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Creosote Treated Timber in the Alaskan Marine Environment

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13. ABSTRACT (Maximum 200 words)

Creosote is a wood preservative that is used in marine structures in Alaska, such as piles, docks, and floating structures. Some of the PAH chemicals in creosote are toxic to marine organisms, and resources agencies and environmental groups question its use. Meso-scale testing of creosoted wood has not indicated significant negative effects of wood treated with Best Management Practices (BMP), which is now standard practice. The EPA pesticide recertification of creosote required only the use of BMP or a risk assessment. The National Marine Fisheries Service issued draft guidelines for wood preservatives, which does not preclude use of creosote, but suggest a risk assessment if the qualities of treated wood are large or they are installed in sensitive areas. This report recommends consideration of the risks of creosote and presents an algorithm for analyzing the risks. Many applications require only an overview risk assessment. Applications of large quantities of preserved wood or in sensitive areas should have a more formal risk assessment. The report and the EPA recertification suggest a screening assessment published by the Western Wood Preservers Institute. If the screening indicates further assessment is needed, the report points to more detailed assessments.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

Creosote Treated Timber in the Alaskan Marine Environment: a Report to the Alaska Department of Transportation and Public Facilities

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Front cover photo: Removing Creosote Piles, Washington State Ferries.

Contents

EXECUTIVE SUMMARY

The Alaska Department of Transportation (ADOT) is responsible for many structures that incorporate wood pilings and other timber in Alaskan waters. Most of these are treated with preservative to inhibit marine borers that will quickly destroy unprotected wood. Creosote is generally the most economical method of wood preservation and has been in use for over a hundred years. It is preferred by owners of marine structures because of its economy and efficiency. Creosote contains many toxic chemicals and some governments and organizations are limiting creosote use. This report reviews the current science regarding the use of creosoted wood in marine waters, the current regulatory matrix that controls its use, and develops recommendations for its use by the ADOT. Some future research may help clarify some issues raised.

Creosote is a coal tar product consisting mostly of polycyclic aromatic hydrocarbons (PAH). PAHs are ubiquitous in the environment and are naturally made by forest fires and anaerobic reduction of organic matter in sediments. There are many PAH chemicals that are known to be toxic to humans, marine animals, and many other forms of life. Indeed, the PAHs in creosote must be toxic to the marine borers in order to be effective. In creosote's long history of beneficial use, harmful effects on unprotected workers and environmental damage from sloppy and unregulated wood treatment plants have been a significant issue. Today, proper worker protection and careful environmental controls in the wood treatment industry have ameliorated these harms. In addition, modern use of creosote involves Best Management Practices (BMP) that leave less creosote on the surface of the timbers and specify construction processes that reduce transfer of the PAHs from the wood to the environment.

Even with BMP, PAH from new creosote timber will be transferred to the marine environment. Laboratory tests and field observations show that PAH chemicals will slowly diffuse from the wood into the water column. Then the heavier PAH chemicals sink to the bottom directly or adsorb to organic or inorganic moieties in the water and then sink. The PAH is then incorporated into the sediment. The lighter PAH chemicals are quickly volatilized and oxidized. Scientific observations of creosote behavior in meso-scale tests verify that the concentrations of PAH from marine piles in the water column are negligible, after the first few weeks. The fate of PAH in the sediment depends on the oxygen status of the upper sediment layers. If the sediment is not anoxic, the PAH will be oxidized. Hence, with sufficient oxygen in the upper layers of sediments the PAH concentration will initially rise, then decline. Thus, with BMP timber, if the sediments are not anoxic and the surrounding waters are not stagnant, and the area is not already contaminated, creosote marine timbers unlikely to have a significant long-term effect on the environment. Further, meso-scale testing has indicated that effects were confined to a region close to the structures themselves.

Are the rapidly declining levels of PAH in the water column and the slowly declining levels in the sediment nonetheless harmful to marine life? The most pertinent meso-scale tests, that installed several sets of treated and untreated piles in pristine marine waters, indicated there was not harm. However there are many papers and reports on this topic, and some do indicate harm. However most are clear that effects, if any, are limited to the timber itself and regions very close to the timber.

The only federal regulation of creosote is by the EPA under FIFRA. The EPA recently issued a favorable re-registration decision on creosote. That decision considered the ecological and economic aspects of creosote and required BMP in sensitive environments, but did not otherwise limit creosote use.

NMFS, and to a lesser extent ADF&G, are involved in decisions about wood treatment methods through a consistency review. That is, other federal agencies, especially the Army Corps of Engineers, when considering issuing a permit to construct in navigable waters, must ask other agencies to review the permit application and comment. The NMFS is always asked for this review in marine waters. They will review the application with respect to the Essential Fish Habitat (EFH) and Endangered Species Act issues. Thus, by finding that creosote treatment of wood may impact an EFH or harm a Threatened or Endangered Species (TES), the NMFS may object to the permit and based on that, the Corps may deny the permit or require other changes.

NMFS should have some definite criteria on which to base its evaluation of permit applications. Publishing definite criteria is difficult because pesticide-treated wood is a nationwide issue and there are many types of wood treatment at many locations all having different climate and ecology. Recently NMFS drafted some guidelines for all types of preservatives, including creosote, in marine waters. These and other NMFS guidance agree that creosote can be used in many marine applications, but the risks need to be evaluated for each proposed use, but the effort required to evaluate the risks should be commensurate with the likely effects and many applications could be approved without an elaborate risk evaluation. Although the NMFS Guidance is not a "cookbook" for approval or disapproval of creosote, its basic guidelines are sound. They are similar to the FIRFA regulations of the EPA and the recommendations of the Western Wood Preservers Institute.

Recommendations for use of creosote in marine waters by the ADOT.

1. Recognize that creosote does introduce contaminants into the marine waters, albeit at very low levels, and some care is needed before specifying its use.
2. Attach to each permit application that involves creosote use a brief statement that it is the material of choice in that particular application and that BMP will be specified in the materials and installation.
3. The wood preservative issue is usually a small part of a larger project, so identification of EFH and TES issues are usually needed, regardless of wood treatment. As part of the design process, note the maximum current velocity and that the sediment in not anaerobic or the site is not already heavily contaminated with PAH.

4. If the number of piles or pile equivalents is less than 100 piles, use the simple WWPI risk assessment chart that indicates if a more elaborate risk assessment is needed. If not, attach to the permit application a brief document with the current velocity, oxygen status, and other notes, to the application, that the WWPI risk assessment chart indicated more risk assessment was not required.
5. If the number of creosote piles is greater than 100, there are other creosote structures in the project or nearby, or the current and sediment parameters indicate a risk assessment is needed, there are two options: One, determine if the project at worst will effect an EFH or TES. Since any risk assessment done will be in relation to EFH and TES, if the site is a small part of the EFH and there is not a TES issue, a risk assessment might not be necessary. Two, use the more advanced recommended risk assessment models distributed by the WWPI. These are slightly more complex and require more input parameters than that matrix and yield conservative results. These models could be used by engineers or others with technical backgrounds within the ADOT.
6. Finally, at worst, unless the waters were actually stagnant, the only significant environmental effect would be the accumulation of PAH in the sediment. Installing creosote in situations where the sediment PAH will increase with time is surely not recommended, but if a situation arises where it is the only effective option, it may be acceptable. The ADOT would need to balance the effects on pubic safety and the direct effect on EFH or TES. This would probably take a consultant to evaluate these effects, although generally, sediment dwelling organisms are not a TES issue. Contamination of shellfish would need to be considered.

Other Management recommendations:

1. Some of the guidelines indicate a preference for water-borne copper-based preservatives over creosote. Copper too has toxicity issues and there are other disadvantages in Alaska. Thus we have not identified any reason to prefer copper-based over creosote in Alaska.
2. Since in almost all cases the concentrations of PAH decrease with time, there is almost never a net environmental benefit from pulling old marine piles to improve the environment.
3. It seems unlikely that creosote treated wood glulam float material would be different than the equivalent amount of wood pile material – regarding total PAH released to the environment or its fate and transport.
4. There are models for overwater creosote structures that likewise transfer to the water and sediment. These are not too complicated to use.
5. There are not standard models for structures such as bulkheads. However if the sediments are aerobic and there is reasonable current flow, for small structures, they would not be much different than the equivalent amount of wood. For larger structures, more effort would be needed to adopt the standard models.
6. Disposal of creosote treated wood is not a hazardous waste.

Chapter 1 Introduction

The Alaska Department of Transportation and Public Facilities (ADOT) is responsible for many structures that incorporate wood pilings in Alaskan marine waters. Most of these are treated with creosote, which is generally the most economical method of wood preservation. However, creosote contains many toxic chemicals, and some governments and organizations are limiting creosote use. ADOT needed to be informed about the best policies for the safe disposal of any creosoted wood removed from its structures and for making decisions about the use of creosoted wood for maintenance and new construction.

In October, 2007, ADOT contracted with the Institute of Northern Engineering of the University of Alaska Fairbanks via Task Order #RES-07-06 for a research project titled, *Environmental Impact of Creosoted Treated Marine Piles.* The objectives of that project were:

- Evaluate the current laws, regulations, and public policies, as well as their likely future changes.
- Evaluate the human and ecological risks of creosoted wood products, as they are used in Alaska.
- Evaluate alternatives to creosote, both their efficacy and safety
- Evaluate the costs of any changes to the current use of creosote, as well as the risks of not changing.

The results of these evaluations have been compiled into this report on creosote use and impacts in Alaska

The major tasks were:
Task 1. Identify and contact all interested parties,
Task 2. Literature search and report on the current status of creosote
Task 3. Economic study
Task 4. Eco-toxicity in Alaska
Task 5. PAH status of Alaska piles
Task 6. Creosote Piles in Alaska Roundtable

Based on early research and input from ADOT professionals, the original scope was modified. Creosoted wood other than piles was included in the research, such as glulam float material, bridge endwalls, and other structures. Some other needed research was identified and the proposal for that work is included in this report and the results will be reported in a separate paper when they are available.

Task 2, the literature review, was largely completed in spring 2008 and reported in a paper given at the Arctic and Marine Oilspill Program organized by Environment Canada. An updated version of that paper forms that background of this report.
Tasks 1 and 6 were completed in the summer and fall of 2008. The roundtable was held at the October 2008 convention of the Alaska Harbormasters and Port Administrators in

Haines. All of the interested parties interested in creosote were invited to the harbormasters and all were copied with the results of the roundtable meeting. Some comments on those results were received.
Task 4, the economic study, also drew some quantitative and qualitative data from the roundtable. That was supplemented with surveys and reviews for this report.
Task 4 and 5 were included in the literature review insofar as practical and an important research component was identified for future work. This is discussed in Chapter 9.

Evaluating the laws and regulations pertaining to creosote and their likely changes resulted in some interesting findings, which are discussed in depth in Chapter 7. Briefly, while the laws and regulations seems fairly stable, the guidance documents used by agencies involved in creosote-related decisions are changing and some are not final as this report is written. This requires some extrapolation for policy recommendations, but enough seems clear that these can be done. Commentaries and information on these guidance documents are contained in appendices. A second volume of this report contains those documents and commentaries, as well as catalog cuts and other information too bulky for the main report.

Recommendations to ADOT are in Chapter 8.

Chapter 2, Background

This Chapter presents a paper given at the **31st AMOP Technical Seminar on Environmental Contamination and Response** *June 3 to 5, 2008, Calgary, AB, Canada* . The paper was updated and revised slightly. The references are now in the reference section of the main report. A more complete discussions of several topics in the paper are given in other chapters of the report.

To Pull or Not to Pull: Risk Management of Creosote Piles in Marine Waters

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Abstract

Creosote, a coal tar product used as a wood preservative, contains polycyclic aromatic hydrocarbons (PAHs) known to be harmful to humans and marine organisms. Many studies indicate that PAHs from creosote-treated piles (wood columns supporting structures such as docks) leach into the surrounding waters and accumulate in marine sediments. Because of the great utility of creosote piles, they are still commonly used in most jurisdictions. Recent studies demonstrate that any lasting contamination due to installed piles is confined to a region near the pile. Do the toxic effects of creosote contamination, if any, outweigh the benefit to society from their use? Here we present a conceptual risk assessment model. We also examine some research issues that will assist risk management decisions.

1 Introduction

Wood marine piles treated with creosote are in common use in US and Canadian waters. Because of their low initial cost and ease and flexibility of installation, wood piles are frequently the most economical design solution for marine applications. However in saltwater wood is readily attacked and degraded by marine borers and must be treated with a preservative. Creosote has been the preservative of choice since the 1850s because of its durability and ability to resist attack. Creosote is the only oil-type wood preservative currently recommended for saltwater. Creosote is a mixture of many chemical constituents and their proportions vary with manufacturers and batch, but the principle components are polycyclic aromatic hydrocarbons (PAHs). Many PAHs are toxic to marine life and some are carcinogenic to humans. Special precautions are needed for workers exposed to creosote during the pile treating and installing process.

Several agencies ban or discourage using PAHs, with some agencies initiating programs to remove creosote-treated piles and replace them with steel or concrete (Washington State Ferries, 2008). Here we review the main issues regarding the use of creosote piles in northern waters and examine them in the context of a risk management decision about the future of creosote piles based on a risk assessment. Some gaps in the existing knowledge are noted and some research questions raised – the answers will enable a better evaluation.

2 Background

2.1 History

Without bacteria, fungi and insects to biodegrade cellulose and lignin, dead wood would choke the landscape. These useful forest recyclers have been the bane of civilization's wood structures. The ancient Egyptians smeared wood funerary objects with cedar oil to preserve them. In the 1800s, the American railroad industry, when faced with a shortage of durable wood for crossties, started saturating them with creosote (Smulski, 2008). Creosote is highly effective against terrestrial fungi, insects and saltwater marine borers such as crustaceans (gribbles, *limnaria* spp.) and mollusks (boring clams, *teredo* or *bankia* spp.).

2.2 Description

Although there are several standards and formulations of creosote, the American Wood-Preservers Association (AWPA) currently approves only the P1/P13 creosote standard. The AWPA defines creosote as a "100% distillate derived entirely from tar produced by the carbonization of bituminous coal." (AWPA, 2007) Currently only creosote treated to 16 to 20 pounds per cubic foot retention is recommended for saltwater use. (WWPI, 2006a) Estimates vary with wood type and installation location, but creosote-treated wood piles may last from 40 to 75 years in marine environments. They cost less than concrete or steel piles to purchase and do not require corrosion protection after installation. Installation is cheaper because of the lighter weight, flotation, and the ease of field modifications. Wood is more flexible than the alternatives and has a greater capacity to absorb shocks. On a whole project basis, wood costs about half the amount of concrete or steel (Smith, 2007).

2.3 Chemistry

Creosote is derived from coal tar. Physically, coal tars are usually black or dark brown viscous liquids or semi-solids with a naphthalene-like odor. The coal tars are complex combinations of polycyclic aromatic hydrocarbons, phenols, and heterocyclic oxygen, sulfur and nitrogen compounds. Creosote is a distillation product of coal tar with an oily liquid consistency and ranges in color from yellowish-dark green to brown. At least 75% of the coal tar creosote mixture is polycyclic aromatic hydrocarbons (PAHs). There are up to 190 identified PAHs in coal tar. Benzo[a]pyrene, a component whose individual toxicity has been examined extensively, ranges from non-detectable levels to 3.9 g/kg of coal tar (ATSDR, 2002).

2.4 Toxicity

Toxicity from human industrial exposure to coal tar and coal tar creosote is well known, and precautions are required for their safe use. Creosote is a restricted-use pesticide and only people who have been trained to use it safely are permitted to use it. (EPA, 2008) NIOSH considers coke oven emissions, including creosote, to be potential occupational carcinogens (NIOSH, 2005). Creosote can also cause chemical burns to the skin, and irritate the eyes and respiratory system. We discuss the toxicity to marine organisms below.

2.5 Occurrence

PAHs form in nature by three general routes: high-temperature pyrolysis of organic materials (forest fires); low- to moderate-temperature diagenesis of sedimentary organic material to form fossil fuels; and direct biosynthesis by many species of microbes and plants (Neff, 1979). Recent research indicates that diagenesis occurs more quickly than geologic time, and diagenetically produced PAH can be found in recent sediments. (Baker, 1980) Thus small quantities of PAH are ubiquitous in the marine and terrestrial environment. Most of the PAH found in the environment near industrialized areas is from pollution including sewage and industrial effluents, waste incineration, oil spills, asphalt production, creosote oil and the combustion of fossil fuels (Kennish, 1997). Until recently, wood treatment sites were a frequent source of contamination from creosote and other wood preservatives.

2.6 Alternatives

There are alternative materials; concrete and steel are common, as well as alternative wood preservation methods. For marine and estuarine waters, creosote is the only oil-type preservative in common use for piles. Because the tar-like surface of creosote is unsuitable for painting and foot traffic, other types of wood preservative are used in marine applications where they are not immersed in the water. Wood is structurally limited, and for heavy structures, steel or pre-stressed concrete are often used; steel and concrete need corrosion protection. Often a mixed system is used with creosote wood for dolphins and fender piles that must accept some shocks, with steel or concrete for the main bearing structure. Today mechanical and elastic devices are sometimes used in place of wood to absorb shocks. Plastic coated piles and plastic piles are still in the experimental stage and need to be vetted in warmer climates before they are tested in colder climates. In general, when wood is used, it is because of its inherent economic value in the particular application. Creosoted wood is often used in floating dock or finger piers for the wood members that contact the water. Often this wood is laminated wood, or “gluelam.”

