cleanup decision solely on a HQ=1 (*small potential for environmental effects*) provides only marginal incremental environmental protection but at a much higher cost.

Guidance provided by EPA for conducting ecological risk assessments at Superfund sites (EPA 1994) also suggests that one should manage risk at the remedial assessment stage to a level less restrictive than that represented by an HQ=1. The HQ ratio is based on the following.

$$HQ = \frac{Estimated\ Exposure}{Toxicity\ Benchmark}$$

To be conservative, the estimated exposures represent an upper bound calculation based on maximum site concentrations. The Toxicity Benchmark is an exposure associated with no chronic, sublethal toxic effects. In practice, the values is a published or estimated NOAEL (No Observable Adverse Effect Level). During the risk assessment, both the estimated exposure and Toxicity Benchmark are selected to be environmentally conservative to avoid false negatives. Thus, if the HQ is less than 1.0, one can be very certain that no unacceptable impacts are occurring or can be expected. If the HQ exceeds 1.0, there is some probability (negligible to high) of effect (risk). Due to its conservative nature, HQs that exceed 1.0 by a small amount are probably not "risky" (hence, the guidance from Menzie et al. [1993] as discussed above).

EPA (1994) recommends that risk management decisions should lead to an action that will result in residual contaminant levels that are somewhat above the NOAELs. This translates into a HQ >1. This is precisely what is done in this Technical Memorandum when a HQ=10 is used as a threshold to begin the risk management process.

Benchmark Screening Value Documentation

The appropriateness of the benchmark screening values used in Step 4 of the protocol was questioned by reviewers. The expressed concern was that some or all of the benchmark values may not be ecologically relevant. The Navy agreed to document the nature of the benchmark values, to the extent possible, for those values used in this Site 06 Technical Memorandum, as follows.

20 mg/kg Oak Ridge earthworm screen for cadmium (Will and Suter 1995a) - This benchmark value is based on 16 toxicity studies conducted with earthworms in the laboratory. Test species included *Eisenia fetida, E. andrei, Lumbricus rubellus* and *Dendrobaena rubida*. Endpoints included survival growth and reproduction. Exposure was in soil of various types ranging from sand to horse manure. Although the earthworm was not designated as a formal ROC in the Facility-Wide ERA, it is nonetheless an important and integral component of the ecosystem at NCBC. Their presence at NCBC was confirmed by field sampling in spring 1995. The specimens collected were analyzed for tissue concentrations of chemical constituents, and the results used in food web modeling in the ERA. Their close contact with the soil makes them an excellent indicator of risk levels from soil constituents.

3 mg/kg **Oak Ridge plant screen for cadmium (Will and Suter 1995b)** - This benchmark value is based on 26 toxicity studies conducted with plants exposed via soil. Tested species included a wide variety of agricultural plants, grains, grasses, flowers and trees. Growth was by far the most common test endpoint. Most test soils were representative of agricultural loam.

5 mg/kg **Beyer (Dutch) screen for cadmium (Beyer 1990)** - The technical basis for this benchmark value is unknown. Beyer adopts the 5 mg/kg concentration from a secondary source, the "B" value soil criteria promulgated under the Dutch Soil Cleanup (Interim) Act. Beyer does not discuss the technical basis for the Dutch criteria. Our own investigations indicate the "B" values are probably based on a consideration of background and toxicological studies (human health and ecological). Only a translation of the original technical documents (in Dutch) upon which the Dutch criteria are based, can reveal the exact technical nature of this benchmark value.

0.22 - 3.5 mg/kg **Rhode Island background range for cadmium (O'Conner1995)** - The technical basis for this range of benchmark values is that it represents the range of cadmium concentrations representative of background conditions in Rhode Island soil. The latter are based on a Rhode Island Department of Environmental Management, Division of Site Remediation, compilation of metals concentrations from 106 background sites throughout the state.

0.52U - 0.59U mg/kg **NCBC background surface soil, cadmium**

Additivity of Chemical Effects

EPA and other reviewers expressed concern that the effects of some constituents may be additive if the effects are expressed in a similar mode and/or target organ of the receptor. This is not taken into account in the present protocol which deals with individual constituents only if they exceed HQ=10 (Step 2 above). The circumstance was proposed whereby several constituents with similar mode and target organ may individually have HQs less than 10, but collectively could add up to greater than 10 and represent collective risk. The Navy agreed to identify those chemical constituents that were detected at Site 06 and which had food-web based HQs greater than 1.0, and to do a systematic literature search for pertinent information on additive effects of chemicals. The results of this search were provided to reviewers in late February 1997, and are summarized below.

The constituents that were detected in Site 06 surface soil, and which produced HQs > 1 for at least one terrestrial receptor, included seven metals: arsenic, barium, cadmium, lead, manganese, vanadium, and zinc. Several PAHs, including anthracene, benzo[a]anthracene, and phenanthrene, were also reported in surface soil at the site.

Several national data bases and resources were accessed, of which the National Library of Medicine's Hazardous Substances Data Bank (HSDB) proved to have the most pertinent information. The search focused on identifying toxicity data and modes of action, particularly for oral exposure routes for non-human terrestrial receptors (mice, rats, guinea pigs, and birds). In general the search revealed little pertinent information on "target organs" and the toxicological mode of action was not always clearly identified. The similarity of target organ(s) and mode of action is critical to the acceptance of additivity of chemical effects.

Of the two classes of constituents identified at Site 06—metals and PAHs—the clearest case of additivity potential exists for PAHs. PAHs such as anthracene, benzo[a]anthracene, and phenanthrene are reported to cross nuclear membranes and bind with DNA. This event is believed to initiate effects that are manifested in different ways (e.g., enzyme induction, carcinogenesis). The primary target organ for PAHs appears to be the liver.

The potential for additivity among metals is much less clear. To provide clarity, it is useful to group metals into categories following Klaassen et al. (1986). Two of the metals at Site 06— manganese and zinc—fall into the category of essential trace elements. In "trace" concentrations, these are required for normal biological function. Determining the threshold between concentrations of these metals that are physiologically essential, and those that may be detrimental or toxic, is very difficult, if at all possible. At high concentrations, manganese has been shown to affect the central nervous system in mammals, by interfering with synaptic transmission. Manganese toxicity has been reported to increase with exposure to lead, and decrease with exposure to vanadium. In mammals, most zinc is present in muscle, bone, liver, kidney and pancreas tissues. It can cause depression of the central nervous system, lowered leucocyte counts, and enteritis. Zinc deficiency is more common than poisoning, and antagonism has been reported between zinc and cadmium.

Barium and vanadium are considered "Minor Toxic Metals" that are not known to be essential nor highly toxic. The literature on barium is very limited. No relevant target organ studies were listed, and HSDB reported “No Data” for modes of action. Accidental poisoning from ingestion of soluble barium salts by humans resulted in gastroenteritis, muscular paralysis, decreased pulse rate and ventricular fibrillation. The chemistry of vanadium is complex. Elevated exposures have been reported to affect the blood, liver, kidney and spleen. Hormone effects have been reported in pigeons. Toxicity of vanadium has been attributed to enzyme inhibition (e.g., ATPase). Interactions with other metals (Cu, Cr, Mn, Zn) is inconsistent, and probably related to vanadium speciation.

Several metals, including cadmium and lead at Site 06, are grouped as "Toxic Metals with Multiple Effects." Toxicity is moderated somewhat by their induction of intracellular metallothioneins (MT), which are low molecular-weight proteins rich in sulfhydryl residues. However, if the magnitude and/or duration of metal exposure is sufficient, the ameliorating effects of MT is overridden, and toxic effects may ensue. The presence of MT greatly confounds the additivity criteria of similar modes of action and target organs. Cadmium affects primarily the kidney and liver, with renal dysfunction being the major effect on humans. Cadmium is poorly absorbed via oral exposure (5-8%), and toxicity is believed to occur after the MT binding capacity is exceeded. Lead affects primarily the central nervous system, the hematopoietic system and the renal system. The mode of action appears to be the uncoupling of oxidative phosphorylation and ion transport. Exposure to lead induces MT synthesis, and zinc in the diet with lead protected horses against toxic effects.

The results of the literature search clearly do not support any attempt to quantify additive effects. There are too many unknowns and uncertainties, not the least of which involves the lack of (or confounding nature of) information on target organs and modes of action—the mechanisms that must be documented before additivity can be accepted. The prudent risk assessor and risk manager must remain aware of the potential for additive effects, notwithstanding the lack of any basis for quantifying such effects. At best, additivity may be incorporated into risk management judgements in a qualitative fashion, particularly if the evidence of additivity is fairly strong, such as for PAHs.