The only water-borne wood preservative recommended for Alaskan marine waters is ACZA. The limitations of ACZA are discussed in Chapter 4.

3 Risk Assessment and Management

3.1 Introduction

Here we examine the issue of creosote marine piles in regard to risk management decisions. First, should existing creosote marine piles be pulled and replaced with other, presumably less toxic, piles and second, should creosote piles be continued to be used in marine waters in new installations and to repair existing installations?

Traditional risk management starts with a four-step risk assessment: hazard identification, toxicity (dose-response) relations, exposure assessment (fate and transport analysis), which result in the fourth step— the risk characterization that contains a statement of the probability and severity of the harm. Following the risk assessment, management decisions may be made to accept the risk or mitigate (NAS, 1983). There are many scenarios of exposure and many management alternatives that arise from the risks associated with chemicals in the environment. While traditional risk management presumes that a strict separation of risk assessment and risk management is possible and desirable, a more recent view insists these two issues are not really separable and considers management matters as well as input from the stakeholders as valuable in the risk assessment, which may now be considered an iterative process (NRC, 1996).

3.2 Assessment

3.2.1 Hazard Identification

The principal hazards facing marine organisms due to creosote are the PAHs released into the water column via leaching from the piles. The toxicity of PAHs are well known and generally accepted. When piles are newly installed, there is often sheen on the water, which, although temporary, indicates transfer of creosote components directly to the marine environment. While PAHs are the principle components of creosote, there are heterocycles as well; however these are typically very minor components and they are not treated separately in discussions of creosote toxicity (Neff, 1979, 1985, Eisler, 2000). Additionally older piles often had a heavy surface coating of creosote. Today, the best management practices (BMP) minimize this coating. In general, it is assumed that the sheen and the lighter PAHs evaporate and/or are oxidized at the surface quickly; thus, are primarily of interest regarding acute toxicity. The heavier PAHs are largely adsorbed by particulates in the water column and/or settle directly to the bottom. These heavier PAH may be of more chronic toxicity – they certainly persist much longer.

3.2.2 Exposure Assessment

We can identify several routes of PAH exposure to marine life from the creosote in piles. They are:

(1) Organisms can be exposed in the water column directly and absorb the PAH.
(2) Organisms can cling to the wood and absorb PAH by a direct route
(3) Organisms can absorb PAH from sediments.
(4) Higher trophic levels can ingest lower trophic levels and bioconcentrate the PAH.

3.2.3 Properties

The cycle of creosote-derived PAHs in the aquatic environment appears to be relatively simple. Creosote leaches from the wood into the water as one of the PAH chemical species and enters the water. The solubility of PAHs varies with their structure and number of aromatic rings. Two-ring naphthalene is soluble to 30 ppm, while five-ring PAHs are soluble in the range of 0.5 to 5 ppb. The solubility also varies with temperature. The solubility of the three ring PAH phenanthrene ranges from 423 to 1277 ppb between 8.5 and 29.9 C and the solubility of the similar three ring PAH anthracene ranges from 12.7 to 55.7 ppb between 5.2 and 28.7 C. (Neff, 1979) Lighter PAHs rise to the surface and quickly evaporate or are oxidized. Heaver PAHs quickly become adsorbed on organic and inorganic particulate mater and large amounts are deposited in bottom sediments. (Eisler, 2000)

3.2.4 Fate

Leaching or biological activity in the sediments may return a small fraction of these PAHs to the water column. PAHs are readily accumulated by aquatic biota, reaching levels higher than those in the ambient medium. Relative concentrations of PAH in aquatic ecosystems are generally highest in the sediments, intermediate in the aquatic biota, and lowest in the water column. PAH concentrations in sediment are, depending on the percentage of organic carbon in the sediments, usually 1000-fold more than the water column. (Eisler, 2000) Techniques for removing PAH from the aquatic environment include volatilization from the water surface (mainly low molecular weight PAH), photoxidation, chemical oxidation, microbial metabolism, and metabolism by higher metazoans; however, once in the sediments they are subjected to lesser photochemical, chemical, or biological degradation than they were in the water column. When incorporated into anoxic sediments, they may persist for a long time, possibly on a geologic timescale. Concentrations in the sediment vary from 100 mg/kg in industrial areas to low ppb range in remote areas. (Eisler, 2000) There is some evidence that creosote can enter the water as micro-droplets and sink into the sediment. (Goyette and Brooks, 2001)

In some controlled water column experiments with creosote piles, all the PAHs were undetectable in the water column at day 17, with approximately 40% deposited in the sediments. (Kang et al., 2005) So the general observation supported by laboratory experiments determined that PAH in the water column due to creosote piles is very low or undetectable. In all but a few cases PAH concentrations that are acutely toxic to aquatic organisms are several orders of magnitude higher than the concentrations found in even the most heavily polluted waters (Eisler, 2000). Field data of sediments from polluted regions, however, may contain PAH concentrations similar to those that are acutely toxic, but their limited bioavailability would probably render them substantially less toxic than PAHs in solution.

3.2.5 Best Management Practices (BMP)

Modern creosote piles are manufactured using “best management practices” (BMP), which reduce the amount of creosote on the surface of the pile. Also, significant reductions in pollution are possible by using BMP for installation, such as keeping the sawdust and wood chips created during cutting and drilling operations out of the water. (WWPI, 2006b) Nonetheless, despite BMP, some creosote can be forced to the surface of the wood by solar heating, and the wood can be abraded in service. Whether or not PAH release is significant if BMP is used is yet to be determined; yet caution is needed when interpreting data from piles treated prior to BMP.

3.3 Toxicity

In general, the toxicity data indicate that the water column concentrations of PAH are very low and not likely to be harmful to pelagic organisms after a few weeks of new pile installation. The body burden of fish and crustaceans is likely to be low and thus, a low threat to humans. Bivalves, muscles from piles or clams from the region near piles may be of concern, however, there are many sources of PAH and other pollution from most dock areas besides the piles, and eating mollusks from these areas is unwise. See the Sooke Basin data below.

Laboratory experiments report large differences in the ability to absorb and assimilate PAH from food between species. Crustaceans and fish readily assimilate PAH from contaminated food, whereas mollusks and polychaete annelids had only limited assimilation. In all cases where assimilation of ingested PAHs was demonstrated, metabolism and excretion of PAHs were rapid. Thus little potential exists for food chain biomagnifications of PAHs. (Eisler, 2000)

The ability of organisms to metabolize and excrete PAHs depends on the species' complement of metabolizing enzymes. Mixed function oxidase (MFO) or P450 enzymes are principally responsible. Fish, arthropods including crustaceans, and annelids have MFO systems, while coelenterates and ctenophores apparently lack MFO. Among echinodermata, *strongylocentrotus sp* and starfish *asterias sp* have low MFO activity (Neff, 1985). Molluska is more complicated; there is no MFO activity in *Mytilus edulis*, the common blue mussel and others, but there are low levels of MFO in oysters, and low levels in the snails and squid.

Toxicity evaluation of creosote-derived PAH is complicated by several factors. Toxicity is often measured relative to a specific PAH chemical. For example, benzo[a]pyrene, a known human carcinogen, is one of many PAH chemicals studied in detail. Another factor is the nature of the exposure. Most PAH chemicals are not very soluble in water and in most practical applications, the concentrations found in the water column are several orders of magnitude less than the test concentrations reported for acute toxicity, typically expressed as a 96-hour LD-50. More relevant perhaps is the possibility of chronic toxicity from smaller concentrations, through direct contact or a photo-induced toxicity.

Certain PAHs exhibit a great (on a scale of several orders of magnitude) increase in toxicity in the presence of sunlight. This phototoxicity has been reported from crude oil and water accommodated fractions of crude oil. In addition, phototoxicity has been reported at light intensities in Alaskan waters (Duesterloh et al., 2002). This toxicity is most important for the very young of the species that are essentially transparent. For pelagic organisms, after the initial pile installation, the PAH in the water column is essentially background. The possibility that an organism could absorb PAH near the sediment then move to waters with more light would imply shallow waters or stronger swimming life stages.

Direct contact is possible if the piles are not fouled. For example, the eggs of the herring cling to whatever they contact. The toxicity of creosote piles to herring eggs was noted. Herring spawn near shore, often near kelp beds. The clouds of sticky eggs are slightly heavier than water, but generally travel with the current and stick to any substrate they encounter, or eventually settle to the bottom. It has been shown that eggs that stick to marine piles have very low survival rates and the larvae that do hatch are often deformed. This was not the case with an untreated wood control (Vines et al., 2000).

4 Combined Fate and Transport and Toxicity, Sooke Basin Studies

While there have been many laboratory studies of PAH toxicity, their relevance to creosote from marine piles is limited due to the very low level concentrations of PAH available from the piles in the water. The concentrations in the sediment, however, will remain relatively high for a long time, although the exposure of fauna from the sediment is uncertain. The Sooke Basin study was a full-scale field test of the effects of creosote piles on the marine environment. Sooke Basin is a pristine waters with low current velocity and ideal for isolating the effects of creosote on the marine environment. It involved the installation of three dolphins constructed with six piling each. The Weathered Piling (WP) dolphin was constructed with eight-year old pilings treated by conventional methods. The second dolphin was constructed with pilings treated using BMP. The third structure, referred to as the Mechanical Control (MC), was constructed of untreated Douglas fir pilings. It was designed to evaluate the environmental response to the physical structure and to organic compounds released from untreated wood. In addition there was an area in the basin that was generally up current from the study area that was chosen as an Open Control (OC). The area was relatively undisturbed without ambient PAH (Goyette and Brooks, 1998, 2001).

The results of the first-year study indicate that PAH lost from creosote-treated wood can create toxic conditions in sediment within 0.65 m of high densities of piling installed in worst case environments. Goyette and Brooks report one year following piling installation, the maximum predicted and observed total PAH concentrations were significantly elevated (5.5 μg/g and 4.8 μg/g, respectively) to a distance of 7.5 m down current from the BMP treated dolphin. Biologically significant increases in sediment PAH were not observed at further distances. Observed total PAH concentrations in sediment declined sharply between 7.5 and 10 m averaging 0.53 μg/g (n=13) at 10 meters and beyond below the Threshold Effects Level or TEL of 0.75 μg/g, dry weight of sediment.

By year four of the study, a diverse and abundant epifaunal community had established itself on the BMP piling. Grazing by starfish and crabs results in significant biodeposits on the benthos. The biological oxygen demand created by the microbial catabolism of this material exceeds the assimilative capacity of the sediments resulting in anaerobic conditions and elevated concentrations of sulfide. "Both the BMP and MC dolphins were covered with an abundance of mussels, barnacles, numerous starfish (15-20 individuals in any given section), plumose sea anemones, calcareous tube worms, hermit crabs, coonstripe shrimp, tunicates, marine snails, sea cucumbers, sponges, filamentous algae and other marine organisms. Large plumose anemones were attached to the inside of the catchment containers, which had been installed only four months previously. Whether they had grown there from juveniles or somehow found another way into the containers as adults is unknown" (Goyette and Brooks, 2001).

In general the Sooke Basin study indicated that the toxicity, if any, is limited to the region near the piles. An interesting confounding factor is the piles quickly became covered with epifauna, which sloughed off and increased the quantity of biomaterial on top of the sediment, which then became anaerobic with high sulfide content. This shuts off oxidation of the remaining PAHs. In any case, there is a decline in PAH with distance. Depending on the sediment criteria used, the significant effects were confined to the two meters down current of the BMP dolphins.

Some of the sediment was used in standard laboratory assays of sediments toxicity. Slight adverse effects were observed at 2.0 m down current but not in the infaunal community. No significant effects were observed on mussel growth, survival, or spawning success. Sediment concentrations of PAH at the BMP dolphin peaked sometime between Day 384 and Day 1360 and then declined.

Water column concentrations of PAH remained close to background concentrations throughout the study. Biologically insignificant increases in mussel tissue concentrations of PAH were observed during the first two weeks of the study. By Day 185, mussel tissue concentrations declined to those observed at the reference station. Mussels growing directly on the heavily fouled BMP treated piling did not contain elevated tissue concentrations of PAH at the end of the study.

4.1 Summary of Sooke Basin Study

The four-year study indicated little ecological effect due to the creosote piles. The region closest to the piles had sediment concentrations that were of theoretical concern, but these seemed to have little effect on the benthic community. The concentrations of PAH were slightly elevated in mussels early in the study, but quickly declined to ambient values. There was no evidence of effect further than 10 m from the piles. One of the study's authors had earlier developed a model of PAH distribution from creosote-treated piles (Brooks, 1997) and this study indicated the model was conservative, - it over-predicted the concentrations.

5 Risk Management

The main risk management options are: 1) Pull piles and replace with non-creosote supports; 2) ban new use of creosote, but let existing remain; 3) continue to use creosote when economy indicates it is the most feasible material; and 4) continue to use creosote piles, but do a risk analysis of each new installation. Here we will review the main issues and suggest data needs.

5.1 Pull and Replace

Pull and replace will eliminate any new PAHs from creosote. Pile pulling will stir the sediments and the effects pulling and construction activities should be examined using standard methods from dredging decisions. The benefits are uncertain, since existing piles do not transmit much PAH to the ecosystem. If the piles predate BMP and had a heavy surface coating some PAH may continue to be transmitted to the sediments. Also, abrasion of the piles by marine traffic may chip the piles and release some fresh creosote. In existing applications, especially in waters that are used by cargo, fishing boats, ferries, and recreational boaters, it is doubtful any beneficial effect of pulling piles could be noted. If it were combined with careful dredging, a long term decrease in PAH from the sediments could be recorded, however a short term increase in PAH in the water column would occur. The harmful effects from PAH in the sediments, if any, is likely confined to the area very near the piles. While the economic costs and ecological effects of pulling and replacing are unlikely to justify it, there may be an intangible benefit from the public relations, especially for industries or facility owners with a history of poor environmental practices.

5.2 Ban New Creosote Piles

Banning new applications of creosote will gradually eliminate PAHs derived from creosote in the local environment. As a practical matter for maintenance and repair, generally wood must be used to replace wood. Creosote is the only oil-type marine preservative recommended by wood preservers for northern waters The only water-borne preservative is also toxic , not known to last as long as creosote, and has other issues discussed in Chapter 4. Thus, the regulators would need to balance the ban with a provision for maintenance and repair of existing piles. Banning new applications would double the cost for building structures that are currently built of wood. In addition, the skill level required for installation and repair will increase an issue that may decrease the ability of small communities and enterprises to maintain their facilities. This increased cost would not be balanced by any benefit, except possibly as noted below regarding herring.

5.3 Continue to Use Creosote Piles Wherever Economical or Use Risk Assessment

The benefits of continued use, primarily cost, are noted above. The risks to the environment from introducing PAH from new creosote piles in general are small, localized and brief. PAHs from natural sources provide a background level in water and sediments. PAHs from anthropogenic activities have increased this level in most locations where piles are likely to be installed. After a brief initial period, two to three weeks, it is unlikely any increase in PAH could be measured in the water column. It is unlikely that, except for the sediment close to the pile, any increase in PAH could be measured in sediment. Analysis of blue mussels growing directly on BMP piles showed an initial small increase in PAH, but shortly this effect disappeared. Risks to the environment that need to be considered are:

1.) Is there sufficient current that initial burden of PAH in the water column dissipates quickly? Quantification of the required current is needed.
2.) Is there a threatened or endangered marine species that could be affected by the brief burden of PAH in the water column? Generally, only the early life stages, would be affected. This would indicate that certain construction windows should be closed, however this would be related to the currents – it would be less of an issue if the currents were sufficient.
3.) Is this in an area where herring are known to spawn and is the herring stock stressed in this location? If the answer to both is “yes,” then creosote piles should not be used – but see research issues below.

These are discussed in more detail in Chapter 8.

6 Conclusions

Creosote-treated wood marine piles do release PAHs to the marine environment. The quantity and location of the PAHs vary with time, but within a few weeks of installation there is little or no measurable PAH in the water column. PAH remains in the sediment and in the wood itself. Field measurements indicate that the amount of PAH in the sediment is generally limited to the region (within 10 m) closest to the piles. This concentration tends to decrease with time. This decrease is less if the sediments become anoxic. Field data indicate that installation of piles increases the benthic load of organic matter under the piles due to organisms coating the piles, which in turn cause the sediment under the piles to become anoxic, thus prolonging the presence of PAH in the sediment. However, the presence of this PAH in the sediments is unlikely to be of any significance to either the local fauna or to humans. PAH in the piles increases PAH in mussels in laboratory experiments, but not in field experiments. Human consumption of mussels attached to creosote-treated piles and clams nearby is probably not advised; most harbors and similar locations of marine piles are not very clean in any case, and in general such consumption is discouraged.

Data indicates that herring eggs attached to creosote-treated wood have a very high mortality and the resultant embryos will be deformed. Herring spawn typically near kelp beds and rocks, and the sticky eggs sink as they are slightly heavier than water. However, herring could spawn near creosote-treated piles and the data indicate the eggs that attach to piles will have a very low survival rate. This indicates placing piles in a critical habitat of a stressed species that spawns sticky eggs into the water column could hinder their survival. However, an issue that should be explored is flora and fauna quickly covered (fouled) the BMP marine piles, while the herring-egg experiments dealt with bare treated wood. Given the absence of PAH measured in the fauna associated with the fouled BMP piles, it seems likely that herring eggs that attached to the fouled piles would have a much higher survival rate than those attached to bare piles. Also, the herring experiments used a new wood control. Wood in marine environments without preservatives is quickly colonized by marine borers, which may likewise not be hospitable to sticky eggs. Finally, some experimentation with the success of herring eggs would need to be done with wood alternatives such as steel or concrete that has corrosion protection systems.

The following are research questions, the answers to which would help in risk management decisions relating to creosote piles.

- Are herring eggs adversely affected by attaching to fouled piles?
- What is the mass transfer mechanism between the wood and herring eggs?
- How long does it take for fouling to occur - what are the key parameters and structural issues?
- Could the BMP piles be treated to encourage fouling?
- What is the survival rate of herring eggs attached to fresh steel or concrete piles?
- What is the survival rate of herring eggs attached to weathered or fouled steel or concrete piles?
- Does the presence of corrosion protection matter?

Today all major owners of marine facilities are committed to protecting the environment. Creosote piles present an interesting conflict between their inherent economic value and their release of PAH to the environment – albeit at very low levels. Another interesting conflict is between the laboratory evaluation of toxicity that indicates toxicity under laboratory conditions and the field studies that indicate no untoward effects. Certainly some caution is needed because one could postulate conditions where creosote may have some measurably adverse effects. These situations are likely rare and in the author’s opinion, application-specific evaluation of these conditions rather than banning creosote is a wise use of society’s resources.

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Chapter 3 Discussion of Alternatives

Non-wood Materials

For new marine construction there are alternatives to wood piles; concrete and steel are common. Wood is structurally limited and for heavy structures steel or pre-stressed concrete are often used. In addition, long wood piles of sufficient quality are harder to procure. Thus for piles, the nature of the structure will sometimes preclude wood. However if wood will suffice structurally, wood will be preferred since the initial costs (both procurement and installation) are about half that of concrete or steel. For the long term maintenance costs, both steel and concrete need corrosion protection.

New Installation

Plastic piles and timbers, some made from recycled plastic, are available for structures and fender piles. One brand features a pile that is filled with recycled plastic with fiberglass reinforced plastic rebar and a UV light and abrasion resistant outer skin. These are available in both pile and beam shapes. (In this chapter we present URLs to manufactures' sites with illustration of these alternates. In addition, catalog cuts of illustrative alternates are bound in Volume II of this report. We are not endorsing any particular manufacturer.) See http://www.trelleborgms.com/catalogue_1.aspx?id=1:30038&cat=1:469203&pagenum=1&pagesize=20 for plastic piles and http://www.trelleborgms.com/catalogue_1.aspx?id=1:30038&cat=1:469282&pagenum=1&pagesize=20 for a plastic beam. The reinforced members are generally slightly stronger than wood. They deform more under compressive stress and this might limit their use for heavy structures in our high seismic regions. See cost information in Chapter 6. Due to the great expense, concrete, steel, or mechanical fenders would probably be the design choice.

Another method of plastic encapsulation is to coat a pile with plastic before it is installed. Spray on polyurea ("truck bed liner") is one type of plastic used and the finished coat may be 250 mil (1/4 inch) thick. See http://www.schraderco.com/pdf/poly1.pdf for a catalog cut of plastic coated pile. These are generally applied over a treated wood to reduce transfer of the treating chemicals to the environment and the coating is not structural. If the coating remains intact, there would be no transfer of creosote components to the marine environment. However the service life of these coatings in Alaska is not known and, once torn or severely abraded, the creosote will be transferred. The coating may be used in lieu of treating the wood, but in that case any tear in the coating would allow marine borers access to the wood. Again the added cost might make wood uneconomical. Since the only benefit of the plastic encapsulation is inhibiting creosote release to the environment, this method would only be practical in very sensitive area, where a risk analysis indicated creosote would harm the marine environment.

Tropical Woods

Several species of wood are inherently decay resistant. Ekki timber (*Lophira elata)* is used for high abrasion applications in the marine highway system in Alaska. It is generally not used for piling or structures. An issue with many tropical hardwoods is the “green” issue of tropical deforestation. The Forest Stewardship Council (FSC 2009) certificate is an example of an international standard to insure sustainable harvesting of such timber. FSC certification is not available for Ekki from some sources. Ekki is listed as “vulnerable” by the International Union for Conservation of Nature (IUCN 2009; Greenpeace 2009). This adds another dimension to cost-benefit analysis of substituting tropical woods for treated domestic wood.

Retrofit

Plastic products are available that attach to the outside of piles. One brand features a petrolatum mat that lays between the plastic and the wood, that, when compressed, seals the wood preventing oxygenated water from reaching the wood and thus preventing marine borers. See http://www.tapecoat.com/marine_pages/seriesr.html. These might be used on installed piles. They attach with fasteners or bands. The durability of these, for example in fender piles is suspect. Installation would required divers and would be expensive. If they were extended from the splash zone to the sediments, they would prevent transfer of creosote from the pile. See next.

Another retrofit method that should work with installed piles is an epoxy grout that will bond to wet wood (or concrete or steel). A metal form sleeve is placed around the pile and the mixed epoxy is placed in the form. http://www.schraderco.com/pile_res.cfm The system is advertised for applications at the waterline, but could be extended to the sediment.

Both the plastic and epoxy sleeves and coatings could be used to prevent creosote transfer. Since most of the creosote transfer occurs in the early years of pile installation, there is less benefit from installing these sleeves later in the piles life.

Other

Even if steel or concrete are used in the piles and main structure, a mixed system is used with creosote wood for dolphins and fender piles that must accept some shocks, with steel or concrete for the main bearing structure. Today mechanical and elastic devices are sometimes used in place of wood to absorb shock, but wood is the most common for docks that handle smaller ships. Generally, for docks for large ships, mechanical systems are used.

Float Material

Most Alaska harbors have finger docks that move with the tide. These are attached to a main dock with hinges and a sliding ramp. The finger docks have vertical guide piles to keep them in horizontal position. There are a variety of other structures that likewise move with the tide, such as seaplane docks. These are collectively known as “floats.” The buoyant material under the floats may be a plastic, such as Styrofoam or urethane foam, steel drums or similar material, concrete floats, or a variety of other materials and combinations. However the most common material for the structure of the floats in the water or splash zone is creosote treated glulam wood. Since creosote is a tar-like coating and unsuitable for painting, the walking surface of the docks is generally treated with a different preservative. Although there is some use of concrete for the float system, including the floatation material and the walking surface, these are expensive and not much used in Alaska, where freeze thaw cycles may damage the surfaces. In general, only creosote glulam wood is used in Alaska for float structures.

Alternate Wood Treatment Methods

There are alternative wood preservation methods. For marine and estuarine waters, creosote is the only preservative in current common use for piles, and is the only oil-based preservative recommended for saltwater immersion subject to marine borer attack. Creosote is an oil-type preservative. There are two types of waterborne preservatives recommended by the WWPI (WWPI 2008) for marine use. They are ACZA and CCA. Both are copper containing preservatives. The most common wood in the Pacific Northwest and Alaska is Douglas Fir. "Doug fir" is resistant to the penetration of CCA and thus it is not in common use in Alaska. Therefore we will only discuss ACZA.

ACZA stands for Ammoniacal Copper Zinc Arsenate; its commercial name is Chemonite® (http://www.archchemicals.com/Fed/WOLW/Products/Preservative/Chemonite/default.htm) ACZA should contain approximately 50% copper oxide, 25% zinc oxide, and 25% arsenic pentoxide dissolved in a solution of ammonia in water. (Ibach 1999) Because copper is highly toxic to marine invertebrates and fish larvae, ACZA gathers almost as much environmental concern as creosote. (Stratus "copper") Thus, ACZA would likely not, based on environmental issues, be proposed as a replacement for creosote. Unlike creosote, ACZA can be painted and walked upon.

ACZA and probably other waterborne preservatives have several disadvantages compared to creosote. First, ACZA tends to split the ends of the glulam lumber – "brooming." This may be overcome with special hardware. Second, ACZA tends to absorb some water and thus, in freezing and thawing environment leads to splitting the wood. Third, galvanic action of the ACZA metals and the iron tends to corrode fasteners in salt water. Stainless steel fasteners or a plastic sleeve for steel fasteners is recommended. See http://www.archchemicals.com/Fed/WOLW/Products/Preservative/Chemonite/hardware.htm for examples. Most of the difficulties with ACZA have be described anecdotally by engineers familiar with its performance in Alaska. To the author's knowledge, there have not been side by side tests of ACZA versus creosote regarding its durability in Alaskan waters. However, based on the similarity of the environmental concerns of creosote and ACZA, testing may not be worthwhile see next.

Chapter 4 Other Creosote Uses

Creosote in marine structures other than piles

First we should consider the effects of creosote from the structure above the piles, if the structure is creosote. Migration of creosote via micro droplets seem likely. In addition, the structure will block sunlight from the water, thus inhibiting photo-degradation. Finally, currents are likely to be attenuated in the region below the structure. All these indicate that the sediments below the structure will have elevated levels of PAH. This needs to be considered in the overall environmental assessment of the project. For example, if a creosoted dock were replaced with a sheet pile bulkhead and concrete pier, all the marine waters below would be lost to the marine environment. This is sometimes called the “technozone,” and acknowledges that any structure will consume some of the environment. This needs to be balanced with the net good to society from the structure. The weight of evidence reviewed elsewhere indicate the contamination is limited to the area near the structure.

Creosoted wood is used for applications other than piles, docks, and marine structures. For structures such as marine grids and retaining walls that are submerged in the water, either continually or by tides, what has been said in the other chapters would apply. The modeling an risk assessment of these may be different, see Chapter 8. Creosoted wood is used in other applications, such as bulkhead walls and bridge end walls, which are usually out of the water. Will creosote runoff from these might affect the marine environment? Since the transfer of creosote from these types of structures would be essentially the same in fresh as in salt water regions, there are two mesocosm experiments that are pertinent. And, by combining these with known effects in marine systems, a reasonable estimate of effects can be made.

There has been research related to bridges made of creosote treated wood.(Brooks 2000) The researcher investigated the PAH concentrations in water and sediment downstream from two creosote treated wooden bridges, one a new bridge and one an older bridge. In general these found that some creosote-derived PAHs are found in the sediments downstream from these structures, but the concentrations, which depend on the current flow and other parameters, are usually not of environmental concern – below standard toxicity benchmarks. Occasionally higher concentrations were found.

There was a significant research project that related to creosote treated railroad cross ties. That study simulated a railroad across a wetland using a mesocosm study of three sets of two ties each. One set was new creosoted ties, one had old creosote ties, and one had wood without creosote. The ties rested on clean railroad ballast, 0.5in to 1.5in gravel, which overlaid wetlands soil. The study over 18 months indicated that PAH from the creosote did migrate into the ballast, but the most of this happened in the first year and there was little migration after that. Further, the PAHs were mostly heavy PAH, 3 to 5 rings. The lighter PAH were not present.

The rail ties used in this study were red oak, a hardwood that does not absorbed creosote readily, and were treated to a refusal standard, rather then a retention standards recommended for Doug fir and other softwoods likely to be used in Alaska. The results however coincide with what would be expected. *In the Updated Ecological Risk Assessment for Creosote* the EPA recognized that "and the PAHs do not move any substantial distance from the railway ballast." (EPA 2008)

Based on these studies, our general knowledge of creosote in the marine environment, we can generalize to these near marine applications. PAHs are degraded by photo- and chemical oxidation (weathering). In addition, PAHs and other hydrocarbons will biodegrade if sufficient oxygen, moisture and nutrients are available. The reasons PAHs accumulate in marine sediments is that these are often anaerobic. In surface soils or tidal areas, small amounts of PAH should be biodegraded quickly. This would be the typical case of gradual leaching or runoff from creosoted wood, especially if it had been treated with BMP. If a large amount of creosote ran onto the soils, the would likely remain as a tar-like coating on the surface soils, since the biodegrading microbes only function at the water-hydrocarbon interface. Sunlight, however, can degrade these tar substances rather quickly. In the rail tie experiment, the gravel ballast was "clean" and thus lacked nutrients and rainwater quickly washed over through it. Thus the heaver PAHs formed a tar on the gravel near the surface.

Even in BMP treated wood, heating by sunlight will force some creosote out of the wood and thus creosote particles will make their way to the soil or sediment beneath the wood.

So, in general, bulkheads or other structures in shallow or tidal marine water would be expected to perform similar to piles. For endwalls and similar structures generally out of the marine water, some migration of the PAHs from creosote would be expected to occur and these would bind to the soils. The LPAH would quickly dissipate and the HPAH would remain longer. If the amounts were small and the local soils aerobic or if the HPAH were exposed to sunlight, the HPAH would soon be degraded. If the soils were anerobic and the soils not exposed to sunlight, the HPAH would remain in the soils longer. In general, little migration to the water from rain would be expected. Earlier we noted that if the migration is to water via dissolved PAH, they are quickly oxidized. If they migrate to water via particles, or adsorb on particles and sink to the bottom and the bottom sediments are anaerobic, the PAH will remain much longer.

Both studies note that the greatest migration of creosote out of the wood is in the first year, and that BMP such as not storing new creosote wood directly on the soil, will decrease the amount of PAH transferred to the environment. Also, the migration of creosote may be largely due to particulates from the surface and this is reduced, but not eliminated, by BMP that reduces the amount of creosote on the surface of the timber.

Chapter 5 Disposal

In general, disposal of creosote treated wood is not a problem. It is not a hazardous waste under the federal RCRA regulations (Woodpoles, 2009; Porter, 1986) and can be placed in a municipal solid waste landfill under state and federal regulations. Some landfills may choose treat it specially and charge an extra fee for it. The Fairbanks and Anchorage landfills do not. Creosote-treated wood cannot be burned in Alaska in open burning (18 AAC 50.400).

Creosote wood can be reused and there is a ready market, for example, for creosote-treated railroad ties. Creosote-treated wood can be chipped and use in coal fired power plants. Creosote-treated wood is still a safety hazard from handling and should not contact foodstuffs. There is a standard EPA-approved caution statement that should be given to parties that purchase or accept creosote wood for reuse. (UPF 2009) If the creosote-treated wood is likely to enter the stream of commerce, an MSDS sheet should be provided. (SIRI 2009) Since creosote-treated wood is not a hazardous waste under RCRA, it can be sold, that is liability for its future uses can be transferred to the purchaser. However the transfer should be documented with a bill-of-sale. “Deep pockets” such as state agencies should exercise some caution when disposing of creosote products.

Chapter 6 Economic Impact

Economic Impact of Replacing Creosote Wood in Alaskan Harbors

One option for managing creosote in Alaskan waters is the removal of all creosote wood products. As discussed in other sections, this would have little positive effect on the environment. Any positive effect would be very gradual over many years, except, perhaps, in herring spawning areas of stressed herring stocks. A second option is banning the use of creosote for new marine structures. Again, the environmental benefits would be small, especially if the new structure is a replacement for an existing creosote structure. Either way, the removal of PAH could be accelerated by dredging the sediment near the existing creosote wood, but this is unlikely to be a net benefit to the environment, since the dredged material would need disposal and the dredging would stir the local sediments, as would construction operations. However, assuming there is some benefit, albeit a small one, it is prudent to examine the costs.

Estimating the costs has many complexities, for example the replacement material design, steel and concrete have higher design loads, but cost more than wood. One study examined two projects that were bid once with creosote wood, not built, then re-bid using steel. Steel was 2.33-fold more expensive in the smaller of those jobs and 1.58-fold more expensive in the larger. (Smith, 2006) The author, who was writing for a wood preservers trade group, used a factor of two for economic comparisons. (Smith 2007) while the re-bids may be the closest to a "apples to apples" comparison available, there were only two of them and that is a very small data base.

The EPA accepted the premise that plastic piles were not a viable alternative to wood. (EPA 2008c) Plastic piles are generally not used for structural members because they are too flexible. Their modulus of elasticity is less than half that of wood. (Perkins 2009)

Here are some approximate costs of creosote and plastic products base on list prices from suppliers. Bid prices would presumably be lower. Prices do not include freight from the dealers in the lower-48 to the Alaska location.

Pile Butt Diameter, inches	Creosote Wood $/linear foot	Plastic Coating of Creosote. * $/linear foot	Plastic Pile** $/linear foot
10	25		45
12	25		
13			75
14	25	53	
16		70	120f
18	45		

*Note only the part of the pile in the water would need to be coated. Also, this cost does not include the pile itself, only the coating.
**These are might be used for structures, if deflection is tolerable.

Many harbors have a mixture of creosoted wood and other materials, such as steel and concrete, other treated wood, and plastics. It may not be practical to replace the creosote piles without destroying the rest of the structure. While steel and concrete can replace wood piles, there is little alternative to using creosote wood in the submerged portions of float systems in Alaska. Mobilization costs and economies of scale are large estimating parameters in Alaska. In addition, there are many small harbors in Alaska. It is impractical to perform an estimate for all the harbors.

We approached estimating the costs by surveying the attendees the 2008 Alaska Harbormasters and Port Administrators Convention in Haines. There were 9 responses, about 25% of the attendee's responded. While this too small a sample to extrapolate with great confidence, it is a representative sample and, with a little judgment, provides some insight into the economics of creosote in Alaska.

Below is a question by question analysis of the results. Here is a summary:
Eight of nine respondents had creosote wood in their harbors. It is present in finger dock guide piles, float material, the understructure of fixed docks, structural piles, fender piles, dolphins and navigation structures, and miscellaneous structures such as bulkheads, launch ramps and curtain fenders. There was little concrete used for piles, but steel is the second most common material.