With regard to the current soil-remediation evaluation of Site 06, the potential for additivity does not appear to warrant concern. As noted above, seven metals resulted in HQs > 1 for one or more terrestrial receptors (based on the ERA COC screening procedure comparing maximum watershed concentrations to three times mean background concentrations). None of the HQs exceeded 10 (see subsequent discussion of cadmium), and they were distributed among three different receptors, the robin, hawk, and shrew. Of the three PAHs detected in Site 06 soils, none produced HQs >1 (reader note that the HQs > 1 for anthracene/hawk, benzo[a]anthracene/shrew, and phenanthrene/robin in Table 6-9 of the ERA were driven by detection limits; Hazard Indices (HIs) calculated for these PAHs and receptors using the highest detected concentrations [Tables A-74 and A-76, August 1995 ERA] at Site 06 were all less than 1).

"New" COCs in Hall Creek Watershed

The COC-screening procedure employed in the February 1996 Freshwater/Terrestrial ERA was criticized by reviewers because the maximum site concentrations were not compared to mean background concentrations. The concern was that a constituent could represent a risk, and yet not be chosen as a COC and further evaluated. Because this could have implications in this surface soil risk-management evaluation, the Navy agreed to re-screen the analytical data, report any "new" COCs, and address these herein in the context of Site 06.

COCs selected in the ERA were determined by comparing maximum on-site concentration to three times the mean site-specific (NCBC) background level and appropriate benchmark screening values. Constituents that exceeded both screens were retained as COCs. If there was no benchmark screen, the constituent was retained as a COC.

To address reviewer concerns, an additional background screen was conducted to ensure hot spots did not pass through the screening process undetected. For this second screen, the maximum watershed concentration was compared to the mean background level (EA 1996a). When this was done, the following constituents in surface soil and sediment were identified, and termed "new COCs."

Aluminum (sediment)
Arsenic (surface soil)
Manganese (surface soil)
Lead (sediment)

Three of these (arsenic, manganese, lead) had already been identified as COC in another medium. When a COC was identified in at least one medium, it was retained as a COC in all media. That constituent in all media was included in the terrestrial food web model for the watershed (ERA). Therefore, there is really only one “new” COC (aluminum) in the Hall Creek watershed and it doesn’t represent significant ecological risk for the following reasons.

Aluminum is not a concern because 1) the maximum watershed concentration (13,000 mg/kg) is less than a benchmark value (57,000 mg/kg) and 2) the mean watershed concentration (5,356 mg/kg) is less than the mean background (5,795 mg/kg). The benchmark value represents background concentrations of aluminum in Eastern U.S. soil (Shacklette and Boerngen 1984). Aluminum is one of the most common elements in soil and sediment and it exists in several chemical states. A relatively small fraction of the total aluminum content of soil or sediment exists in a form that can be absorbed by and is toxic to plants and animals. Aluminum must be present in very high concentrations to cause a toxic response in animals or plants. Unlike some other metals, toxicity of aluminum to plants is at least equal to that of animals.

Application of Ecological Risk-Based Soil-Remediation Evaluation at Site 06

Description of Site 06

This site is a flat, grassy area, approximately 1/4-acre in size, located between Buildings 38 and 67 near the intersection of Exeter and Bristol streets in the eastern portion of NCBC. The eastern boundary is fenced parallel to Exeter Street, and the western portion is bounded by a paved parking lot. The site is located within the Hall Creek watershed. Between 1970 and 1972, waste chlorinated hydrocarbon solvents were reportedly disposed of in an area of the site. Phase I and II sampling conducted between 1989 and 1993 reported generally low levels of VOC and SVOC in surface soil samples, and elevated metals concentrations (Phase I).

Evaluation of Site 06

Site 06 was evaluated with the stepwise protocol described above.

Step 1 - Conduct the ERA

A Freshwater/Terrestrial Ecological Risk Assessment for NCBC was completed in 1995 and results reported in the Draft Final version dated 15 February 1996 (EA 1996b). References to ERA results herein refer to that document.

Step 2 - Select Risk Threshold

A risk threshold of HQ = 10 was chosen based on modeled results for terrestrial receptors whose food base derives ultimately from soil (rather than aquatic sediment). These receptors were the hawk, robin, and shrew.

Step 3 - Identify Watershed-Specific Risk Drivers

Identification of watershed-specific risk drivers was based on examining Table 6-9 of the Draft Final ERA. This table contains food web-based, modeled HQs based on the maximum COC concentration in a given watershed. All COC/ROC pairs exhibiting an HQ in excess of 10 for either the hawk, robin, or shrew were identified as possible risk drivers in the watershed. The maximum HQs were used in lieu of average because the latter might cause one to overlook a "risky" location in a watershed containing more than one site.

A total of 17 COC/ROC pairs exhibited HQs exceeding 10. These ranged from HQ = 20.3 for Aroclor 1254/robin to HQ = 2,508.7 for Aroclor 1260/shrew (Table 6-9, Draft Final ERA). Maximum surface soil concentrations corresponding to those values were 17.5 mg/kg Aroclor 1254 and 12,000 mg/kg for Aroclor 1260. In all, 10 COC were associated with maximum HQs exceeding 10 in Hall Creek watershed. In addition to Aroclors 1254 and 1260, there were cadmium, fluorene, DDT, DDE, Aroclor 1248, dieldrin, endrin, and endrin ketone. These are considered potential risk drivers in surface soil at one or more sites in the Hall Creek watershed.

Step 4 - Determine Occurrence and Validation of Risk Drivers

Because there are 5 IR sites in the Hall Creek watershed, the surface soil data for Site 06 were examined to determine if the site contained any of the potential risk drivers. Of 10 constituents involved, nine were not detected at all in surface soil at Site 06. Only cadmium was detected in surface soil at Site 06 at a maximum concentration of 0.75 mg/kg. Cadmium is a potential risk driver somewhere in the Hall Creek watershed because of the cadmium/shrew maximum HQ of 28.3, and associated maximum surface soil concentration of 2.35 mg/kg. However, at Site 06, the maximum surface soil concentration of 0.75 mg/kg would only produce a shrew HQ of 9. Although this is below the designated risk threshold of 10, it is prudent to examine it further to be sure that a risk from cadmium is not overlooked. This is done in Step 5.

Step 5 - Create Decision Diagram for Ecological Risk-Based Cleanup

The Site 06 maximum surface soil cadmium concentration of 0.75 mg/kg is compared in Figure 1 to various benchmark values, including soil-screening values and background. The maximum cadmium concentration at Site 06 is lower than all of the commonly available soil screening values. It exceeds the NCBC background range, but lies in the lower end of the Rhode Island background range. This information supports a judgment that cadmium in surface soil at Site 06 does not pose an unacceptable ecological risk. Also, given the scaled equivalent HQ of 9 associated with the maximum surface soil concentration at Site 06, the exercise again illustrates the conservative nature of the HQs derived via food web modeling in the Terrestrial ERA.

Due to lack of a demonstrated risk from cadmium or other COC in surface soil at Site 06, the soil-based remediation evaluation is halted at Step 5. Remediation of surface soil at Site 06 is not recommended.