We asked about the expected service life of the respondents' creosoted wood, since if it would need to be replaced soon for service reasons, the economics of removing for environmental reasons would be affected. About 22% of the respondents report some creosote wood must be replaced within the next five years – but generally only a portion of their creosote. About 33% reported that they would need to replace some creosote in 5 to 15 years and 44% reported that their existing creosote would last more than 15 year. Thus, only a small portion of the existing creosote would need to be replaced in the normal course of maintenance, and thus would have only a small effect on these economic calculations.

The survey respondents felt the economic consequences of removing creosote were heavy. Most, 80%, felt it would be a large consequence. Half of those felt it was unlikely they could get the funding to remove it without special appropriations or bonding and the other half felt it was unlikely they could finance it at all.

When asked to estimate the costs of removing creosote, the responders gave a variety of answers – many did not try to present a cost. However five of the nine did present an estimate. When normalized for the size of their harbors, the result was consistent, about $16,000 per berth with a standard deviation of only $8,000.

From those numbers, some rough order of magnitude estimates can be done. For example, the 1995 Alaska Harbor Directory lists 101 harbors that were managed by the state in 1995, although many of them have been transferred to municipal governments and other entities since then. Those harbors had approximately 11,000 berths. At $16,000 per berth, it would cost $176 million to remove the creosote and replace it. Not included above is the Alaska Ferry System Harbors. Most of these are large modern structures which have steel piles to support the heavy loads, but these often have wood in fender systems and sometimes dolphins. A few of the ferry terminals are older structures of wood and these are all creosoted.

Besides the listed harbors, there are many unlisted harbors, many private and some industrial associated with fishing or mining activities. Some of these are abandoned.

The cost for berthing at municipal harbors is generally shared between state and federal governments, which contribute capital costs for some new harbor construction, local governments, which pay for some maintenance and overhead, and berthing fees that pay for some of the ongoing maintenance costs. The ratio between these contributors is quite varied, but in general, berthing costs do not cover the cost of current O&M, which includes needed repairs and environmental upgrades. Municipalities that benefit from tourism and fishing, both commercial and sport, often contribute to the O&M, and the beneficiaries of these industries strive to keep the berthing fees down through the political process. Communities with many sport boaters do likewise. Thus, most harbors are currently in a whipsaw between mandated low berthing fees, which are set by the municipality, and dependency on local government contributions, which is stress by non-beneficiaries of the harbor through the political process. Grants by the federal and state government are generally for new harbors, major expansions, or total renovations. The AMHS is run at a cost to the state government of over $50 million a year.

Clearly funding for the removal of creosote treated wood from publically-owned harbors would need to come via some sort special appropriation. While some minor removal might take place as part of routine maintenance, for example replacing worn fenders and fender piles, any program to remove creosote from structures would be out of the economic range of most municipal harbors. The effect on non-municipal harbors cannot be estimated, but some industries, a prosperous mine or cannery, might be able to support such an operation, but many of these, commercial fishing, are currently economically stressed and it might be economically impossible for them to do it.

Thus, it seems likely that for any significant removal of creosote, it would need to be paid by direct appropriations from the state or federal government. A rough estimate of this might be $175 million for state affiliated harbors and perhaps the same for non-state affiliated, for a total of $350 million.

Details of the economic survey

There were 9 responses. One of those was an anomaly, a harbor in Washington, but the description seemed typical of Alaskan harbors and was retained. One harbor, a recent harbor built by the Corps of Engineers did not report any creosote.

Most of the respondents describe their harbors as larger rather than smaller

Qualitative Description of Harbor	
11%	Large, ferry terminal, or non-fish industrial
44%	Large, commercial fishing and fish handling
33%	Medium, commercial and sport fishing, recreational, transportation
	Medium, sport fishing, relational, transportation
	Small, mostly transportation and mixed non-commercial
11%	Small, some commercial

Quantitatively, over half had more than 400 berths, but a third had 100 or less berths.

Number of berths in harbor	
22%	More than 700 berths
33%	400 to 700 berths
	200 to 400 berths
11%	100 to 200 berths
33%	50-100 berths
	Less than 50 berths.

The guide piles for the finger docks are about evenly divided between creosote wood and steel. There is some concrete and ACZA wood used for this. All the respondents have finger docks.

Finger dock guide pile material	
54%	Creosote wood
4%	Concrete,
48%	Steel,
6%	ACZA wood,
	Other
	Don't have finger docks

The understructure of the floats are about 40% creosote wood and ACZA wood. However 22% reported "other," but not "plastic." Concrete is often used for this, but the survey did not query that material.

Is the understructure of your floats, mostly:	
39%	Creosoted Wood
39%	ACZA wood
	Plastic
22%	Other

The understructure of the fixed docks are 60% creosote.

Is the understructure of your fixed docks	
61%	Creosote Wood,
11%	Concrete,
33%	Steel,

	ACZA wood,
6%	Other

Creosote is the predominant pile material for fixed docks over water, with almost 70%. About 30% are steel. There were no concrete or ACZA piles reported

For your fixed docks that are over water and supported by piles, what is the pile material?	
69%	Creosote Wood,
	Concrete,
31%	Steel,
	ACZA wood

Creosote is the predominate fender system

The fender system of your fixed docks is:	
22%	Mechanical/rubber,
56%	Creosote wood piles
22%	ACZA wood plies
	Other

The answers to the question, "If you have mooring or guide dolphins within the general purview of "your" harbor, about how many piles of each type" were difficult to interpret. The answer would indicate 325 creosote wood and 680 steel, however the majority of those were at one harbor. Also, there were "curtain fenders" mentioned, which were creosote timber.

The answers to the question about other structures with creosote were varied. It would appear that the majority have such structures

Do you have other structures such as breakwaters, retaining bulkheads, or bridges associated with your harbor that have creosoted wood? Please describe:
Creosote at bulkhead wall
No
Old main dock no longer used is creosote.
Creosote at other docks
Launch ramps
Large dock mostly creosote
Curtain fender on deep draft docks
Bulkhead

Some, 22%, indicated that they had creosote that would need changing within the next five years, but those were generally limited to smaller sections of the harbor. 33% indicted they had portions of their harbor that would need changing in 5 to 15 years, and 44% indicted they would be unlikely to replace their creosote within 15 years.

In general and broad terms, what is the status of your creosote wood relative to its life cycle: (check one)	
22% (Answers were qualified, generally indicating only a small portion of the harbor would need to be replaced, for example: 1. "some floats," 2. "fender curtain," "80 piles."	Under normal circumstance, we would have to replace all or most of the creosote wood within the next five years.
33% (One was qualified to a portion of the	Under normal circumstance, we would have to

harbor that need to be replaced.	replace all or most of the creosote wood within the next five to 15 years.
44%	Our wood is unlikely to need replacement within 15 years.

To the question, "Do you have significant (relative to the size of your facility) quantities of creosoted wood that are difficult to replace, such as a dock understructure. (yes or no)" 86% answered "yes."

Most, 80%, believe it would have a large economic consequence to remove creosote wood. One harbor did not have any creosote.

In general, if you were required for environmental concerns to remove all your creosoted wood within five years and replace it with non-creosote, what would be the economic consequence for your sized harbor:	
11%	Small, since we have little or no creosote.
	Small, since we are likely to replace for other reasons.
	Small, we could accomplish within our maintenance budget or a slight increase.
	Moderate, we would need at least a doubling of our maintenance budget.
11%	Moderate, it would be a capital project requiring funding from our owner city/agency.
39%	Large, it would be major capital project requiring funding from outside sources, our owner city/agency would not fund it without special appropriations or bonding.
39%	Large to impractical, the economics of our harbor make it unlikely we would get

The free answers were interesting.

In general, if you were required for environmental concerns to remove all your creosoted wood with five years and replacement with non-creosote, what would you estimate your costs to be, in current dollars, for your sized harbor.
(Has no creosote)
No idea
No idea - over 2000 piles
$4 million,
Substantial
$10-15 million
one harbor, $8 million
$20 million
1 million, 250-300 creo piles at $4,000/pile

They seem quite varied, but by comparing those that gave a definite answer to their number of berths from question 3 (using 800 berths for the >700), the answers averaged out to $16,000 per berth with a standard deviation of $8,000.

Chapter 7 Consultations

Consultations with Agencies, Regulations and Guidance

Nature and necessity of consultations
Introduction
Use of creosote-treated wood products in marine waters presents an interesting policy choice for the ADOT. There is current opposition to the use of creosote and other treated wood in the marine environment and some of this opposition is based on many scientific studies that show some of the components of creosote are quite toxic, and some of these components can be extracted from even old creosote-treated wood or nearby sediments, and these extracted components are likewise toxic. However many of these scientific studies are based on laboratory procedures that are not equivalent to the natural situation. Others tests were done in locations with many sources of non-creosote contamination that confound the results. Meso-scale testing of creosote piles in a pristine area did not demonstrate any significant effects on the biota. The effects demonstrated some contamination, but the effects were short term and localized. Most marine piles are quickly covered by fouling organisms, most of which migrate to the pile as larvae or other immature life stage. Since these life stages are presumably the most susceptible to the toxic effects of the creosote components, their presence demonstrates lack of observable toxicity to those organisms. More details are presented elsewhere in this report. Thus there is a policy stress from the choice between using an economical and efficient product that has been in common use for over a century but that has components that under some circumstances are toxic to marine life.

We should note a fallacy of the comparative risk analysis. While outboard motors or bilge pumping might introduce more toxic components into a harbor, the ADOT is not doing those things. While with the use of creosote the ADOT is deliberately introducing these toxic components albeit at a level not likely to harm marine life. This stress may be ameliorated by considering the ADOT's primary obligation to provide for safety for highway, airport, and marine traffic. Inefficient or uneconomical structures may impact safety directly if the structures fail, or indirectly by consuming resources that might be used on other safety improvements. The stress should be eliminated if the ADOT is confident that the harm is minuscule and unlikely to have measurable adverse effects on the environment.

The policy stress could be avoided if there were laws or regulations of other agencies that clearly addressed the use of creosote. There are few laws or regulations that apply directly to the DOT's use of creosoted wood in marine structures. Since creosote is a pesticide, it is regulated by the federal EPA under FIFRA. FIFRA does have regulations, but these are mostly labeling and manufacturing instructions. We discuss these is some detail below because the EPA performed a careful risk assessment on use of creosote and made its risk management decisions – approval – based on that risk assessment. The guidance provided by the regulations requires things that the ADOT is already doing.

The chief constraint to DOT's use of creosote comes from indirectly through the consistency reviews of other agencies, chiefly the NMFS and ADF&G. Briefly, the usual mechanism for these reviews is the Corps of Engineers permit required to construct structures in navigable waters. The permit will often require a consistency review whereby other state and federal agencies are requested to review the project and comment. Such reviews are required if an EIS is needed, but also if the work is in an Essential Fish Habitat (EFH) or might affect a threatened or endangered species (TES). Most Alaska waters are EFH for some species and TES must be considered in any case. For marine waters, NMFS is the lead agency. However regarding anadromous species, ADF&G has a joint responsibility with NMFS and ADF&G will also be asked for a consistency review. For smaller or routine projects the Corps has general or area-wide permits, however if project may affect an EFH or TES, the Corps may ask still ask for the consistency review. In addition, any project in the "coastal zone" must meet the requirements of the "Coastal Zone Management Plan." This likewise requires a consistency review by all the agencies. Thus, even a treated wood project that did not directly affect navigable water, such as replacing a wood retaining wall near the water, might likewise be subject to consistency reviews.

The consistency reviews will pertain the project as a whole. The use of treated wood may be only a small issue in the overall project approval cycle. However regarding the treated wood, we ask, what are the standards the agencies use in their review? Below we discuss those standards and attempt to fill in some details. But note that the standards, such as they are, are not a cookbook that NMFS or other agency personnel must follow. Rather, those agency personnel must extrapolate from their knowledge of the science relating to wood treatment and the biology of the many organisms in the environment as well as the population biology of the species to found their recommendation. Since for any chemical or any species these are topics about which experts disagree, the agency personnel should have more specific guidance. NOAA has tried to provide these by generating two "technical reviews and use recommendations" by a firm Stratus, and a more recent document draft, *The Use of Pesticide Treated Wood Products in Aquatic Environments: Guidelines to NOAA Fisheries Staff for the Endangered Species Act and Essential Fish Habitat.* (NMFS 2009) One of the Stratus documents deals with non-creosote wood treatments and we will not discuss that further. (Stratus Copper 2006) The other Stratus document deals exclusively with creosote and that is one we will refer to as "Stratus." (Stratus 2006) We will refer to the other more recent document as "draft Guidelines." We discuss these and the EPA's review and NOAA documents in detail Appendices, C, D, and E, but here we will quickly review them.

Regulatory Basis of Reviews

Since creosote is used as a pesticide, the agency that had direct regulatory control over creosote in the federal EPA, under FIFRA, the Federal Insecticide Fungicide and Rodentcide Act. In late 2008, the EPA completed its Reregistration Eligibility Decision (RED) for creosote and found it eligible for reregistration. (EPA 20008a)

The National Marine Fisheries Service (NMFS), an agency of the National Oceanic and Atmospheric Administration, has input into creosote-related decisions through is consultative role in the actions of other agencies, especially the US Army Corps of Engineers, and many agencies through the Coastal Zone Management Act. The Corps must issue a permit for any new structures or alteration to existing structures in navigable waters. The CZMA requires a "consistency evaluation" for any agencies actions that affect the coastal zone. In either case, the agency considering issuing a permit, or an action of the agency itself, must consult with the NMFS. The two laws that NMFS will consider are the Endangered Species Act (ESA) and the Magnuson-Stevens Act (MSA), the NMFS is responsible for managing commercially harvested aquatic species by implementing fishery management plans and designating Essential Fish Habitat (EFH) areas. Under the ESA the NMFS will consider if the action threatens a listed or endangered species or its habitat. Under the MSA, NMFS will consider if the action threatens an "Essential Fish Habitat" of a protected species. In the event NMFS finds that the agencies action, such a approving a permit, will threaten a listed species under the ESA or an EFH, NMFS will convey that to the agency. This may result in the action such as a permit being disapproved, or may result in negotiations or design changes to remove the threat. Thus, via an ESA or EFH consultation process, NMFS may determine creosote piles are not an issue, or essentially ban the use of creosote, or delay a project while creosote-related details are revised or determined. Of course the permit applicant might protest the decisions to ban creosote, alternatively, a third party, such as an environmental group, may protest the decision to allow creosote. Either approach will be an action against the agency issuing or denying the permit, probably not NMFS directly.

Guidance

EPA

Since creosote is used as a pesticide, the agency that had direct regulatory control over creosote in the federal EPA, under FIFRA, the Federal Insecticide Fungicide and Rodentcide Act. Especially interesting for the ADOT is the fact that the EPA decision is "risk management" decision that is founded upon a "risk assessment." Certainly some if not most of FIFRA regulated substances are toxic, thus the agency's decisions will considered the benefits to society from the application of the substance versus the stress to humans and the environment from its application. In late 2008, the EPA completed its Reregistration Eligibility Decision (RED) for creosote. (EPA 2008) "As a result of this review, EPA has determined that creosote containing products are eligible for reregistration, provided that risk mitigation measures are adopted and labels are amended accordingly. The reregistration eligibility decision and associated risk mitigation measures are discussed fully in this document." That is, after characterizing all the risk associated with creosote, the EPA considered the benefits and economics, including those of reasonable alternates. The EPA FIFRA Office of Pesticide Program then promulgates "mitigation measures" and "labeling requirements" that the manufacturers and distributors of FIFRA controlled substances must in turn follow. Because creosote, as all coal tar volatiles, is toxic to humans, most of the mitigation and labeling requirements relate to human exposure in the manufacturing process, some of which would apply to field construction, but this is chiefly a concern of federal OSHA and Alaska DOL.

The most stringent interpretation of the EPA FIFRA requirements is that Best Management Practices (BMPs) must be use in sensitive environments. Since elsewhere we suggest BMPs be used for all creosote applications, this is not a burdensome requirement for the ADOT.

NOAA NMFS Guidance

Stratus

Since the NOAA draft guidance is still in draft not final, and that document frequently refers to the Straus documents, we will discuss Stratus here and in Appendix D

In 2004 NMFS commissioned a consulting firm, Stratus, to write a report titled "Treated Wood in Aquatic Environments: Technical Review and Use Recommendations." The preface to that document states:

> These reports are the findings of Stratus Consulting regarding the use of treated wood. They have been subject to peer review and public comment. NMFS may utilize these reports and other available information, as appropriate, to develop or update guidelines on the use of treated wood in aquatic environments. Accordingly, these documents are not NMFS guidelines themselves.

The original report dealt with copper treated wood only. (Stratus Copper 2006) A second report was commissioned about that same time the dealt exclusively with creosote. (Stratus 2006)

Both documents were available in late 2005 or early 2006 and the version placed on the NMFS website is dated December 31, 2006. A notice of the availably of these documents was placed in the Federal Register March 3, 2006, which requested public comment. That notice said

> The intent of the reports is to ensure NMFS is informed of relevant studies and recommendations when making decisions related to the use of treated wood in aquatic environments. This information may be used for future development or revision of NMFS treated wood-use guidelines. NMFS is soliciting public comment on whether the treated wood documents sufficiently summarize the existing body of knowledge concerning copper and creosote treated wood products, including the fate and transport of leached materials, the appropriate use of treated wood products, and the potential effects on living marine resources and their habitats. In addition to this public comment opportunity, the reports will also be subject to independent peer review.

There were three sets of public comments, one set by the Creosote Counsel and Dr. Brooks, who consults for the WWPI, which might be considered industry comments, one set by the USDA Forest Products Lab and a university researcher that would not be considered industry. The third set would be the three peer reviews. Together six of those seven documents were quite critical of the Stratus Creosote Report. The extent of changes provoked by those reviews is not clear, but it appears the specific comments were not changed in the final document.

Although this author finds the Stratus document strangely inconsistent, as discussed in the appendix, the main conclusion of the document is that creosote is a useful product and can be safely used in the marine environment, but that certain risk factors should be considered.

NOAA Guidance

The Public Review Draft of *The Use of Pesticide Treated Wood Products in Aquatic Environments: Guidelines to NOAA Fisheries Staff for the Endangered Species Act and Essential Fish Habitat* is dated December 5, 2008, and was placed in circulation via a Federal Register announcement in January, 2009. The FR stated the comments period was closed in March 2009 . At this writing (August 2009) the status of the document was uncertain, and emails from the author have not been answered. The only comment document this author received was from the WWPI. My comments and the WWPI comments are in the appendix. Both agree the NOAA Guidance is a reasonable treatment of the issues. WWPI believes that more specific guidance is needed. Until that is provided, individual biologists are free to use their own bias in the process, and project owners, sensing this bias might hold up their permit, might not use creosote in favor of less economical or efficient design solutions. While I don't disagree more guidance would help, I don't believe with the proactive approach outlined in Chapter 8 more specific guidance is needed. In the final analysis, the consultation will depend on the professional opinion of the NMFS experts.

The main conclusions of the Draft Guidance are that:

- The use of creosote-treated wood in aquatic environment could be acceptable in many proposed projects.
- They are not categorically safe and require risk assessment
- Many projects only require a screening assessment for pesticide treated wood impacts.
- Local knowledge is needed to make a case by case determination
- Information is limited, but creosote may not impact ESA listed salmonids in a manner that can be detected

All of which the author agrees with. The report does express a preference of copper over creosote for EFH. The document is intended for nationwide application, however because of the poor performance of copper treated wood in Alaska, that preference, which is not that strong to start with, would not be appropriate in Alaska.

Chapter 8 Management Policy

Management Policy for ADOT use of creosote in the marine environment.

In most applications of creosoted wood in Alaskan marine waters any contamination released is likely to be slight and confined to an area near the installation and unlikely to significantly affect marine life. Nonetheless the installation of creosote adds something to burden of contamination in the environment. The perception of this burden will vary considerably with individuals and will evoke negative responses from some even where the science indicates harm is unlikely. In addition, the charge of the agency will alter the perspective: DOT's primary concern is the safety of the public, while NMFS and ADFG primary concern, in this regard, is the protection of the fisheries and endangered species. In addition, and this may be often the case, the science does not give a firm answer, the negative perception regarding creosote will bias decision makers towards other materials and approaches – this despite the fact that the alternates may be no better – for example steel pilings need painting with its possible contamination and catholic protection with its unknown effects on immature life stages. So, when planning a project where creosoted wood is the material of choice, the risks to the environment from its use must be assessed by the designers and DOT's opinion of the risks must be communicated. Further, this risk evaluation should be done early in the project and transmitted to the agencies with the initial permit applications.

Here we will make recommendations for the ADOT to proceed in the permit process. We assume that the ADOT designers have already made a determination that wood is the material of choice and that creosote wood treatment is required. Also, that the wood treatment method is a small part of the project and that the ADOT designers have been communicating with NMFS and ADF&G about the project and are aware of their general concerns regarding EFH and TES.

The first step in the risk evaluation we will call "preliminary evaluation." It is similar to the hazard identification of a standard risk assessment or the environmental assessment portion of an EIS. The point it simply to determine if more evaluation is warranted. In this regard, the preliminary evaluation phase will likely be part of a more complete permit application.

First some in almost all cases where creosoted wood is the material of choice, a statement should be made in the initial permit application or attached to it. The statement has two parts, first an acknowledgement that the ADOT is aware of the creosote issues and second that BMP will be taken.

1. The DOT should state at the beginning that it recognizes that creosote is a pesticide and not a benign material, but that the ADOT has evaluated the situation and determined that the pubic interest is best served by use of creosote in this particular application. The boilerplate language would indicate

   a. Wood is the most economical material for initial cost/ shock absorption/ ease of installation and replacement.

b. The threat of marine borers is present and threaten the wood
c. Creosote will only be used for wood that is subject to borer attack
d. Copper-based preservative, ACZA, is not benign either and in addition, does not hold up as well in freeze thaw cycles and has corrosion issues.

It is not necessary to provide detailed calculations, just an assertion by a responsible designer, presumably a PE.

2. That BMP will be taken, specifically that the wood will be treated to the WWPI BMP specifications that allows less retention for northern waters. All other WWPI and EPA recommended BMP will be in the specifications. (This is somewhat redundant, since the WWPI BMP are more stringent than the EPA.) Those WWPI specifications are found at WWPI *Best Management Practices for the Use of Treated Wood in Aquatic and Other Sensitive Environments* (WWPI) and the EPA's in the RED (EPA 2008a).

The next will be project specific. For most small or medium sized projects, unless the project planning and discussions with the agencies indicates there is a specific EFH or TES issue, the risk analysis may be brief and simply note that after a few weeks there is no creosote derived PAH in the water column, and PAH in the sediment near the structure is unlikely to affect any EFH or TES.

2. Is the project in an EFH or will a TES species be affected.
    a. Most Alaskan waters are mapped as EFH for one species or another. However within the EFH is the concept of a habitat areas of particular concern (HAPC). The risk analysis should note that the project is or is not in an HAPC.
    b. In general, in order for an activity to adversely affect an EFH, it will be a larger activity, such as: "port development, marine disposal of dredged materials, development of coastal wetlands, coastal transportation projects such as roadways, pollutant discharges, and certain resource extraction activities such as mining, logging, and oil and gas exploration." (NOAA 2009) Thus smaller projects such as replacing a worn fender system are unlikely to affect an EFH. On the other hand, larger project such a new marina are likely to require an analysis. However for these projects, the wood treating method would be a small part of the general impact to the EFH – these projects will often require an EIS.
    c. In general construction activities of all types will be scheduled or staged to avoid contact with endangered species, typically salmon fry migration
    d. The project as a whole will be evaluated with respect to EFH and TES . So, it seems unlikely that a creosote-related issue will arise independent of other major concerns about the project.

With this risk evaluation, if there no HAPC and the construction will be staged to avoid TES, the ADOT could conclude the ecological risks from creosote use are small and further inquiry is not warranted. A simple statement to this effect would be needed in the permit application, perhaps saying," We examined the use of creosote with respect to EFH and TES and determined any adverse effects are unlikely.

If an EFH or TES is an issue, the next step is a risk assessment. We may divide these projects into four categories:

1. Small pile structures less than 100 piles
2. Large pile structures over 100 piles
3. Floats and other light structures
4. Bulkheads and other special structures.

In all cases, some basic data about the harbor is needed:

1. maximum current velocity
2. oxygen status of the sediments
3. pollution status of the harbor

These should be obtained from the project design documents of field investigations.

1. Small pile structures less than 100 piles
    a. Here the risk assessment is adequate covered in the WWPI document, *Treated Wood Treated Wood in Aquatic Environments.* (WWPI 2008)
    b. Table C of WWPI provides a matrix of current speed and oxygen status of the sediments. With moderate current speeds, only anoxic sediments require a more elaborate risk assessment, see below.
    c. Some special considerations may be needed if the area is already polluted, creosote has large surface area, such as a bulkhead, or is close to other large projects using the same preservative.
2. Large pile structures, more than 100 piles
    a. A risk assessment is generally required.
3. Floats and light structures
    a. Compare the area of creosote treated wood with an equivalent area of a pile. The use the criteria from small pile structures, above.
4. Bulkheads and other special structures
    ii. If these are largely above high tide, see Chapter 4. These are unlikely to have any effect on marine life or pollution.
    iii. If they are submerged, use the equivalent pile method to screen
        1. Very small area, treat as small project, above
        2. Area is larger, say equivalent to 20 piles, do a risk assessment.

Risk Assessments in General

Risk assessments can be simple or complex. Some can easily be done by ADOT staff and others would require the help of consultants. As a general rule, the simple risk assessments are very conservative. That is, they save field work and analysis by making reasonable assumptions that are conservative. However, if the risk characterization is acceptable, even through it overstates the risks, there is no need to spend the time and expense doing a more detailed risk assessment. We mention the WWPI screening risk assessment, which requires only a few easily determined parameters and little computation time. Next level, are Dr. Brooks models, which require a few more parameters, although these can be assumed with conservative default assumptions, and require some computational effort. Central to these risk models is a conservative maximum level of PAH in the sediment of 10 mg/kg based on 1% organic carbon. If the models yield terminal PAH concentration higher than 10mg/kg, a more in depth assessment is needed that looks at the specific species affect, their habitats, and other biological, chemical, and oceanographic data specific to the project.

Basic assumptions

We can simplify the risk assessment process by noting that water column concentrations of creosote-derived PAH fall to background very quickly after pile installation. There is some leaching of PAH for the life of the pile, but the LPAH are degraded quickly and the HPAH settle to the bottom quickly. Therefore the steady state water column concentrations are too low to be of practical concern. The initial concentrations may be of concern, but avoiding the critical seasons in step 2 above will take care of that.

The sediment quality may be of some concern and the next steps consider that. If there were no PAH other than that derived from newly installed creosote piles, and the sediments were not anoxic, the sediment PAH would be expected to increase for a time, then decrease. The rate of increase can be computed for BMP piles for water temperature and salinity and current velocity. The chief factor influencing the degradation of PAH and its subsequent decrease in the sediment is the oxygen status of the sediment. This can be estimated from RPD and the current velocity.

However if there is PAH in the sediments prior to the pile installation, these must be considered. The pre-construction sediment concentration of PAHs is affected by natural and anthropogenic PAH deposition, the basic sediment concentration of organic carbon, and the BOD placed in the water. These affect both the background PAH concentrations and the oxygen available to degrade new PAH from creosote. Thus, if the background PAH were over 10mg/kg based on 1% OC, the sediment would be considered polluted already and not suitable for creosote piles.

Next from the HPAH leached from the piles, the settling depends on the current velocity. Once in the sediments, the rate of degradation of the PAH depends on supply of oxygen in the upper layers of the sediment. More exactly, it depends on the depth of the reduction potential discontinuity (RDP), which in most sediment is the depth at which the color of the sediment changes brown or light grey to black or dark grey.

5. What is the current flow and sediment conditions?.
    e. The WWPI risk model present a simple matrix based on current speed and sediment quality. If the current is high enough and the sediment quality (aerobic and not already polluted) is sufficient, a more detailed risk assessment is not needed.
    f. The parameter is the maximum current velocity, which is generally known to the designers and
    g. The depth to the RPD – the reduction-oxidation potential discontinuity. Roughly the depth at which the character of the sediment changes from aerobic to anaerobic
    h. The WWPI guidelines provide a conservative estimation of the maximum sediment PAH concentration due to the piles.

i. If the matrix indicates the sediment concentrations will exceed a given value, more evaluation is needed.

In Appendix F we discuss Dr. Brooks models. These allow the introduction of more parameters then the WWPI screening risk assessment and thus more exact predictions.

More complex risk assessment

The goal of the risk assessments process is termed the "risk characterization." It states the probability and severity of harm to a receptor. For ecological risk assessments, determining the receptor involves considerations of species and life stage, as well as exposure duration. Selection criteria for the receptor species should include its role in the food chain of other organisms. The risk characterization depends on two parallel processes, a toxicity evaluation and an exposure assessment. The toxicity evaluation determines, for each species and life stage, determines the likely effects for each dose or, for aquatic species, the exposure concentrations. The exposure assessment evaluates the fate and transport of the contaminant from the source to the receptor and it's the likely time course of exposure to the receptor.

While this algorithm is simple and based on scientific principles, its practical application can be extremely complex, and therefore time consuming and costly. For example deciding which of the PAH constitutions is the chemical of concern – of course many of them are. The risk assessment process can be facilitated by using various benchmarks with the assumption that meeting them will protect relevant species and the ecosystem. For example, assuming that if the sediment concentrations of PAH remain below 10 mg/kg, the ecosystem will be protected. Since most of the approved benchmarks are quite conservative, this is probably a good assumption. A second aide to risk assessment is to only examine the species important by their listing as a TES species or part of a fishery. Of course the prey of these species needs to be considered as well. For many of these, there is a definite time window when they are present in a particular location. Further, for most of these, it is only the immature life stages that need be considered. Finally, since projects that use creosoted wood are very limited in area, and science indicates the PAH contamination is limited, one may determine that even if the affected are were "removed" from the ecosystem, there would be not measurable affect of TES or fisheries.

Further, based on science, the effects of creosote are limited. In the water column, PAHs decline to background values very quickly. Thus, water column effects are limited in time even in a still basin. In currents typical of Alaskan harbors, the effects in the water column may be nil. There is a definite transport of creosote from piles and creosote structures into the sediment, and these may persist if the sediments are anaerobic. However this effect is limited to a region close to the structure. There is one research paper that indicates that herring eggs that stick to creosote piles have very poor survival rates. However at worst this would be a localized effect. See Chapters 2 and 9 regarding that issue.

Thus, if construction is staged so that immature life stages are avoided (or not important at that location) the risk assessment can be limited to the likely sediment concentrations.

However water column concentrations, which decline with time, can be used to determine the length of closure. The models in Appendix F can help with this, but generally 17 days is the maximum that any PAH above background was detected and that was with non-BMP piles. (Kang, et al., 2005) Thorough evaluations of sediment require the sediment triad: sediment chemistry; benthic survey, and sediment toxicity. However for a prospective evaluation, we can only use the likely sediment chemistry – the predicted concentrations of PAH. Further, we should look at the steady state concentrations, considering organic content of the sediment and RPD. The organic content reduces toxicity by binding PAH. The RPD determines the rate of degradation. An often accepted sediment criteria is 10 mg of PAH/ kg of dried sediment. For sediment with more organics, the allowable concentration would be higher. A review of the literature shows an enormous range of sediment toxicity value, because of the number of species tested and the varying test conditions. Also, for sediments, there are often many other contaminants besides PAH. And other organics in the sediment affect bioavailability. Also, many sediment criteria are promulgated for environmental remediations or dredging spoil disposal, activities that purposely disturb the sediment, which may not be an appropriate model for the gradual disposition of PAH or creosote particles.

However, 10 mg/kg of PAH in sediment with 1% organic is accepted by, for example, the State of Washington, Sediment Quality Guidelines, and thus 10 mg/kg should be conservative, unless there is good evidence, based on the species and site specifics, for a lower standard.

The most expedient method of estimating the sediment PAH is to use a model. The models of Dr. Brooks have been tested and found to generally predict the levels of contamination, although they tend to be conservative. That is, to overstate the risk. A recent version of Dr. Brooks' model is described in Appendix F.

Once the time course of contamination is estimated, it may be used as input into the risk management decision. For example, if the final sediment concentration predicted by the model is 100 mg/kg, ten times the benchmark level, caution is required. Although this level will be confined to a region with about 10 meters of the structure, it will be there for a long time – many years. Thus, a region of the structure's footprint, plus a 10 meters margin may have toxic levels in the water above the sediment. However the nature of the ecosystem may indicate that does not matter to the health of fishing stock or TES. For example if the structure will be behind a breakwater and not in migration channels of fish.

Chapter 9 Research Workplan

Revised Research Workplan

The research to date, literature search and interviews with persons knowledgeable in creosote use, has indicated research gaps that should be addressed which are different than the research originally proposed. The three main gaps are the effects of fouling on the toxicity potential of creosote treated marine piles, the nature of creosote emissions from treated wood material, usually glulam, used in marine floats, and performance of copper treated wood in Alaska.

Background

The most relevant mesocosm studies of the effects of creosote piles on the marine environment were the Sooke Basin studies.[ref] These demonstrated that, after a small time, there was no measurable PAH from the creosote in the water column. PAHs were found in the sediment, but these sediments were anoxic because of deposits from the vast increase in marine life growing in and around the piles, and were not likely to be transferred to pelagic (water column) species. Low levels of PAH were found in mussels growing on the piles in the first year, but none in following years. So, while there are reams of studies that indicate that PAHs are harmful to marine life and that creosote treated piles do release PAHs to the environment, the effects of that PAH are small to start with, limited to a region close to the pile, and diminish rapidly with time. There was one study, however, that did indicate some potential for harm from creosote treated piles. The relevant part of that study compared the mortality of herring eggs and larvae that were scrapped from a pile that had been in the water for 40 years versus those that were scrapped from a nearby plastic pipe. Virtually all the eggs and larvae were dead or deranged while those from the plastic had only a normal death rate. At first impression, this would seem to indicate that creosote piles should not be used in regions where the herring stock is stressed. The author of that study said the piles were not fouled – covered with marine growth. Also, chemical analysis of the old piles was not done. But the more common experience is that marine piles are quickly covered with marine growth. So, there are two questions that need to be answered before we suggest creosote should not be used if the herring stocks are stressed in the region and herring are likely to spawn on them. One, would a modern BMP pile, especially one that was fouled, be harmful to herring eggs, and two, how does a creosote BMP pile compare with other wood treatments, such a ACZA or copper Napenthate, or with alternate pile materials, such as galvanized steel or steel with cathodic protection, or concrete piles?