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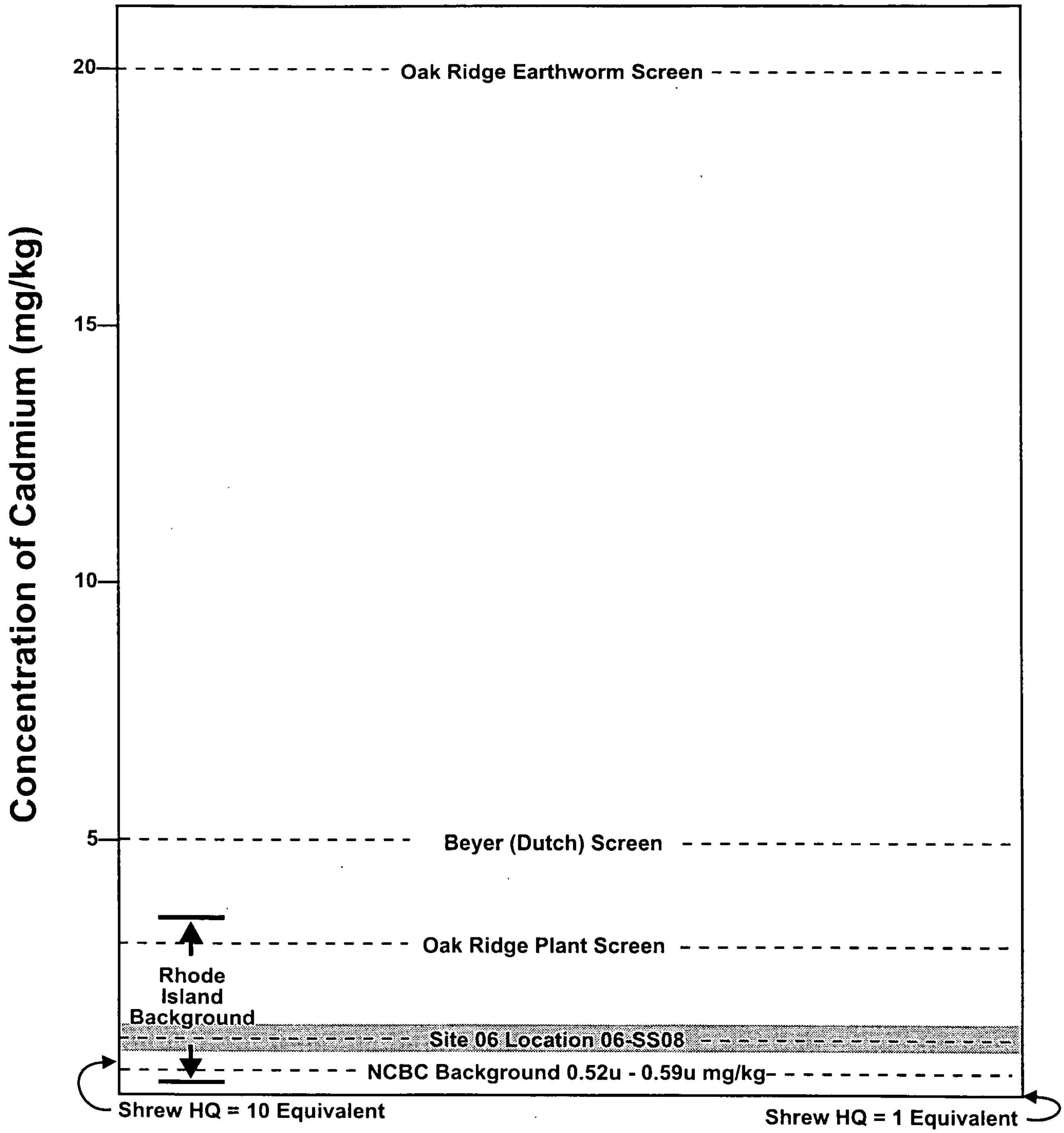

Figure 1. Concentration of cadmium in Site 06 surface soil compared to benchmark values.

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REVISED FINAL
TECHNICAL MEMORANDUM

Ecological Risk-Based Surface Soil Remediation Evaluation For IR Program Site 10

Naval Construction Battalion Center
Davisville, RI

16 January 1998

TECHNICAL MEMORANDUM

TO: Christine Williams, EPA Region I and Richard Gottlieb, RIDEM

FROM: Philip Otis, Navy RPM, NCBC Davisville

SUBJECT: Ecological Risk-Based Soil Remediation Evaluation at IR Site 10

The information provided in this Technical Memorandum serves to document evaluations of ecological risk from surface soil at Site 10. The format has evolved through iterative discussions among the Navy, EPA, and other members of the BCT. In August 1996, the Navy submitted to the BCT a protocol to address the need for remediation of surface soil at IR sites at NCBC (*Use of Ecological Risk Assessment Results to Support Remedial Decision-Making: An Example at the NCBC Davisville*). This protocol employed a stepwise process of balancing ecological risk estimates for surface soil with available toxicological-based screening criteria and background information. The protocol culminates in a judgement regarding the need for remediation of surface soil at a site. After extensive comment by EPA and other reviewers, the Navy prepared and submitted in December 1996 a document, *Technical Memoranda and Responses to Comments on Soil and Related Ecological Risk Evaluations at NCBC Sites 06, 10, and 11* (EA 1996a). In addition to the site-specific soil-remediation evaluations, this document contained the Navy's responses to comments on the August 1996 draft of the protocol, and responses to outstanding comments of the February 1996 *Draft Final Facility-Wide Freshwater/Terrestrial Ecological Risk Assessment* (EA 1996b). Based on review of this document and subsequent discussions among all parties, the Navy submitted in February 1997 several text sections that EPA wanted to have included in the Technical Memos. These text sections concerned additivity of similar chemicals, selection of the risk threshold for the soil evaluation, documentation of soil benchmark criteria, and a revised metals screen of NCBC data. These were reviewed, revised, and are incorporated herein for Site 10. It should be noted that soil samples upon which this evaluation is based were collected subsequent to a soil-removal action at the disposal area mandated by RIDEM.

Soil-Based Remediation Evaluation Protocol

Step 1 — Conduct the ERA.-for Site 10 and other NCBC sites, the baseline document is the *Facility-Wide Freshwater Terrestrial Ecological Risk Assessment at NCBC Davisville* (EA 1996b).

Step 2 — Select a Risk Threshold-A Hazard Quotient (HQ) of 10 is selected as a threshold for terrestrial-based Receptors of Concern (ROC) (robin, hawk, shrew) based on the maximum Constituent of Concern (COC) concentration in surface soil in the watershed containing the IR site (data based on ERA modeling). The robin, hawk, and shrew, unlike other receptors such as the great blue heron and mink, receive their entire chemical dose via surface soil, either through the food web or by direct ingestion. Therefore, basing the soil-remediation evaluation on these receptors is the most conservative approach. (Reader note that the potential for chemical constituents in Site 10 and other IR site soils having been transported to nearby watershed sediment and surface water is evaluated under separate cover in a report, *Watershed Evaluation Report.*)

Step 3 Identify Watershed-Specific Risk Drivers--All COC/ROC HQ combinations that exceed the risk threshold are identified (data from ERA Table 6-9).

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Step 7 Identify Sample Locations Exceeding PRG in Site Under Investigation

Step 8 Repeat Steps 4 Through 7 for Each Designated Risk Driver COC

Step 9 Determine Extent of Projected Site-Specific Remediation

Step 10 If Necessary, Reassess PRG Selection in Light of Projected Level of Remediation Effort and Ecological Risk Reduction--The PRG selection and proposed remediation effort are evaluated in light of perceived risk reduction and take into account the areal extent of COCs and other factors.

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HQ=1 vs. HQ=10 for Risk Management Threshold

The Navy's use of HQ=10 as a threshold for evaluating the necessity for remediation (Step 2 above) was questioned by reviewers. The concern was raised that a real risk could be overlooked by ignoring HQs < 10. The Navy's position on this has to do with the difference between risk assessment and risk management.

A threshold of HQ=1 was used in the ERA document (February 1996) to select COCs and to model ecological risks to terrestrial receptors. Selecting a threshold of HQ=1 is generally appropriate at this stage to avoid false negatives (i.e., concluding there is *de minimus* risk when, in fact, significant risks may exist).

In contrast to the ERA, this Technical Memorandum is a risk management document designed to support remedial decision-making for soils at Site 10. A threshold of HQ=10 is used in this risk management Technical Memorandum to help identify constituents that are risk-drivers. To do this, one must filter some of the "noise" present in the ERA. We have selected a threshold of HQ=10 based, in part, on general guidance offered by Menzie et al. (1993) for interpreting the importance of HQs.

- HQ between 1.0 and 10 suggests some small potential for environmental effects
- HQ between 10 and 100 suggests a significant potential that greater exposures could result in environmental effects
- HQ greater than 100 indicates that effects may be expected

Menzie et al. (1993) suggest that HQs greater than 1.0 do not necessarily indicate that an effect will occur, but only that a lower threshold of toxicity may have been exceeded. This guidance is based on a great deal of data and experience of the authors conducting a variety of ecological risk assessment projects.

By basing the site-specific action/no action remedial decision on a threshold above which there is a *significant potential that greater exposures could result in environmental effects*, an environmentally protective decision has been preserved. In contrast, basing a cleanup decision solely on a HQ=1 (*small potential for environmental effects*) provides only marginal incremental environmental protection but at a much higher cost.

Guidance provided by EPA for conducting ecological risk assessments at Superfund sites (EPA 1994) also suggests that one should manage risk at the remedial assessment stage to a level less restrictive than that represented by an HQ=1. The HQ ratio is based on the following.

$$HQ = \frac{Estimated\ Exposure}{Toxicity\ Benchmark}$$

To be conservative, the estimated exposures represent an upper bound calculation based on maximum site concentrations. The Toxicity Benchmark is an exposure associated with no chronic, sublethal toxic effects. In practice, the values is a published or estimated NOAEL (No Observable Adverse Effect Level). During the risk assessment, both the estimated exposure and Toxicity Benchmark are selected to be environmentally conservative to avoid false negatives. Thus, if the HQ is less than 1.0, one can be very certain that no unacceptable impacts are occurring or can be expected. If the HQ exceeds 1.0, there is some probability (negligible to high) of effect (risk). Due to its conservative nature, HQs that exceed 1.0 by a small amount are probably not "risky" (hence, the guidance from Menzie et al. [1993] as discussed above).