The second issue is that the greatest need for creosote treated wood today in not in piles, for which alternates are available, but in wooden material used in floats – floating docks – in which the creosote in members that are only partially submerged. Studies have shown that in a pile, the creosote is not in the water column after only a short time, 17 days in one study. Thus, if we wanted to determine a window for which creosote piles would not be allowed because of issues related to the water column, there is data to support that window need only be two weeks long. However for wood float material, which is only partly submerged, this window might be longer. Of course since there is less material than from piles, the amount of creosote might be less. In any case, there is nothing in the literature about the transfer of creosote from floats. As part of this study, it may be useful to determine if the transfer from the wood is via chemical diffusion or via micro-droplets of creosote that are squeezed out of the wood due to solar heating cycles.

The third issue is the serviceability of copper-treated (ACZA) wood in Alaska marine environment. Some of the issues are well-known, such as corrosion, because they are not particular to cold regions. However in cold regions, there are often freeze thaw cycles. In wood in Southeast Alaska marine waters, there may be hundreds of cycles per year. A water soluble wood treatment absorbs water and this freezing and expansion of the water may lead to brooming or other deterioration of the wood. Anecdotal evidence confirms this, but there have not been controlled studies to verify this. Controlled studies might indicate a clear preference for creosote (or other oil-based treatment) for cold regions, and this could result in a standard design specification.

Outline of research

I. Test of herring egg toxicity of creosote treated piles that have been fouled and alternate pile systems.

There are two hypotheses to be tested.

1. Are BMP piles a substrate harmful to herring eggs?
2. Does the fouling of piles reduce the toxicity to herring eggs?
3. Are alternate pile systems toxic to herring eggs?

Both are tested in the same general experimental procedure. Pile sections will be hung below the low tide line for varying amounts of time and permitted to foul. Then sections will be tested for their toxicity to herring eggs. Since that will be limited to a year or two, an effort will be made to procure some sections of creosote treated piles that have been in the water for several years. The nature of the creosote of these sections will be assessed and compared with recently tested piles by laboratory testing.

II. Creosote transfer from float material.

The hypothesis to be tested

1. Does the transfer of creosote to the water column diminish quickly?
2. Does the PAH content of the sediment increase measurably?
3. Does the transfer of creosote to the sediment occur by diffusion/ adhesion, or by transfer of microdroplets.

These will be tested by observing the removal and replacement of a long existing dock and its replacement with creosote treated floats without creosote treated plies. The water column will be tested at one week intervals for several months after the installation and the sediment tested before and after the installation at one month interval. In addition, sediment traps will be sample the sediment directly below the floats and the sediments examined to determine if the creosote in droplets or dispersed into other particles.

III. Use of ACZA wood in Alaska marine float material.

The hypothesis to be tested is

1. Does ACZA float material compare favorably with creosote treated float material in Alaska?

This will be tested with a “case control” method of comparing applications of ACZA float material with creosote material of the same age and application situation. The method will be observations, interviews, and photographs.

Detailed Herring Egg Proposal

Creosote Piles and Pacific Herring Eggs - Research Need and Outline Plan

The use of Creosote treated wood in marine environments has been reviewed by several agencies. Creosote was recently approved by the EPA with its *Reregistration Eligibility Decision for Creosote* (RED). (EPA 2008a) Another agency, the NMFS of NOAA has presented a public review draft, *THE USE OF PESTICIDE-TREATED WOOD PRODUCTS IN AQUATIC ENVIRONMENTS: Guidelines to NOAA Fisheries Staff for the Endangered Species Act and Essential Fish Habitat Consultations.* (NMFS 2009) The EPA document proposes a ecological risk assessment for creosote use, but the result would be if the risks were large, Best Management Practices (BMP) should be used. A plain reading of the RED is that BMP would not be needed, unless the ecological risks were large. Since BMP is more or less standard today, as a practical matter, the EPA document would not require a risk assessment. The NMFS document also requires a risk assessment but is more ambiguous about the details. However that document recommends the Western Wood Preservers Institute (WWPI 2006a) BMP and the WWPI risk assessment method for smaller projects, but recommend a site specific risk assessment for larger projects.

Two studies are often mentioned in these another other policy reviews, one is the series of Sooke Basin studies where creosote and non-creosote piles were driven in a pristine bay and the environment near the piles monitored for four years. (Goyette and Brooks, 1998a and 1998b) That study indicated that shortly after installation, the PAH from the piles was not detected in the water column nor were marine life affected. PAH was transferred from the piles to the sediment, but these effects were confined to a region close to the piles and declines with time. The low current speeds (<2 cm/sec) and other factors made this a worst-case test. Thus, in general, the Sooke Basin studies are cited as indicating a low level of risk to marine life from BMP treated marine pile.

The other study, by Vines, et al., (Vines 2000) seemed to indicate extreme toxicity of creosote to herring eggs, even creosote from 40-year old piles. The bulk of that study was made with pieces of wood from the interior of the piles, and thus did not replicate the normal situation, where creosote from the interior of the pile must diffuse cross-grain to enter the water. It was not surprising that there were high levels of PAH from the interior of the piles, since it is this PAH that allows the pile to resist the marine borers. Thus the bulk of the Vines, et al., study is not directly applicable to creosote-treated piles in situ.

However a preliminary study made by Vines was quite pertinent. In that study, herring eggs were scrapped from a 40-year old pile and from a nearby plastic pipe. The eggs scrapped from the pile had a very low survival rate and deformities of the larvae – it essentially lethal to 100% of the eggs. This preliminary study of Vines would indicate that creosote piles, even older piles, may be highly toxic to herring eggs. However, in a personal communications with Dr. Vines, I learned that the 40-year old piles from which she scrapped the herring eggs were not visibly fouled. This is unusual, since most creosote piles are quickly covered by fouling organisms. Thus, in the preliminary study of Vines, the eggs were stuck to pile directly, where in most applications, the eggs would stick to fouling organisms on the surface of the pile, not the creosote-treated wood. Since this preliminary study of Vines is the only research that directly indicates the toxicity of creosote-treated in situ piles to marine organisms and conflicts with the Sooke Basin studies, some research is needed that examines the toxicity of in situ marine piles, with their typical fouling organisms, to herring eggs. Also, since the pile in Vines preliminary study was not fouled, it may have had an atypical creosote formulation. It surely was not treated to BMP. In addition, alternate piling materials have not been tested, to my knowledge, for toxicity to herring eggs. Thus, I propose testing, pile sections, in three replicates:

1. A BMP pile that has been transported and conditioned in sea water for a short time, a week or two.
2. A BMP pile that has been in salt water for over a year, and presumably fouled.
3. A older pile, verified to be creosote treated, that has been in service for several years.
4. ASZA pile, similar to 1.).
5. A plastic coated pile
6. A steel pile with corrosion resistant paint
7. A steel pile with cathodic protection
8. A concrete pile, new or brushed
9. A concrete pile that has been in service
10. A PVC control pipe.

The basic exposure set up is that the ends are sealed and a bag placed around the center of the pile, sealed top and bottom with hose-clamp type bands. The unit is placed in a seawater bath at the Seward marine center with flowing seawater. The bath keeps the temperature of the bag at sea water temperature and supports the bag. The bag has an influent and effluent water supply from a peristaltic pump. The influent line is filtered seawater. The lines are tapped to use the influent line for feeding and the effluent line for taking samples. The fertilized eggs are introduced and monitored through larvae stage. At the stated time the success is measured by comparing the groups with the control. In addition, the PAH content of the influent and effluent water will be tested.

Clearly there are some issues that must be resolved for this test:

a. Herring eggs are extremely sticky after fertilization. Fertilizing them and then transferring them to the bags may be difficult.
b. The unfertilized eggs may be introduced into the bags and then the sperm. I need expert advice on this, but it may work. But
c. The fertilization success would be difficult to assess through the bag material.
d. The larvae should be easier to observe, but difficult to count. Thus, the endpoint needs to be chosen, and then the contents of the bag counted. Thus, observing the larvae at intermediate times would be difficult.
e. The nature of the fouling organisms must be considered. Some are toxic and other organisms may be predators or harbor predators.
f. However it may be possible to test 50 or 100 eggs on each pile segment, thus making the test robust to fate of individual eggs.
g.
h. The fouling organisms are alive and thus need to be handled carefully to keep them healthy.

Here I would propose gather sections of BMP piles and placing them in seawater in early summer and leaving them until the following year. Also, we can locate older piles and that may be available, and take samples to verify the creosote content.

Detailed Proposal for Creosote-treated floats
Creosote treated floats

Creosoted wood float material is likely to be in use of a long time. In service, most of the wood should be above the water. However the wood will be in the water during installation. After installation, creosote may be transferred to the water by micro drops spalling off the wood, especially if they are warmed by the sun. Here our hypotheses are:

1. There will be a measurable increase in PAH in the water column near the newly installed floats
2. The PAH in the water column will decrease to ambient levels in a week or two.
3. There will be some PAH transferred to the sediment, even though there is very little in the water column.

Method
Identify a project that will install floats in the summer of 2010, preferably one in a location not expected to be heavily polluted. Take sediment samples in a grid pattern where the flats will be installed. Take some water samples at different tides. During the installation, take water samples at different tides. Take sediment samples at one week, one month, and several months after the installation. It would be nice to take some the following year, as well.

ADOT issue
While there are viable alternates to wood piles, float material is more problematic. If the float material is assumed to be above the salt water, other wood treatments might be used. However this may not be good practice. We need to evaluate that.

Expected results

I would expect the water column to have some PAH immediately after installation and that this would decrease to ambient very quickly. Also, the sediment would slowly increase, but that the absolute levels would be quite small.

List of Appendices

Appendix A Guidance and Risk

Introduction

The scope of work of this research involved an assessment of "likely future laws and regulations." Our analysis to date indicates that new laws or regulations are unlikely, but that agencies "guidance" will be very important. In this appendix we examine some issues related to "guidance," especially as it effects NMFS consultations. In later appendixes we treat the two main guidance documents, Stratus and Treated-Wood.

Because wood preservatives are a contentious issue nationwide, NMFS is desirous of having a policy or guidelines to aid their staff in such consultations. First we should consider the nature of such policies or guidelines in the legal context of agency decisions. Agencies promulgate regulations ("rules") under two laws. First the enabling law that requires the agency to regulate the subject matter, and second the Administrative Procedures Act (APA), that requires the agency to go through a definite process in the promulgation of the rule. The rule-making process may be long and arduous, requiring public notice, publishing of drafts, public hearings, revision of proposals, and if there are major revisions, the entire process is often repeated. Once the process is complete, the regulation is a "law" as binding as the statue law that mandated it. Contrasted with regulations, all agencies have myriad "procedures" that guide the work of the regulators. These may be very definite articles, such as published laboratory procedures, or administrative things like, "all applications originating north of Anchorage are processed by our Fairbanks office." These may be published in "Standard Operating Procedures" (SOPs) or simply arise by habit and custom within the agency. Using term "SOPs" to include all variations of procedures, we note several issues. The largest is that once an SOP is established, it may have a profound effect on the interpretation of regulations and thus itself become a regulation itself, but one that was not vetted under the APA. However in a contentious matter, if an agency "fails to follow it own procedures," aggrieved parties will use this as proof of unfairness and often prevail in the ensuing dispute. This makes it difficult for agency staff to vary SOPs in contentious situations. Thus, once an SOP is established, agency personnel feel bound by it. On the other hand, without such SOPs the agency staff could not function efficiently or perhaps at all.

Risk, Guidance, and the Precautionary Principle

Risk

Risk involves the probability and severity of some harm. (Sometimes the word "opportunity" is used for the opposite of risk, the probably and severity of some benefit.) In complex human transactions, the various risks are a "cost" to the party who bears the risk. They might be insured against, in which case the risks have a definite monetary cost, or the risks are simply borne by one or the other parties to the transaction with the costs "real but uncertain." Of course the costs of these risks must be balanced by some benefit to the parties, or the transaction would not complete. Note these benefits may be opportunities, that likewise have a probability associated with them. The balancing of risks and benefits is difficult for a government agency, where the risks include bad publicity, time lost responding to increased scrutiny of the pubic and the media, possible loss of budget, job insecurity for top administrators, and so on. Benefits on the other hand are very nebulous, other than the satisfaction of doing one's job well.

Caution about *Precaution*

In a later appendix we treat the Stratus document in some detail, but here want to comment on a section of the report that cites the "precautionary principle" as dictating some courses of action regarding creosote. The irrelevance of that is discussed in the Stratus appendix, but here we will discuss the underlying principles of precaution and risk.

We have learned that risks are characterized by stating the probability and severity of some harm. Later those characterized risks are used in a risk management decision. We also recognize that do-nothing is a management option and different than simply ignoring a risk. Both the risks and the management decisions from a current hazard, say MTBE in a city's water supply, is different from the risks and management decision regarding the possibly of some future hazard, say building a landfill near the city's water supply wells. The nature of the do-nothing alternative is quite different. If the hazard existed prior to the management decision, the decision itself did not contribute to the hazard. Thus, the moral implications of the decision for the decisions makers are quite different. Of course prior decisions by that same manager may have contributed, but that is a "sunk cost" and not relevant to the decision of the moment. Conversely, if all the effects of the decision will occur in the future, the decision itself may contribute to the hazard. Thus a present decision to change or not change the current state of nature in the future that has risks in the future is quite different than making a decision about a present hazard. Here the decision itself invokes the hazard. Now of course there were other hazards in the likely future states of nature, that's why we are making the decision – for example the city's current landfill is at capacity we have a court order to close it in two years. But no hazard at all existed for the City's wells, prior to our decision - the do-nothing alternative eliminates the risk to wells.

"Soft precautionary principle"

The precautionary principle was stated by the Rio Conference[1] "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of <u>serious or irreversible damage</u>, lack of full scientific certainty shall not be used as a reason for postponing <u>cost-effective measures</u> to prevent environmental degradation." [Emphasis mine.]

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[1] The **Rio Declaration on Environment and Development**, often shortened to **Rio Declaration**, was a short document produced at the 1992 United Nations "Conference on Environment and Development" (UNCED), informally known as the Earth Summit. The Rio Declaration consisted of 27 principles intended to guide future sustainable development around the world.
[http://en.wikipedia.org/wiki/Rio_Declaration_on_Environment_and_Development]
The "precautionary principle" is one of the 27 principles. Of course these do not have the effect of law in any country.

So Rio requires serious or irreversible damage, albeit only a threat of those, would trigger measures to prevent this, but only if they are cost-effective. This could mean that the costs would be overwhelming in themselves or that the costs are large in relationship to the damage. The damage may be hard to evaluate. For example, the extermination of a rare species that is little known or useful, might be regarded as of infinite value, since the species will never appear again, or no value, since it would not be missed. Of course real world decisions are always complicated by economics and politics.

Hard precautionary principle.
The more recent 1998 Wingspread Conference[2] issued a document that states: "When an activity raises threat upon to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically"
Note a broad reading of this is simply that if there is a "threat" some precaution is warranted – a notion that is hard to argue with. However it seems to demand that some measures be taken, even if the science does not establish causation.

While these general policy notions might be thought provoking, the application of them is hardly scientific. As van den Belt (2003) notes:

> [Definitions such as Wingspread] beg many questions. Is there ever full scientific certainty? Do we need a minimal threshold of scientific certainty or plausibility before we may (or should) undertake preventative action? And do we really know how to prevent harm if we are so much ignorant about the underlying cause-effect relationships? The definitions that are currently on offer fail to spell out the precise conditions that have to be fulfilled before the PP may be invoked or the nature of the preventative action that has to be taken. The types of action suggested range from implementing a ban, imposing a moratorium while further research is conducted, allowing the potentially harmful activity to proceed while closely monitoring its effects, to just conducting more research. The PP does not have a very precise meaning as long as such crucial aspects are left largely unanswered.
>
> In practice, however, the PP is often given a more definite meaning by reducing it to an absurdity. Normally, no minimal threshold of plausibility is specified as a "triggering" condition, so that even the slightest indication that a particular product or activity might possibly produce some harm to human health or the environment will suffice to invoke the principle. And just as often no other preventative action is contemplated than an outright ban on the incriminated product or activity. The intervention of Greenpeace in the monarch butterfly case seems to fit this pattern.

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[2] The **Wingspread Conference on the Precautionary Principle** was a three day academic conference where the precautionary principle was defined. The January 1998 meeting took place at Wingspread, headquarters of the Johnson Foundation in Racine, Wisconsin, and involved 35 scientists, lawyers, policy makers and environmentalists from the United States, Canada and Europe.
[http://en.wikipedia.org/wiki/Wingspread_Conference_on_the_Precautionary_Principle]

> Closely linked to various versions of the PP is the idea of reversing the onus of proof. Thus, the adherents of the Wingspread Statement declare that "the applicant or proponent of an activity or process or chemical needs to demonstrate that the environment and public health will be safe. The proof must shift to the party or entity that will benefit from the activity and that is most likely to have the information" (Raffensberger and Tickner, 1999). Greenpeace also holds that effective implementation of the PP requires a shift in the burden of proof (Greenpeace, 2001). Shifting the burden of proof seems a fairly straightforward way to ensure, as Jonas demanded, that greater weight will be given to the "prognosis of doom" than to the "prognosis of bliss."
>
> Before looking into the proper assignment of the burden of proof, we must first examine more closely the underlying justification for the strong version of the PP. Why should the prospect of harmful effects of a new technology take precedence over the prospect of beneficial effects, quite apart from the inherent likelihood of each of these possibilities? The obvious answer seems to be that such a priority is defensible only when the harmful effects are of such magnitude that they carry catastrophic (or, as Jonas would say, "apocalyptic") potential. The infinite costs of a possible catastrophic outcome necessarily outweigh even the slightest probability of its occurrence.
>
> This type of reasoning exhibits a remarkable resemblance to a well-known example of a "zero-infinity dilemma," namely Pascal's famous "wager." When it comes to wagering on the existence of God, the 17th century French philosopher argued incisively in his *Pensées* that it is better to be safe than sorry (Haller, 2000; Graham, 2002; Manson, 2002). Given an unknown but nonzero probability of God's existence and the infinity of the reward of an eternal life, the rational option would be to conduct one's earthly life as if God exists.
>
> Alas, Pascal's reasoning contains a fatal flaw. His argument is vulnerable to the "many gods" objection (Manson, 2002). Consider the possible existence of another deity than God, say Odin. If Odin is jealous, he will resent our worship of God, and we will have to pay an infinite price for our mistake. Never mind that Odin's existence may not seem likely or plausible to us. It is sufficient that we cannot exclude the possibility that he exists with absolute certainty. Therefore, the very same logic of Pascal's wager would lead us to adopt the opposite conclusion not to worship God. Pascal's argument, then, cannot be valid.

If the reader will pardon another long quote, Chauncey Starr writes in Risk Analysis (2003):

> This brings us back to the precautionary principle. Governments asked to regulate public exposure to risks from man-made sources (food, water, air, radiation, pollutants, electromagnetic fields, etc.) face a tortuous decision process because of the above uncertainties of risk analysis. The use of the precautionary principle as a politically defensible umbrella is a tempting escape from this difficulty. However, it

> is not cost-less, as protection from a risk that may be nonexistent or trivial may deprive the public of attractive and valuable lifetime choices. The only defensible approach is a comparative risk analysis of alternative pathways, taking into account our most credible projections of the lifetime economic, environmental, and health values of these alternatives.
>
> The precautionary principle exists only as a rhetorical statement; it provides no useful input to decision making. Expert opinions should be sought, but be recognized as conservatively biased. The search for science-based guidance is commendable, but is rarely achievable. In areas of public health and safety, comparative benefit/cost/risk analysis of all options should provide the judgmental base for decision making. Between the horserace bet and a credible, scientifically established projection, the decision maker will always be faced with a choice and no guarantees. There will always be room for pragmatic judgments on the limitations of long-range management.

Or to summarize, the agency must make a decision based on the best available science and other issues, then apply judgment. Citing "precaution" to avoid a decision is not valid, since most decisions will be made with many uncertainties involved.

Appendix B Sediment Quality

PAH Sediment Quality Levels

The threat to marine organisms from creosote derives from exposure of those organism to PAHs. Elsewhere we establish that water column concentrations are close to zero after a short time and not of long-term concern. (Chapter 2) The most likely source of PAH exposure to marine life would come via the PAH in sediments. The Brooks model provides an estimate of the sediment PAH concentrations, albeit a conservative estimate. Further, the basic risk analysis guidelines preclude the use of creosote if the sediments are anoxic or already polluted with PAH. Thus, the question is, what the level is of PAH, predicted by the Brooks model, or other trusted models, which would be acceptable. In general, the Brooks models show in increase in sediment PAH concentrations that reaches a maximum and then declines.

While there is much publish research and many standard methods about sediment toxicity, most of those refer to issues relating to dredging and deposition of dredge spoil. That is, will the relocated dredged material harm the marine life at the location where it is dumped? Ideally the in situ sediment quality is assayed using the “sediment triad” which combines first, a chemical analysis of the sediment, second a benthic survey of the marine life in the sediment, and thirdly a laboratory toxicity test of sediment taken from location. The results of these three are then used to make a qualitative decision about the dredged material. Indeed, the Sooke Basin study did a sediment quality tirade investigation of the creosote piles which is discussed elsewhere. However for a prospective analysis of the effects of adding some PAH at a location, only the first step of the triad can be used, the chemical analysis, or better, an estimate of what the chemical analysis would yield in the future. Thus, some notion of the acceptable levels of PAH as demonstrated by the sediment chemistry may be useful.

First, the acceptable sediment concentrations would need to be related to the exposed organisms, especially the organisms identified by the ESA/TES or EFH. These are seldom sediment dwelling organisms. The toxicity of sediment to pelagic species is seldom reported. The one study that resulted in several papers (Horness et al. 1998) often quoted regarding the toxicity of PAH in sediment to English sole, a bottom dwelling but free swimming fish. That study was confounded by many other contaminants in the sediment studied and likely migration of the fish to more highly contaminated areas prior to the study.. See Brooks (2006) and Poston (2001) for a discussion of the Horness paper.

Second, levels of organic contaminants in sediments are usually expressed in weight of contaminant per dry weight of sediment, but then some allowance is made for the percentage of organic carbon in the sediment. Binding of the organic contaminant to the organic carbon reduces the bioavailability of the contaminant. Another approach is to express contamination in weight of contaminant per weight of organic carbon. In any case, the relation is not straightforward and involves the Koc or partitioning of the contaminant between organic carbon and water, which is different for each PAH chemical. For example, if the weight of Benzo(a)pyrene was 10 mg/kg of dry weight of sediment, and the organic carbon content were 2%, the equilibrium concentration of BaP in the water would be about 4 ppb. However in the water near creosote treated piles placed in the pristine water of Sooke Basin, there was little PAH measured in the waters, about 20 nanograms per liter, or approximately background. These are measured by an extraction process, so the free PAHs are likely uncommon, they are more likely sorbed to organic centers in the water and not directly bioavailable to free swimming fish.

Swartz tried to reconcile the many published standards for PAH levels in sediments and came up with a consensus Threshold Effects Level of 2.9 ppm for sediment with 1% organic content or 5.4 ppm for 2% OC. (Swartz 1999). This level would be protective for sediment dwelling organisms. The state of Washington developed sediment quality standards for their regulations, (Chapter 173-204 WAC) of 370 ppm LPAH and 960 ppm HPAH both as wt/wt carbon. So for sediment with 1% organic carbon, the level of heavy PAHs would be 9.6 mg/kg, if the sediment had a 2% organic carbon, a more common situation, the acceptable level of heavy PAH would be 19.2 mg/kg.

There has been some published research that indicates water column concentrations of PAH in the 1 ppb range may be harmful to salmonid eggs and larvae. (Heintz, 1999) Although this seems a very low level, since ambient level are often higher in many locations, it is not incompatible with a sediment level of 10 ppm. For the heavier PAHs, which are assumed to be most harmful to the eggs and larvae, benzo(a)pyrene for example, the sediment-water partition coefficient would indicate most of the PAH would remain bound to the organic carbon in the sediment. For example, if the sediment were 2% organic carbon, 10 ppm BaP would result in a concentration in the water of 0.5 to 1.0 ppb of BaP. The lighter PAHs are more soluble, but these are also assumed less toxic. In addition, the salmonid eggs studies were done with weathered Alaska North Slope Crude, presumed from the Exxon Valdez. The nature of PAH from weathered ANS is quite different than PAH from weathered creosote from piles. Weathered ANS (and petrogenic PAH in general) have many alkylated PAHs, while weathered creosote and pyrogenic PAHs have mostly parent (unalkylated) PAHs. For example, a sample of heavily weathered EVC PAH has less than 1% parent phenanthrene but it has 30% C1, C2, C3 and C4 phenanthrenes. On the other hand, PAH from creosote 32% parent phenanthrene and only 6% total alkylated phenanthrenes. Although the body of research related to the toxicity of alkylated versus parent PAH in the marine environment is not large, there is some evidence they are more toxic in mammals, and likely more toxic in any animals that have a robust p-450 xenobiotic metabolizing system.

Unless there were specific knowledge that sediment dwelling organism were a TES or the sediment itself was a EFH, a final sediment concentration of 10 ppm PAH dry weight should be amply protective of pelagic species if the OC is 1% or greater. If there is a sediment dwelling organism that is a TES or if the sediment itself were a EFH, some research would be needed regarding the levels of PAH that might be acceptable.

Appendix C EPA RED

EPA's Reregistration Eligibility Decision
Since creosote is used as a pesticide, the agency that had direct regulatory control over creosote is the federal EPA, under FIFRA, the Federal Insecticide Fungicide and Rodentcide Act. Especially interesting for the ADOT is the fact that the EPA decision is "risk management" decision that is founded upon a "risk assessment." Certainly some, if not most, of FIFRA regulated substances are toxic, thus the agency's decisions will consider the benefits to society from the application of the substance versus the stress to humans and the environment from its application. In late 2008, the EPA completed its Reregistration Eligibility Decision (RED) for creosote. (EPA 2008a) "As a result of this review, EPA has determined that creosote containing products are eligible for reregistration, provided that risk mitigation measures are adopted and labels are amended accordingly. The reregistration eligibility decision and associated risk mitigation measures are discussed fully in this document." That is, after characterizing all the risk associated with creosote, the EPA considered the benefits and economics, including those of reasonable alternates. The EPA FIFRA Office of Pesticide Program then promulgates "mitigation measures" and "labeling requirements" that the manufacturers and distributors of FIFRA controlled substances must in turn follow. Because creosote, as all coal tar volatiles, is toxic to humans, most of the mitigation and labeling requirements relate to human exposure in the manufacturing process, some of which would apply to field construction, but this is chiefly a concern of federal OSHA and Alaska DOL.

The only mitigation measure germane here is that "for treated wood that will be used in marine or other aquatic or sensitive environments, a double vacuum must be used…." This is the same as the AWPA BMPs that are already standard practice in Alaska. (WWPI 2006b)

The labeling requirements require the AWPA BMPs discussed elsewhere. This means that BMPs are required if a risk assessment indicates there is acute or chronic risk and implies that BMPs are not required if the risk assessment indicates no such risk. This is probably not important to the ADOT because elsewhere we recommend BMP be used and indeed piles not treated to BMP may not be available. However it may be important for endwalls and other structures that would not need to be treated to BMP, if risk to aquatic organisms is not demonstrated. (The rail road tie studies indicated there is not a significant risk, for most end wall locations, as discussed elsewhere.)

The risk management decision appears to be well thought out and followed public comment on a draft version. It should be pointed out that the ecological risk assessment (2008b) that was part of the risk assessment considered was likewise published in draft and likewise subject to public comments. The risk assessment makes clear that there are ecological risks associated with the use of creosote in the marine environment; while the risk management indicates that the EPA believes these risks are reduced to levels acceptable to the EPA, with proper mitigation and labeling. However even the EPA's risk assessment document concludes the chief mitigation measure is a label to preclude effluent, presumably from wood treating plants, from being discharged to aquatic environment. It indicates that acute exposures for some species is above the level of concern for some species, but indicates the chronic level is uncertain, although several risks were mentioned. In the latest and final version of EPA's ecological risk assessment says "chronic RQs (risk quotients, the ratio of exposure divided by toxicity) can not be calculated due to lack of chronic toxicity data, but available evidence indicates that chronic risk (survival, growth, reproduction, immunotoxicity) is possible to aquatic organisms inhabiting the water column." The term "is possible" is not very definite and difficult to input into a risk management decision.

The final document also states, " impacts of creosote-treated aquatic pilings are likely to vary locally, depending on abiotic and biotic factors such as current speed, amount of structure per unit area, air and water temperature, salinity, and the aquatic species occurring in the immediate area of the structures; thus, a site evaluation is essential prior to installation of new structures.

However, regarding a "site evaluation" the final RED seems to limit that evaluation to determining if BMP is required. That is not a burdensome requirement.

Appendix D Stratus Creosote

Stratus report: Creosote-Treated Wood in Aquatic Environments: Technical Review and Use Recommendations

When the draft is accepted, the more recent NOAA Guidelines document described in Chapter 7 and Appendix E will supersede this Status report. However, since the NOAA Guidelines are still in draft and the draft often references this Stratus document, some consideration of the document is warranted. Here we review the main findings of the document and its criticisms.

Introduction

The National Marine Fisheries Service, an agency of the National Oceanic and Atmospheric Administration has input into creosote-related decisions through is consultative role in the actions of other agencies, especially the US Army Corps of Engineers, and many agencies through the Coastal Zone Management Act. The Corps must issue a permit for any new structures or alteration to existing structures in navigable waters. The CZMA requires a "consistency evaluation" for any agencies actions that affect the coastal zone. In either case, the agency considering issuing a permit, or an action of the agency itself, must consult with the NMFS. The two laws that NMFS will consider are the Endangered Species Act (ESA) and the Magnuson-Stevens Act (MSA), the NMFS is responsible for managing commercially harvested aquatic species by implementing fishery management plans and designating Essential Fish Habitat (EFH) areas. Under the ESA the NMFS will consider if the action threatens a listed or endangered species or its habitat. Under the MSA, NMFS will consider if the action threatens an "Essential Fish Habitat" (EFH) of a protected species. In the event NMFS finds that the agency's action, such a approving a permit, will threaten a listed species under the ESA or an EFH, NMFS will convey that to the agency. This may result in the action such as a permit being disapproved, or may result in negotiations or design changes to remove the threat. Thus, via a ESA or EFH consultation process, NMFS may determine creosote piles are not an issue, or essentially ban the use of creosote, or delay a project while creosote-related details are revised or determined. Of course the permit applicant might protest the decisions to ban creosote, alternatively, a third party, such as an environmental group, may protest the decision to allow creosote. Either approach will be an action against the agency issuing or denying the permit, probably not NMFS directly.

Because wood preservatives are a contentious issue nationwide, NMFS is desirous of having a policy or guidelines to aid their staff in such consultations. In 2004 NMFS commissioned a consulting firm, Stratus, to write a report titled "Treated Wood in Aquatic Environments: Technical Review and Use Recommendations." The preface to that document states:

> These reports are the findings of Stratus Consulting regarding the use of treated wood. They have been subject to peer review and public comment. NMFS may utilize these reports and other available information, as appropriate, to develop or update

> guidelines on the use of treated wood in aquatic environments. Accordingly, these documents are not NMFS guidelines themselves.

The original report dealt with copper treated wood only. (Stratus Copper 2006) A second report was commissioned about that same time the dealt exclusively with creosote. Stratus 2006.

Both documents were available in late 2005 or early 2006 and the version placed on the NMFS website is dated December 31, 2006. A notice of the availably of these documents was placed in the Federal Register March 3, 2006, which requested public comment. That notice said

> The intent of the reports is to ensure NMFS is informed of relevant studies and recommendations when making decisions related to the use of treated wood in aquatic environments. This information may be used for future development or revision of NMFS treated wood-use guidelines. NMFS is soliciting public comment on whether the treated wood documents sufficiently summarize the existing body of knowledge concerning copper and creosote treated wood products, including the fate and transport of leached materials, the appropriate use of treated wood products, and the potential effects on living marine resources and their habitats. In addition to this public comment opportunity, the reports will also be subject to independent peer review.

There were three sets of public comments, one by the Creosote Counsel and one by Dr. Brooks, who consults for the WWPA, which might be considered industry comments, and two by the USDA Forest Products Lab and one by an academic researcher that would not be considered industry. There were three peer reviews. Together six of those eight documents were quite critical of the Stratus Creosote Report. The extent of changes provoked by those reviews is not clear, but it appears the specific comments were not changed in the final document.

Before we examine the draft NMFS guidance in Appendix E, we should examine some details the Strauss report, since some of them appear to be the chief basis of the NMFS guidance.

With that introduction, we consider what the Stratus report says with respect to marine creosote applications of the ADOT. We begin with the Stratus conclusions. The first paragraph comports with the author's analysis based on the literature:

> Overall, the laboratory and field studies described above indicate that treated wood structures can leach PAHs and other toxic compounds into the environment. However, the degree of PAH accumulation to sediment associated with these structures appears to be relatively minor in many settings, particularly in well-circulated waters and over time. PAH accumulation also appears to be relatively limited spatially (within approximately 10 m of the structure) and has not generally been associated with measured, significant, biological effects except in close proximity to the structures. The duration of any biological effects also appears to become attenuated within several months of construction (the time period when leaching rates are likely to be highest).

The first part of the second paragraph is difficult to interpret:

> Nevertheless, there are several factors that suggest that a precautionary principle might be applicable to certain treated wood uses. First, the above studies typically have evaluated responses at the community level (e.g., the benthic invertebrate studies) or to tolerant life stages (e.g., adult oysters and mussels). However, the level of environmental protectiveness applied to T&E species (such as endangered salmonids) should occur at the *individual* rather than the *population* or *community* level.

The first difficulty is that, unlike human health risk evaluations, ecological risk evaluations are always carried out at the population level. The "precautionary principle" has many interpretations and is subject to many criticisms. However the basic statement of that principle is

> "Nations shall use the precautionary approach to protect the environment. Where there are threats of serious or irreversible damage, scientific uncertainty shall not be used to postpone cost-effective measures to prevent environmental degradation."

That statement has two important qualifiers. First the damage must be "serous or irreversible" and second the measures must be "cost effective." With those qualifiers, the precautionary principle seems sound. However it could not be applied to threats to individuals, as Stratus holds, unless those threats to individuals would be lead to be serous or irreversible to the population. We discuss the precautionary principle itself further in Appendix A.

The last part of the Status conclusion is a qualitative basis for a risk assessment. Here we quote it:

> Moreover, field studies have indicated that PAHs can accumulate to potentially deleterious concentrations in poorly circulated water bodies or when the density of treated wood structures is high compared to the overall surface area of the water body. As a result, site-specific evaluations of risk should be conducted for treated wood projects that are proposed for areas containing sensitive life stages, species of special concern, or where water circulation and dilution are potentially low.