EPA (1994) recommends that risk management decisions should lead to an action that will result in residual contaminant levels that are somewhat above the NOAELs. This translates into a HQ >1. This is precisely what is done in this Technical Memorandum when a HQ=10 is used as a threshold to begin the risk management process.

Benchmark Screening Value Documentation

The appropriateness of the benchmark screening values used in Step 4 of the protocol was questioned by reviewers. The expressed concern was that some or all of the benchmark values may not be ecologically relevant. The Navy agreed to document the nature of the benchmark values, to the extent possible, for those values used in this Site 10 Technical Memorandum, as follows.

2 - 5.9 mg/kg Rhode Island background range for antimony (O'Conner 1995) - The technical basis for this range of benchmark values is that it represents the range of antimony concentrations representative of background conditions in Rhode Island soil. The latter are based on a Rhode Island Department of Environmental Management, Division of Site Remediation, compilation of metals concentrations from 106 background sites throughout the state.

8.7U - 9.9U mg/kg NCBC background surface soil

Additivity of Chemical Effects

EPA and other reviewers expressed concern that the effects of some chemicals may be additive if the effects are expressed in a similar mode and/or target organ of the receptor.

This is not taken into account in the present protocol which deals with individual chemical constituents only if they exceed HQ=10 (Step 2 above). The circumstance was proposed whereby several constituents with similar mode and target organ may individually have HQs less than 10, but collectively could add up to greater than 10 and represent collective risk. The Navy agreed to identify those constituents that were detected at Site 10 and which had food-web based HQs greater than 1.0, and to do a systematic literature search for pertinent information on additive effects of chemicals. The results of this search were provided to reviewers in late February 1997, and are summarized below.

The constituents that were detected in Site 10 surface soil, and which produced HQs > 1 for at least one terrestrial receptor, were four metals (lead, manganese, antimony, and zinc); the PAH compound, benzo(a)anthracene; and the pesticides DDT and dieldrin.

Several national data bases and resources were accessed, of which the National Library of Medicine's Hazardous Substances Data Bank (HSDB) proved to have the most pertinent information. The search focused on identifying toxicity data and modes of action, particularly for oral exposure routes for non-human terrestrial receptors (mice, rats, guinea pigs, and birds). In general the search revealed little pertinent information on "target organs" and the toxicological mode of action was not always clearly identified. The similarity of target organ(s) and mode of action is critical to the acceptance of additivity of chemical effects.

Of the three classes of chemicals identified at Site 10 - metals, PAHs, and pesticides - the clearest case of additivity potential exists for PAHs. Benzo(a)anthracene, among other PAHs, is reported to cross nuclear membranes and bind with DNA. This event is believed to initiate effects that are manifested in different ways (e.g., enzyme induction, carcinogenesis). The primary target organ for PAHs appears to be the liver.

The potential for additivity among metals is much less clear. To provide clarity, it is useful to group metals into categories following Klaassen et al. (1986). Two of the metals at Site 10— manganese and zinc—fall into the category of essential trace elements. In "trace" concentrations, these are required for normal biological function. Determining the threshold between concentrations of these metals that are physiologically essential, and those that may be detrimental or toxic, is very difficult, if at all possible. At high concentrations, manganese has been shown to affect the central nervous system in mammals, by interfering with synaptic transmission. Manganese toxicity has been reported to increase with exposure to lead, and decrease with exposure to vanadium. In mammals, most zinc is present in muscle, bone, liver, kidney and pancreas tissues. It can cause depression of the central nervous system, lowered leucocyte counts, and enteritis. Zinc deficiency is more common than poisoning, and antagonism has been reported between zinc and cadmium.

Antimony, reported in Site 10 surface soil, is classified as a "Minor Toxic Metal," which also includes barium and vanadium. These metals are not known to be essential nor highly toxic. The literature on antimony is sparse. No particularly relevant target organ studies were listed. Acute poisoning in rats affected the blood, and there was congestion of the heart, liver, and kidneys. HSDB reported "not data" for modes of action.

Several metals, including lead at Site 10, are grouped as "Toxic Metals with Multiple Effects." Toxicity is moderated somewhat by their induction of intracellular metallothioneins (MT), which are low molecular-weight proteins rich in sulfhydryl residues. However, if the magnitude and/or duration of metal exposure is sufficient, the ameliorating effects of MT is overridden, and toxic effects may ensue. The presence of MT greatly confounds the additivity criteria of similar modes of action and target organs. Lead affects primarily the central nervous system, the hematopoietic system and the renal system. The mode of action appears to be the uncoupling of oxidative phosphorylation and ion transport. Exposure to lead induces MT synthesis, and zinc in the diet with lead protected horses against toxic effects.

Additivity among the chlorinated hydrocarbons is also possible although the picture is less clear. DDT and dieldrin, both reported in Site 10 surface soil, are neural toxicants (primarily CNS) and adversely affect the liver. Aldrin and endrin are also neural toxicants, but were not detected in Site 10 surface soil. Based upon chemical structure and breakdown products, aldrin, dieldrin, and endrin are probably additive. One study indicated that DDT and aldrin *increased* the excretion rate of dieldrin, which would tend to minimize chemical interactions. Another reference stated that aldrin and dieldrin together reduced the toxicity of organophosphates. Another study stated that aldrin and endrin had synergistic effects in chicken egg studies. Thus, an assumption of additivity may not be unreasonable for aldrin, endrin, and dieldrin, but the inclusion of DDT is uncertain.

The results of the literature search clearly do not support any attempt to quantify additive effects. There are too many unknowns and uncertainties, not the least of which involves the lack of (or confounding nature of) information on target organs and modes of action—the mechanisms that must be documented before additivity can be accepted. The prudent risk assessor and risk manager must remain aware of the potential for additive effects, notwithstanding the lack of any basis for quantifying such effects. At best, additivity may be incorporated into risk management judgements in a qualitative fashion, particularly if the evidence of additivity is fairly strong, such as for PAHs.

With regard to the current soil-remediation evaluation of Site 10, the potential for additivity does not appear to warrant concern. The findings of the literature review on additivity of metals provides little support for such an analysis. As noted above, four metals resulted in HQs > 1 for one or more terrestrial receptors. Only one, antimony, had an HQ exceeding 10.0 for any receptor. Antimony is discussed in a subsequent section of this memo. Neither pesticide exceeded HQ=10, either individually or together. Of the PAHs detected in surface soil at Site 10, only benzo(a)anthracene produced an HQ > 1 (4.1 for the shrew, ERA Table 6-9). As is evident from Table 6-9 of the ERA, the addition of all eight PAH HQs produces a Hazard Index (HI) of only 4.5, which is well below the risk/remediation threshold for this analysis. Therefore, remediation based on combined effects of PAH compounds at Site 10 is not recommended.

"New" COCs in Hall Creek Watershed

The COC-screening procedure employed in the February 1996 Freshwater/Terrestrial ERA was criticized by reviewers because the maximum site concentrations were not compared to mean background concentrations. The concern was that a chemical constituent could represent a risk, and yet not be chosen as a COC and further evaluated. Because this could have implications in this surface soil risk-management evaluation, the Navy agreed to re-screen the analytical data, report any "new" COCs, and address these herein in the context of Site 10.

COCs selected in the ERA were determined by comparing maximum on-site concentration to three times the mean site-specific (NCBC) background level and appropriate benchmark screening values. Constituents that exceeded both screens were retained as COCs. If there was no benchmark screen, the constituent was retained as a COC.

To address reviewer concerns, an additional background screen was conducted to ensure hot spots did not pass through the screening process undetected. For this second screen, the maximum watershed concentration was compared to the mean background level (EA 1996a). When this was done, the following constituents in sediment were identified, and termed "new COCs."

Aluminum
Barium
Lead
Vanadium

Because the more conservative screening procedure produced no "new COCs" in surface soil in the Hunt River/Frenchtown Brook watershed, no additional evaluations are required in this soil remediation evaluation for Site 10. The COC list upon which the evaluation is based (Table 6-9 in ERA) is complete.

Application of Ecological Risk-Based Soil-Remediation Evaluation at Site 10

Site 10 Description

Site 10 consists of three small disposal areas totaling approximately two acres, located near an active firing range in Camp Fogarty and located four miles west of the Main Center. The site is in a low-lying area between the firing range berm and a steep hill, in an area subject to seasonal flooding. Access is restricted by fencing. Between 1950 and 1970, empty cans that had contained weapons cleaning oils and preservatives, and construction debris were disposed at the site. Phase I and II sampling revealed primarily PAH and inorganic constituents at low levels in surface soil samples.

Site 10 Evaluation

Site 10 was evaluated with the stepwise protocol described above.

Step 1 - Conduct the ERA

A Freshwater/Terrestrial Ecological Risk Assessment for NCBC was completed in 1995 and results reported in the Draft Final version dated 15 February 1996 (EA 1996b). References to ERA results herein refer to that document.

Step 2 - Select a Risk Threshold

A risk threshold of HQ = 10 was chosen based on modeled results for terrestrial receptors whose food base derives ultimately from soil (rather than aquatic sediment). These receptors were the hawk, robin, and shrew.

Step 3 - Identify Watershed-Specific Risk Drivers

Identification of watershed-specific risk drivers was based on examining Table 6-9 of the Draft Final ERA. This table contains food web-based, modeled HQs based on the maximum COC concentration in a given watershed. All COC/ROC pairs exhibiting an HQ in excess of 10 for either the hawk, robin, or shrew were identified as possible risk drivers in the Hunt River/Frenchtown Brook watershed.

Table 6-9 revealed only one HQ for terrestrial receptors in excess of 10: a maximum HQ of 19.87 was calculated for the antimony/shrew COC/ROC pair. The maximum surface soil concentration of antimony corresponding to this maximum HQ was 35.8(J) mg/kg (Table 5-7, Draft Final Terrestrial ERA). The "J" qualifier indicates that the true concentration is unknown and the given value is estimated. Antimony is considered to be a potential risk driver in surface soil in the Hunt River watershed.

Step 4 - Determine Occurrence and Validation of Risk Drivers

Because Site 10 is the only NCBC waste site in the Hunt River watershed, all surface soil samples employed in food web modeling were from Site 10. Consequently, the maximum HQ of 19.87 (ERA Table 6-9) and associated maximum surface soil concentration of 35.8 mg/kg (ERA Table 5-7) are associated with Site 10. To evaluate whether this maximum antimony concentration is a potential ecological risk in surface soil, a comparison is made below to available benchmark data, and to soil concentrations equivalent to HQs of 1 and 10.

35.8 mg/kg	Site 10 maximum antimony concentration (antimony/shrew HQ=19.87)

2.0 - 5.9 mg/kg 8.7U - 9.9U mg/kg	Rhode Island background range NCBC background range
18.0 mg/kg	Equivalent shrew HQ=10
1.8 mg/kg	Equivalent shrew HQ=1

Although benchmark data are few, the fact that the highest value (5.9 mg/kg) is six times lower than the maximum Site 10 concentration requires, in this protocol, that antimony be considered to represent potential ecological risk in surface soil.

Step 5 - Create Decision Diagram for Ecological Risk-Based Cleanup

The few HQs and minimal benchmark data obviate the need for graphical displays. The validation process was completed in step 4.

Step 6 - Select an Ecological Risk-Based Preliminary Remediation Goal (PRG)

The Navy acknowledged in the August 1996 Site 11 Demonstration the that the selection of a cleanup goal or PRG would involve a process of iteration and negotiation with EPA, RIDEM, and other appropriate parties. In the present case of antimony at Site 10, any PRG selected should fall between the highest benchmark value (5.9 mg/kg) and the maximum concentration reflecting unacceptable ecological risk (35.8 mg/kg). However, it is felt that the selection of a PRG for antimony is premature before all information is considered and an ultimate decision regarding the need for remediation is made. Additional discussion is provided under Step 10 below.

Step 7 - Identify Sample Locations Exceeding PRG

Figure C-7 from the Draft Final Terrestrial ERA is appended to this technical memo to illustrate Site 10 surface soil sampling locations. The location associated with the maximum surface soil concentration of antimony of 35.8 mg/kg is identified as sample location 10-SS09 in the northernmost disposal area.

Step 8 - Repeat Steps 4 Through 7 for Each Designated Risk Driver

Not applicable.

Step 9 - Determine Extent of Projected Site-Specific Remediation

Not applicable (see remarks under step 10).

Step 10 - If Necessary, Reassess PRG Selection in Light of Projected Level of Remediation Effort and Ecological Risk Reduction

The 35.8 mg/kg value at location 10-SS09 that is driving risk was "J" qualified, i.e., an estimated value. Of 27 sample locations (Figure C-7), only five produced analytical detections of antimony, and four of these—including the 35.8 mg/kg value—were estimated values. Only one unqualified concentration was reported, 9.2 mg/kg at sampling location S-10-04-00-S. This concentration was the second highest reported and it equates to a shrew/antimony HQ of 5.3. The fact that antimony was detected in only a few samples, and the single sample "driving" risk is based on a questionable (estimated) concentration, support a decision not to undertake remediation of surface soil due to antimony concentration at Site 10.

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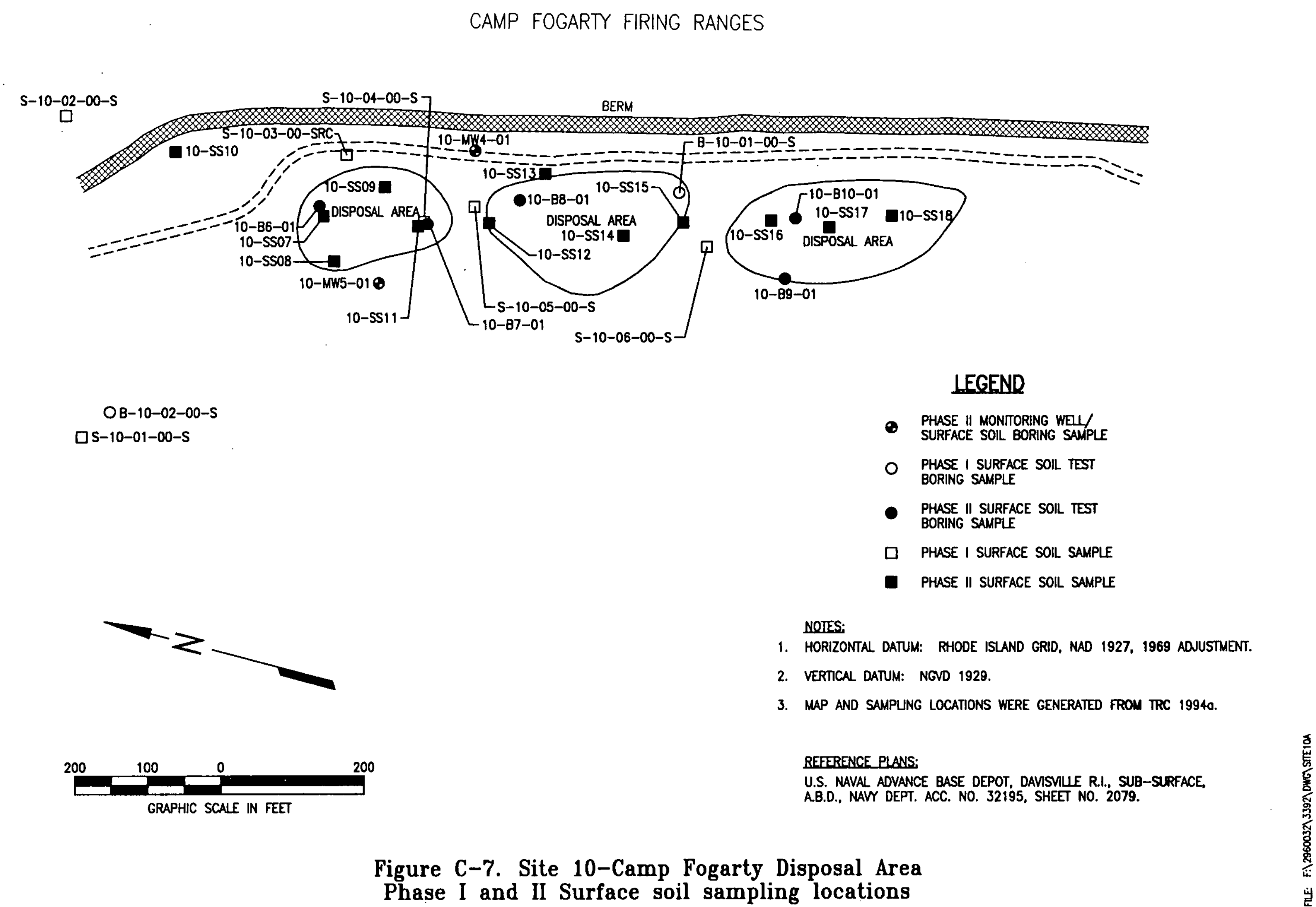

Figure C-7. Site 10-Camp Fogarty Disposal Area Phase I and II Surface soil sampling locations

REVISED FINAL
TECHNICAL MEMORANDUM

Ecological Risk-Based Surface Soil Remediation Evaluation For IR Program Site 11

Naval Construction Battalion Center
Davisville, RI

16 January 1998

TECHNICAL MEMORANDUM

TO: Christine Williams, EPA Region I and Richard Gottlieb, RIDEM

FROM: Philip Otis, Navy RPM, NCBC Davisville

SUBJECT: Ecological Risk-Based Soil Remediation Evaluation at IR Site 11

The information provided in this Technical Memorandum serves to document evaluations of ecological risk from surface soil at Site 11. The format has evolved through iterative discussions among the Navy, EPA, and other members of the BCT. In August 1996, the Navy submitted to the BCT a protocol to address the need for remediation of surface soil at IR sites at NCBC (*Use of Ecological Risk Assessment Results to Support Remedial Decision-Making: An Example at the NCBC Davisville*). This protocol employed a stepwise process of balancing ecological risk estimates for surface soil with available toxicological-based screening criteria and background information. The protocol culminates in a judgement regarding the need for remediation of surface soil at a site. After extensive comment by EPA and other reviewers, the Navy prepared and submitted in December 1996 a document, *Technical Memoranda and Responses to Comments on Soil and Related Ecological Risk Evaluations at NCBC Sites 06, 10, and 11* (EA 1996a). In addition to the site-specific soil-remediation evaluations, this document contained the Navy's responses to comments on the August 1996 draft of the protocol, and responses to outstanding comments of the February 1996 *Draft Final Facility-Wide Freshwater/Terrestrial Ecological Risk Assessment* (EA 1996b). Based on review of this document and subsequent discussions among all parties, the Navy submitted in February 1997 several text sections that EPA wanted to have included in the Technical Memos. These text sections concerned additivity of similar chemicals, selection of the risk threshold for the soil evaluation, documentation of soil benchmark criteria, and a revised metals screen of NCBC data. These were reviewed, revised, and are incorporated herein for Site 11.

Soil-Based Remediation Evaluation Protocol

The protocol consists of 10 sequential steps directed at identifying and validating chemical risk drivers, selecting Preliminary Remediation Goals (PRGs), and determining the need for, and extent of, remediation of surface soil.

Step 1 Conduct the ERA--for Site 11 and other NCBC sites, the baseline document is the *Facility-Wide Freshwater Terrestrial Ecological Risk Assessment at NCBC Davisville* (EA 1996b).

Step 2 Select a Risk Threshold--A Hazard Quotient (HQ) of 10 is selected as a threshold for terrestrial-based Receptors of Concern (ROC) (robin, hawk, shrew) based on the maximum Chemical of Concern (COC) concentration in surface soil in the watershed containing the IR site (data based on ERA modeling). The robin, hawk, and shrew, unlike other receptors such as the great blue heron and mink, receive their entire chemical dose via surface soil, either through the food web or by direct ingestion. Therefore, basing the soil-remediation evaluation on these receptors is the most conservative approach. (Reader note that the potential for chemical constituents in Site 11 and other IR site soils having been transported to nearby watershed sediment and surface water is evaluated under separate cover in a report, *Watershed Evaluation Report.*)

Step 3 Identify Watershed-Specific Risk Drivers--All COC/ROC HQ combinations in the watershed that exceed the risk threshold are identified (data from ERA).

Step 4 Determine if Risk Drivers Occur at Site Being Evaluated and, if so, Validate Risk Drivers--If none of the risk drivers occur at the site in question (they are at one or more other sites in the watershed), then the process stops here for this site. If risk driver(s) occur at the site in question, then maximum soil concentrations are compared to published benchmark soil concentrations (background, criteria, detection limits). This comparison allows one to evaluate whether the HQ(s) represent unacceptable risk. If benchmark data and elevated HQs are few, this comparison may be done as a tabulation. If not, visual displays are employed (Step 5).

Step 5 Create Decision Diagram for Ecological Risk-Based Cleanup (DDERC)--If a number of HQs and benchmark data are involved, the risk validation of step 4 is best done graphically.

Step 6 Select an Ecological Risk-Based Preliminary Remediation Goal (PRG)--Using the graphical and/or tabular data, a PRG is identified that will reduce ecological risk to desired level.

Step 7 Identify Sample Locations Exceeding PRG in Site Under Investigation

Step 8 Repeat Steps 4 Through 7 for Each Designated Risk Driver COC

Step 9 Determine Extent of Projected Site-Specific Remediation

Step 10 If Necessary, Reassess PRG Selection in Light of Projected Level of Remediation Effort and Ecological Risk Reduction--The PRG selection and proposed remediation effort are evaluated in light of perceived risk reduction and take into account the areal extent of COCs and other factors.

As indicated above, the EPA and other reviewers raised several issues bearing on earlier drafts of the Technical Memo protocol for ecological risk-based soil-remediation evaluation. They asked that these issues be addressed in the Technical Memoranda. Each of the four issues is addressed below, prior to actually describing the soil protocol-evaluation results for Site 11.

HQ=1 vs. HQ=10 for Risk Management Threshold

The Navy's use of HQ=10 as a threshold for evaluating the necessity for remediation (Step 2 above) was questioned by reviewers. The concern was raised that a real risk could be overlooked by ignoring HQs < 10. The Navy's position on this has to do with the difference between risk assessment and risk management.

A threshold of HQ=1 was used in the ERA document (February 1996) to select COCs and to model ecological risks to terrestrial receptors. Selecting a threshold of HQ=1 is generally appropriate at this stage to avoid false negatives (i.e., concluding there is *de minimus* risk when, in fact, significant risks may exist).

In contrast to the ERA, soil evaluation portion of this Technical Memorandum is a risk management document designed to support remedial decision-making for soils at Site 11. A threshold of HQ=10 is used in this risk management Technical Memorandum to help identify chemicals that are risk-drivers. To do this, one must filter some of the "noise" present in the ERA. We have selected a threshold of HQ=10 based, in part, on general guidance offered by Menzie et al. (1993) for interpreting the importance of HQs.

- HQ between 1.0 and 10 suggests some small potential for environmental effects
- HQ between 10 and 100 suggests a significant potential that greater exposures could result in environmental effects
- HQ greater than 100 indicates that effects may be expected

Menzie et al. (1993) suggest that HQs greater than 1.0 do not necessarily indicate that an effect will occur, but only that a lower threshold of toxicity may have been exceeded. This guidance is based on a great deal of data and experience of the authors conducting a variety of ecological risk assessment projects.

By basing the site-specific action/no action remedial decision on a threshold above which there is a *significant potential that greater exposures could result in environmental effects*, an environmentally protective decision has been preserved. In contrast, basing a clean up decision solely on a HQ=1 (*small potential for environmental effects*) provides only marginal incremental environmental protection but at a much higher cost.

Guidance provided by EPA for conducting ecological risk assessments at Superfund sites (EPA 1994) also suggests that one should manage risk at the remedial assessment stage to a level less restrictive than that represented by an HQ=1. The HQ ratio is based on the following.

$$HQ = \frac{Estimated\ Exposure}{Toxicity\ Benchmark}$$

To be conservative, the estimated exposures represent an upper bound calculation based on maximum site concentrations. The Toxicity Benchmark is an exposure associated with no chronic, sublethal toxic effects. In practice, the values is a published or estimated NOAEL (No Observable Adverse Effect Level). During the risk assessment, both the estimated exposure and Toxicity Benchmark are selected to be environmentally conservative to avoid false negatives. Thus, if the HQ is less than 1.0, one can be very certain that no unacceptable impacts are occurring or can be expected. If the HQ exceeds 1.0, there is some probability (negligible to high) of effect (risk). Due to its conservative nature, HQs that exceed 1.0 by a small amount are probably not "risky" (hence, the guidance from Menzie et al.[1993] as discussed above).

EPA (1994) recommends that risk management decisions should lead to an action that will result in residual contaminant levels that are somewhat above the NOAELs. This translates into a HQ >1. This is precisely what is done in this Technical Memorandum when a HQ=10 is used as a threshold to begin the risk management process.

Benchmark Screening Value Documentation

The appropriateness of the benchmark screening values used in Step 4 of the protocol was questioned by reviewers. The expressed concern was that some or all of the benchmark values may not be ecologically relevant. The Navy agreed to document the nature of the benchmark values, to the extent possible, for those values used in this Site 11 Technical Memorandum, as follows.

70 mg/kg **Oak Ridge earthworm screen for selenium (Will and Suter 1995a)** - This value is based on one study with the earthworm *Eisenia fetida*. Worms were exposed to selenium (as sodium arsenite) at concentrations up to 77 mg/kg added to a combination of peaty marshland soil and horse manure. Test endpoints were survival and reproduction. The reproductive endpoint showed the highest sensitivity to selenium.

1 mg/kg **Oak Ridge plant screen for selenium (Will and Suter 1995b)** - This benchmark was based on growth experiments with alfalfa and sorgrass seedlings exposed to selenium VI as Na_2SeO_4. The endpoint was shoot weight. Authors expressed low confidence in benchmark because some growth reduction was measured at 1 mg/kg, the lowest concentration tested.

2 mg/kg **Ontario screening concentration for selenium (Environment Ontario 1989)** - The technical basis for this benchmark value is unclear. The value in the source document has a footnote suggesting it is based on the health of grazing animals but no further documentation is provided. The source document recommends 2 mg/kg as the cleanup guideline for agricultural/residential/parkland land use while 10 mg/kg is recommended for commercial/industrial land use.

0.5 - 1.1 mg/kg **Rhode Island background range for selenium (O'Conner 1995)** - The technical basis for this range of benchmark values is that it represents the range of selenium concentrations representative of background conditions in Rhode Island soil. The latter are based on a Rhode Island Department of Environmental Management, Division of Site Remediation, compilation of metals concentrations from 106 background sites throughout the state.

0.71U - 0.84 mg/kg **NCBC surface soil background for selenium**

Additivity of Chemical Effects

EPA and other reviewers expressed concern that the effects of some chemicals may be additive if the chemical effects are expressed in a similar mode and/or target organ of the receptor. This is not taken into account in the present protocol which deals with individual chemicals only if they exceed HQ=10 (Step 2 above). The circumstance was proposed whereby several chemicals with similar mode and target organ may individually have HQs less than 10, but collectively could add up to greater than 10 and represent collective risk. The Navy agreed to identify those chemicals that were detected at Site 11 and which had food-web based HQs greater than 1.0, and to do a systematic literature search for pertinent information on additive effects of chemicals. The results of this search were provided to reviewers in late February 1997, and are summarized below.

The chemicals that were detected in Site 11 surface soil, and which produced HQs > 1 for at least one terrestrial receptor, were six metals (arsenic, cadmium, manganese, mercury, selenium, and vanadium); one PAH (benzo[a]anthracene); and three pesticides/PCBs (DDT, aldrin, and Aroclor-1254) (based on Table 6-9, February 1996 Freshwater/Terrestrial ERA).

Several national data bases and resources were accessed, of which the National Library of Medicine's Hazardous Substances Data Bank (HSDB) proved to have the most pertinent information. The search focused on identifying toxicity data and modes of action, particularly for oral exposure routes for non-human terrestrial receptors (mice, rats, guinea pigs, and birds). In general the search revealed little pertinent information on "target organs" and the toxicological mode of action was not always clearly identified. The similarity of target organ(s) and mode of action is critical to the acceptance of additivity of chemical effects.

Of the three classes of chemicals identified at Site 11, the clearest case of additivity potential exists for PAHs. Some PAHs, including the benzo[a]anthracene at Site 11, are reported to cross nuclear membranes and bind with DNA. This event is believed to initiate effects that are manifested in different ways (e.g., enzyme induction, carcinogenesis). The primary target organ for PAHs appears to be the liver.

The potential for additivity among metals is much less clear. To provide clarity, it is useful to group metals into categories following Klaassen et al. (1986). Two of the metals at Site 11— manganese and selenium—fall into the category of essential trace elements. In "trace" concentrations, these are required for normal biological function. Determining the threshold between concentrations of these metals that are physiologically essential, and those that may be detrimental or toxic, is very difficult, if at all possible. At high concentrations, manganese has been shown to affect the central nervous system in mammals, by interfering with synaptic transmission. Manganese toxicity has been reported to increase with exposure to lead, and decrease with exposure to vanadium. Liver and kidney are the principal sites of deposition of selenium. HSDB reported "No Data" for mode of action of selenium. Reproductive anomalies have been reported in mammals and birds. Selenium is reported to protect biota from toxic effects of arsenic, cadmium, copper, mercury, and silver.

Vanadium is grouped with antimony and barium as "Minor Toxic Metals" that are not known to be essential nor highly toxic. The chemistry of vanadium is complex. Elevated exposures have been reported to affect the blood, liver, kidney and spleen. Hormone effects have been reported in pigeons. Toxicity of vanadium has been attributed to enzyme inhibition (e.g., ATPase). Interactions with other metals (Cu, Cr, Mn, Zn) is inconsistent, and probably related to vanadium speciation.

Several metals, including cadmium and mercury at Site 11, are grouped as "Toxic Metals with Multiple Effects." Toxicity is moderated somewhat by their induction of intracellular metallothioneins (MT), which are low molecular-weight proteins rich in sulfhydryl residues. However, if the magnitude and/or duration of metal exposure is sufficient, the ameliorating effects of MT is overridden, and toxic effects may ensue. The presence of MT greatly confounds the additivity criteria of similar modes of action and target organs. Cadmium affects primarily the kidney and liver, with renal dysfunction being the major effect on humans. Cadmium is poorly absorbed via oral exposure (5-8%), and toxicity is believed to occur after the MT binding capacity is exceeded. Mercury primarily affects the kidney, liver, and intestinal tract. It forms covalent bonds with sulfur, thereby inactivating sulfhydryl enzymes and adversely affecting cellular respiration. Mercury has been shown to bind to selenium with antagonistic effects on toxicity.

Additivity among chlorinated hydrocarbons at Site 11—such as DDT, aldrin, endrin, dieldrin, and Aroclor-1254—is also possible although the picture is less clear. The first four are neural toxicants (primarily CNS) and adversely affect the liver. Aroclors affect the liver, kidney, and reproductive system. Based upon chemical structure and breakdown products, aldrin, endrin, and dieldrin are probably additive. One study indicated that DDT and aldrin *increased* the excretion rate of dieldrin, which would tend to minimize chemical interactions.

Another reference stated that aldrin and dieldrin together reduced the toxicity of organophosphates. Another reference stated that aldrin and endrin had synergistic effects in chicken egg studies. Thus, an assumption of additivity may not be unreasonable for aldrin, endrin, and dieldrin, but the inclusion of DDT and Aroclor-1254 is uncertain.

The results of the literature search clearly do not support any attempt to quantify additive effects. There are too many unknowns and uncertainties, not the least of which involves the lack of (or confounding nature of) information on target organs and modes of action—the mechanisms that must be documented before additivity can be accepted. The prudent risk assessor and risk manager must remain aware of the potential for additive effects, notwithstanding the lack of any basis for quantifying such effects. At best, additivity may be incorporated into risk management judgements in a qualitative fashion, particularly if the evidence of additivity is fairly strong, such as for PAHs.

With regard to the current soil-remediation evaluation of Site 11, the potential for additivity does not appear to warrant concern. The findings of the literature review on additivity of metals provides little support for such an analysis. As noted above, six metals resulted in HQs > 1 for one or more terrestrial receptors. Only one, selenium, had an HQ exceeding 10.0 for any receptor. Selenium is discussed in a subsequent section of this memo. Of the PAHs detected in surface soil at Site 11, only benzo(a)anthracene produced an HQ > 1 (3.8 for the shrew, ERA Table 6-9). As is evident from Table 6-9 of the ERA, the addition of all sixteen PAH HQs produces a Hazard Index (HI) of only 4.9 for the shrew, which is well below the risk/remediation threshold for this analysis. Therefore, remediation based on combined effects of PAH compounds at Site 10 is not recommended. Additivity of chlorinated hydrocarbons is questionable, as noted above, but assuming a relationship between aldrin and dieldrin, the highest possible Hazard Index at Site 11 is 2.1 for the hawk (from ERA Table 6-9), a value which is clearly below the remediation/risk threshold.

"New" COCs in Hall Creek Watershed

The COC-screening procedure employed in the February 1996 Freshwater/Terrestrial ERA was criticized by reviewers because the maximum site concentrations were not compared to mean background concentrations. The concern was that an analyte could represent a risk, and yet not be chosen as a COC and further evaluated. Because this could have implications in this surface soil risk-management evaluation, the Navy agreed to re-screen the analytical data, report any "new" COCs, and address these herein in the context of Site 11.

COCs selected in the ERA were determined by comparing maximum on-site concentration to three times the mean site-specific (NCBC) background level and appropriate benchmark screening values. Analytes that exceeded both screens were retained as COCs. If there was no benchmark screen, the analyte was retained as a COC.

To address reviewer concerns, an additional background screen was conducted to ensure hot spots did not pass through the screening process undetected. For this second screen, the maximum watershed concentration was compared to the mean background level. When this was done, the following analytes in surface soil and sediment were identified, and termed "new COCs."

Aluminum (sediment)
Chromium (sediment)
Copper (sediment)
Nickel (sediment)
Beryllium (surface soil)
Manganese (surface soil)

Because this Technical Memo for Site 11 is concerned with the potential need for remediation of surface soil, only the beryllium and manganese "new COCs" in surface soil are pertinent. However, in the food-web modeling in the ERA, all analytes were evaluated that had been designated as COCs in any medium. Since beryllium and manganese had been designated as COCs in sediment in the ERA (ERA Table 4-8) and consequently modeled, they are not, in fact, "new" and the COC list in Table 6-9 of the ERA is complete for the purposes of this Technical Memo.

Application of Ecological Risk-Based Soil-Remediation Evaluation at Site 11

Site 11 Description

Site 11 is the former Fire-Fighting Training Area located in the Mill Creek watershed (ERA Figure 3-1). The site is a mowed, grassy field with several large unvegetated areas where fire training exercises had been conducted between 1942 and 1955. Unknown quantities of waste oil, solvents, and other materials were poured onto the ground and ignited and then extinguished. Storm drains on this site drain to nearby Mill Creek. During Phase I and II remedial investigations, thirty-nine surface soil samples were collected (ERA Figure C-8) to characterize nature and extent.

Site 11 Evaluation

Site 11 was evaluated with the stepwise protocol described above.

Step 1 - Conduct the ERA

A Freshwater/Terrestrial Ecological Risk Assessment for NCBC was completed in 1995 and results reported in the Draft Final version dated 15 February 1996 (EA 1996b). References to ERA results herein refer to that document.

Step 2 - Select Risk Threshold

A risk threshold of HQ = 10 was chosen based on modeled results for terrestrial receptors whose food base derives ultimately from soil (rather than aquatic sediment). These receptors were the hawk, robin, and shrew.

Step 3 - Identify Watershed-Specific Risk Drivers

Identification of watershed-specific risk drivers was based on examining Table 6-9 of the Draft Final ERA. This table contains food web-based, modeled HQs based on the maximum COC concentration in a given watershed. All COC/ROC pairs exhibiting an HQ in excess of 10 for either the hawk, robin, or shrew were identified as possible risk drivers in the watershed.

Because the potentially contaminated area at Site 11 is surface soil, HQs were employed from those receptors whose entire exposure dose via the food web is derived from surface soil, i.e., robin, hawk, and shrew. The maximum watershed model results (ERA Table 6-9) were examined to identify any HQs > 10 for these receptors. In the Mill Creek Watershed which contains Site 11, one COC/receptor pair produced an HQ > 10: selenium/shrew (HQ=16.9).

The DDT HQs of 55.3 and 71.9 for the robin and hawk, respectively in Table 6-9 of the Draft Final ERA are based on an erroneous literature value for the TRV. Since this TRV was low by one order-of-magnitude, the corrected HQs would be 5.5 and 7.2, respectively. Therefore, DDT does not require evaluation under this technical memo protocol.

Step 4 - Determine Occurrence and Validation of Risk Drivers

Site 11 is the only IR site in the Mill Creek watershed, thus the identified HQ of 16.9 for selenium/shrew resulted from Site 11 surface soil data. The potential of selenium as a risk driver at Site 11 is evaluated under Step 5.

Step 5 - Create Decision Diagram for Ecological Risk-Based Cleanup

The maximum concentration of selenium is compared to available benchmark data in Figure 1. The maximum site concentration falls below the Oak Ridge earthworm and Ontario screening values, but slightly exceeds the Oak Ridge plant screening benchmark. The maximum site concentration equals the upper end of the Rhode Island background range for selenium, and slightly exceeds the NCBC background range. The fact that the site value is near both Rhode Island and NCBC background ranges provides little support for remediation of selenium. Also, the maximum site 11 concentration of 1.1 mg/kg is based on a non-detect value of 2.2 mg/kg (ERA Table A-45, August 1995). Whereas use of one half the detection limit of a non-detect value is appropriate in the ERA, it is not appropriate in the present context of remediation evaluation. The highest detected concentration of selenium at Site 11 was 0.72 mg/kg (ERA Table A-49, August 1995). Referencing this value to Figure 1, it is apparent that the maximum detected concentration of selenium at Site 11 is below the available toxicologically-based screening benchmarks and within both the Rhode Island and NCBC background ranges. Another ameliorating factor is that the value of 0.72 mg/kg represents the only sample among 32 collected in which selenium was detected. Consequently, the process terminates here as there is no need to investigate individual sample data for possible remediation. No remediation of surface soil is warranted at this site.

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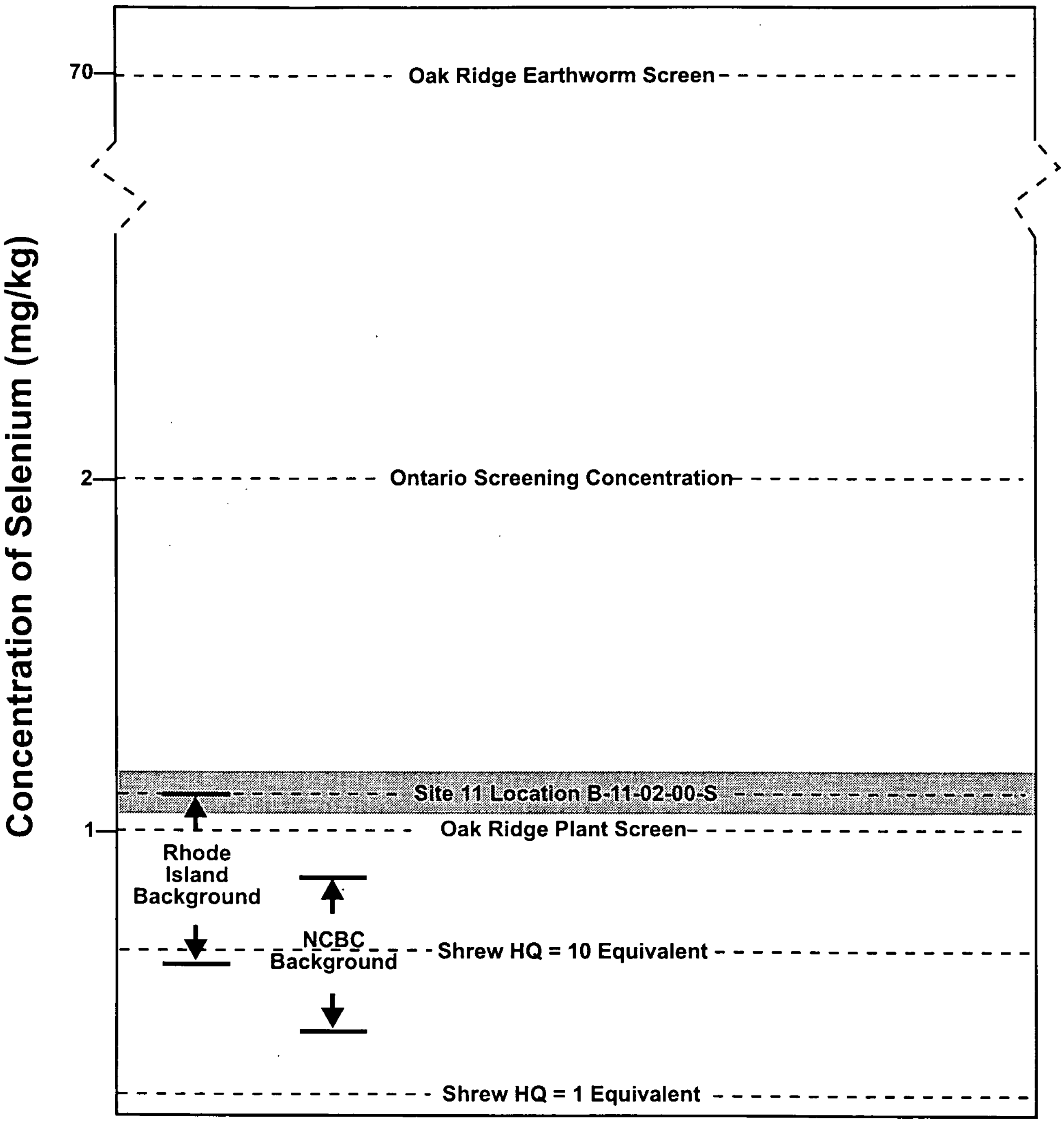

Note: Lower End of NCBC Background Range = 1/2 Detection Limit.

Figure 1. Concentration of selenium in Site 11 surface soil compared to benchmark values.

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