Note the use of qualifiers, such as "can accumulate" and "potentially deleterious concentrations." A general reading of that statement would seem to limit the need for a "site specific evaluation," that is a risk assessment, only if those special conditions exist. That is if the application is an area "containing sensitive life stages, species of special concern, or where water circulation and dilution are potentially low." Creosote would not be banned even from these areas, but a risk assessment, presumably limited to the sensitive life stages of key species, would be required. If those conditions were not there, a risk assessment would not be needed. We discuss considerations associated with such site specific risk assessments below.

Thus, this author agrees with those qualitative descriptions and indeed, so does the creosote industry, since the "Treated Wood in the Aquatic Environment" publish by the WWPI (2006a) has essentially the same general recommendations.

The conclusions list the major "factors to be considered" in an aquatic risk assessment" regarding creosote use. Again, the author notes these are the same, or vary similar to those implied by the US Forest Products Lab (Lebow and Tippie, 2001), The Canadian Fisheries (Hutton and Samis, 2000) and are included in Dr. Brooks models.

- **Background water quality variables such as salinity** The salinity of the receiving environment should be considered because leaching increases with decreasing salinity, as in estuarine environments.
- **Current velocity and direction** Although total leaching rates from treated wood can be relatively low, potential environmental effects will be dictated by local water mixing, with poorly mixed waters at greater risk. Information on current velocities – at the specific micro-environment – of the project location (including the influence of the structure itself on ambient current velocities) should be developed and integrated into a site-specific risk evaluation.
- **Proximity to sensitive fish habitat** The presence of sensitive life stages, especially T&E species or their essential prey species, should prompt an evaluation of potential risks at that location. Essential fish habitats for Pacific salmon include all streams, lakes, and other water bodies currently or historically accessible to salmon. This includes essentially all estuarine and marine waters of the Pacific Coast. The most sensitive life stages for these species are fry (particularly post swim-up) and juveniles. Because the initial leach rates are higher for treated wood, risk assessments should consider the timing of PAH releases relative to periods when sensitive life stages of fish are present.
- **Timing of proposed construction** Because initial leach rates tend to be greater, the timing of proposed construction should be considered with respect to the presence of sensitive life stages of aquatic receptors, water flow rates and temperature, environmental and climatic factors that can influence mixing and dilution, and the relationship between season, annual hydrograph, and water quality conditions.
- **Size of proposed structure** As discussed previously, environmental effects are likely to be greatest when the size of the proposed structure is large relative to the receiving environment. Factors to consider include number and size of pilings, surface area of exposed wood area relative to a mixing zone, density of pilings relative to the mixing zone (to evaluate potential behavioral avoidance responses), and potential effects of structure size on current flows.
- **Application methods** Treatment and application methods should be confirmed to meet industry BMPs.
- **Proximity of other treated-wood structures and other sources of contamination that may contribute to cumulative effects** In

> evaluations of site-specific risks, assessments should consider potential effects in light of the cumulative effect of the proposed structure relative to other existing environmental perturbations at the site.

All of these seem quite reasonable and should be considered. The salinity may not be too important in Alaskan waters, since cold temperatures predominate over salinity in determining leaching rates. Also, leaching reaches a steady state soon enough, regardless of salinity. Also, almost all Alaska construction is limited to a window that protects salmon fry migrations.

However, following those quite reasonable (in this author's opinion) guidelines, Status finishes up their conclusions with examples of local agencies that have banned or reduced creosote use and, without presenting scientific justification, then concludes:

> [Corps of Engineers, Los Angles policy] shows that regulatory agencies are increasingly recognizing that creosote treatments in marine environments can cause ecological harm under common enough circumstances that new structures should avoid the use of creosote-treated wood, and creosote should be isolated from the environment wherever it is used. Based on the findings of this report that creosote moves into the environment under a variety of realistic conditions, and environmental levels of contaminants originating from creosote-treated wood are often toxic, precautions to avoid creosote-treated wood where practical, and measures to isolate potential toxic effects appear to be justified. We recommend that similar precautions be implemented by regulating agencies throughout the United States.

Thus, presenting as justification for eliminating creosote, the fact that a few agencies have banned it, and ignoring their 50 some pages of scientific evidence, that the summarize above – that if there are sufficient currents and the sediment is aerobic, there is unlikely to be any significant environmental harm from BMP piles.

We will proceed by assuming that the later is an interpolation by a biased contributor in otherwise reasonable science and not deal with it further.

Because they are not available on-line, I have bound the comment documents into Volume II of this report. Most of the reviewers were commenting on the Stratus reports, the copper and the creosote. We could summarize the comments as follows:

Name	Employer/Industry	Comments
David Webb	Creosote Council III/Creosote trade group	Strongly critical
David Brooks	Consultant/ WWPI	Strongly critical, believes risks overstated
Chris Risbrudt	Director/ USDA Forest Products Lab	Transmits critical document by Lebow. But says: "Forest Service scientists have reviewed the reports and have noted that

		the recommendations have the potential to significantly impact construction projects conducted by the Forest Service and other government agencies. In several cases, the recommendations in the reports do not appear to be well-supported by the relevant science. "
Stan Lebow	Researcher/ USDA Forest Products	Strongly critical, believes risks overstated.
William B. Smith	Wood Products Engineering/ SUNY Syracuse	Critical, including: "Unfortunately, the use of inappropriate analysis, editorializing without scientific justification, and suggestions without merit that alternative materials such as steel or plastic pilings and timbers (which take considerably more energy, petroleum and other non-renewable resources to manufacture, are of considerably higher cost, and have questionable performance characteristics as compared to wood) would be better than treated wood, make the conclusions in these reports unusable and much of the rest of the information provided potentially suspect.
Peter Townsend	(Unclear)	Neutral. Suggests more work is needed to translate into good decision tool.
Jason M Weeks	CEFAS, UK	Neutral on the whole. Positive and negative in places. Emphasizes uncertainties in the data.
Judith S. Weis	Rutgers/ part of the Univ. of Miami Independent Peer Review System.	Strongly critical of the report, but believes the report understates the risk. Notes many of her own publications that were not used in the Stratus documents.

Finally, this author's evaluation is that, besides what appear to be interpolations by a biased reviewer, such as the "precautionary principle" and LA District Corps of Engineers references, the Stratus document as a whole is sound, and its recommendations: do a risk assessment only if certain key risk factors are identified, otherwise creosote piles are acceptable, as well as the outline of the risk assessment process, are protective of the environment and marine species. Of course some sort of preliminary investigation and analysis is needed to determine if those key factors are present. We discuss that further in Chapter 8.

Appendix E NOAA Draft Guidelines

Comments on NOAA's Draft Guidelines for Use of Pesticide-Treated Wood Products.

NOAA produced a guide document that became available in early January 2009. *The Use of Pesticide-Treated Wood Products in Aquatic Environments : Guidelines to NOAA Fisheies Staff for the Endangered Species Act and Essential Fish Habitat Consultations,* which I'll call "*guidelines*" in this appendix. (NOAA 2009) Public comments were solicited with the comment period closing on March 16, 2009. (FR 2009). The public notice gives a succinct purpose of the document:

> The intent of the guidelines is to aid NMFS personnel conducting Endangered Species Act (ESA) and Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) Essential Fish Habitat (EFH) consultations in making consistent determinations regarding projects proposing to use pesticide-treated wood products in habitats utilized by NOAA trust resources. The guidelines attempt to convey a summary of information that should be considered when examining the effects determinations made by the action agency and to direct personnel to documents containing more detailed information when needed.

The author was unable to get copies of the comments submitted to NOAA, however I was able to get the comments made by the WWPI, which are part of this appendix. The guidelines address all the common types of wood preservatives in use nationwide. Thus the guidelines and WWPI's comments have much that is not pertinent to Alaska. My comments are limited to creosote in Alaska.

The major finding in the conclusions of the Guidelines is:

> Overall, the use of pesticide-treated wood products in aquatic environments with the examined formulations (ACZA, CCA, and creosote) could be acceptable in many proposed projects. However, the products can not be considered categorically safe, and therefore, require project and site-specific assessment. Many projects, that still propose to use pesticide-treated wood, may pass a screen level examination and require relatively little assessment for the pesticide-treated wood impacts. These determinations require a level of local knowledge that may be applied on a case-by-case basis, or through regional watershed based procedures. The variability between locations makes it difficult to provide guidance on the scale of the entire west coast of the U.S. and Alaska.

Elsewhere the conclusions recommend BMP in all situations that involve EFH and TES and appear to limit the requirement for risk assessments to structures with over 100 piles and further imply that if the current exceeds 10 cm/sec (roughly 0.25 mph) likewise a more detailed risk assessment is not needed. This section of the conclusions is vague and probably refers to studies with copper in the Columbia River, but in general, it fits with the WWPI recommendations.

The conclusions seem to recommend copper over creosote, although the conclusions are not specific to Alaska.

Author's Review of *Guidelines*

Because the *Guidelines* covers many situations and at times to appear to present conflicting information, and because these draft guidelines may be pressed into service in lieu of final guidelines, I will present my review of them. The WWPI review and comments that pertain to creosote are listed in this appendix. The entire Guidelines and Comments are copied in Volume II.

Page 6, end of first paragraph, says models are uncertain and therefore need to be used with site specific information – relying on Status [3, and discussed in Appendix D]. The Brooks Model [see Appendix F] has been field tested in several locals and shown to be conservative. That is, it overpredicts the sediment concentration. The Brooks Model does require site specific information.

Page 6, second paragraph, tries to determine the level of impact deduced by a screening that would not require a full risk assessment and further differentiates an ESA issue from an EFH issue. It explains that the screening is similar to an "initial review" in an ESA determination, where a finding that the action "may affect" but is "not likely to adversely affect" an endangered species. If there were established local procedures for making that determination, they could be used to screen the project. The next paragraph then refers this process to local knowledge, rather than the *guidelines*. My comment is that this "local knowledge" would refer to the species under ESA or EFH consideration, not the effects of creosote, which are established by nationwide science.

Page 7, first paragraph, states "concrete pilings are cost-competitive with pesticide-treated wood pilings over the long-term and are competing in those markets." This is often not true. In any case, the choice between wood, concrete, and steel is made by the design engineer. In general, if wood will work for structure, wood is about half the cost of concrete.

Page 12, middle paragraph has some toxicity information that needs to be clarified. Two of the most interesting studies are those of Vines (2000) and Carls (1999) [5]. The main thrust of Vines study was that toxic levels of creosote diffusible material exist in the interior of 40-year old piles. This was determined by taking pieces out of old creosote piles and placing them in static renewal chambers with herring eggs, etc. This is quite unlike the potential exposures from in situ creosote piles, since the cutting the piles into pieces for the laboratory experiment exposes new creosote faces and allows end grain transfer of PAH to the water. In order for the pile to maintain its integrity in water with marine borers, the pile must have creosote within its wood structure. Thus Vines' findings were not unexpected. The most intriguing part of the paper, however, was not those laboratory studies, but rather a study of eggs scrapped from the exterior of old creosote piles. Compared with eggs scrapped from a nearby PVC pipe, the eggs scrapped from the pile had a very low survival. Because this was a preliminary part of the study and not controlled, the eggs may have come from different fish or been exposed to slightly different environmental conditions. However, more interesting, was that Dr. Vines did not note any fouling on the piles. (Vines 2008) Generally piles in marine waters foul very quickly, usually within a year. Lack of fouling may indicate the piles were atypical in other respects. In any case, one would expect that BMP piles underwater would have much less creosote on their surfaces than piles treated 40 years ago. The Carls study used PAHs that were leached from oil contaminated gravel and indicated toxicity in the range of 1 ppb, mostly of heavier PAHs, to salmon larvae. The methods seem quite through and the researchers are well known, thus this study is often quoted to indicate that a PAH level of 1 ppb may be toxic to salmon eggs. However I would note that Neff found levels of PAH in "pristine waters" of 1 to 2 ppb [Neff 1979]. And fish and invertebrates spawn and thrive in non-pristine waters that have much higher concentrations of PAHs. Thus, there may be a disconnect between the Carls study and nature. Two other issues are the nature of the oil and its location. In general crude oil, and certainly ANS from which the PWS oil came, is highly alkylated. Often the parent PAH is present in only very small quantities. On the other hand, creosote is often pure parent PAH and has few alkylated compounds. Alkylated PAHs are metabolized at different rates than the parent and are often assumed to more toxic. The second is that in the natural environment the heavier PAHs are bound to organic particulates or other organic matter and are not bioavailable. Also, see the "Page 12" comments from WWPI below.

Page 13, top paragraph, states that main concern is for PAHs that leach from creosote and they "accumulate in sediments and are assimilated into the food web." This implies that the PAHs that enter the sediment find their way into the food web. That is not the case. In oxygenated sediments most of the PAH are oxidized. Regardless of oxygen state, most PAH do not make it into the food web. Also misleading in that paragraph it says, "chronic and dietary exposure to the higher weight PAHs remain in sediments that cause the [harmful] effects ….[which are] more prominent in benthic species due to their frequent contact with the sediment. (Citing Stratus). The only study that purports this used a sediment that was contaminated with many things other than PAHs. True, toxic PAHs can be extracted from sediments, but this is not their course in nature. Further, that paragraph can be read that pelagic species are affected by PAH in the sediment, and that is simply not true.

Page 13, third paragraph, is key to risk assessment, since it strives to present sediment levels that may be harmful. This analysis for PAHs is always limited, because PAH is not a chemical, but a mixture of many chemicals, all of differing chemical, physical, and toxicity characteristics. The paragraph is not easy to read or interpret but seems to say that levels above some very low conservative limit should not be exceeded. Several problems with that are first, that these levels are frequently encountered in harbors and other habitat that seem to have thriving marine life communities. Second, science shows that the PAH in sediment is limited to the regions very close to the piles. Thus, regarding an EFH, the question would be, “even if the entire area beneath the structure were removed from the fishery habitat, would it affect the fishery?”

Page 20, middle paragraph, again repeats the tumors from sediment issue that is not accurate. It says that if the water body is “impaired” additional PAH from piles should not be permitted. Certainly if the water body is impaired by PAHs, creosote should not be used. This is stated in all the risk assessment paradigms. The third paragraph is particularly poor science. It extrapolates from the work of Vines to pelagic concentrations of creosote, but actual measurements of the pelagic concentration of PAH are essentially zero after a few weeks. It then goes on to cite the Corps of Engineers in Los Angles requiring wrapping of creosote piles, which has no relevance – is not science-based. The last paragraph seems to say that a region could adopt a standard number of piles, below which a risk assessment is not needed. The reference quoted, SLOPES III, used 50 piles as the cut off. That is, a project with less than 50 piles was considered not to require a full consultation – the Corps could grant the permit without NMFS consultations.

Page 22, first sentence, says copper-based and creosote treatments are interchangeable. This is not true in Alaska, as discussed in Chapter 4. Also, they discuss use of creosote in fresh water, which is not recommended anywhere, but is not allowed in Alaska.

Page 25, second paragraph, is erroneous. It seems to recommend coating piles with wraps in projects proposed for “sensitive locations” and could have been written by a supplier of coated piles. It cites “unnecessary environmental risk” which misuses both the words “unnecessary and “risk.” Coatings or wraps are expensive and should not be used unless there is a demonstration that the EFH or ES would be harmed if they were not used. If the currents are slow, sediment anoxic, or background PAH are high, they may be a useful alterative. True Pacific herring may spawn onto wood, but they spawn everywhere, especially on eel grass in Alaska. Only a minuscule proportion would land on piles. The last part about pile replacement does not fit. If they are only replacing a few piles, they will not matter.

Coatings are fine also, but only if somewhere is demonstrated if they are not coated there would be some problem. This section of the guidelines is not science-based.

Page 27, second paragraph, is not appropriate. If another material will be more cost effective, the engineer will specify it. This says nothing and implies that concrete is comparative. If it is, it will be used. It is generally not comparable in Alaska.

Page 28, first paragraph, regarding costs - Status in not competent to estimate prices, which will vary with location. In general treated wood will last a long time. Wood is much more resilient than concrete. Concrete life is quite variable. Intact it may last forever. If it is damaged, the rebar will corrode and the pile may not last long. Steel is more resilient, but needs cathodic protection or coating which may not be benign. In addition, steel needs repainting or coating and this is an operation that can contaminate the environment.

Page 32, first paragraph of Conclusions, says “leaching stays at easily detectable levels.” The word “easily” is a poor word choice. PAH can be detected, but “easily” implies there is a lot, which in fact there is not. It is at very low levels. In the Sooke Basin study, which was in a pristine area, the PAH after a year was not different than background, by the most sensitive methods. In the last sentence again implies that PAH from sediment is “most often associated with impacts to benthic species,” this not correct. PAH can cause those effects in all species, but there is little evidence that the low levels from creosote in a natural sediment can cause them.. The tests they cite were done in sediment contaminated with other chemicals and/or with PAH extracted from the sediments.

Page 33, top paragraph again refers to Vines study which we discuss above.
Effect would at worst be seen in unfouled piles with eggs laid directly on the wood. The next sentence is incorrect. Heitz et al (1999) dealt with weathered crude oil extracted from gravels not marine sediments. There is no connection between the work of Heintz and the creosote contamination under piles, which diminishes with time.

Page 33, second paragraphs, says models did not over- or underpredict. The model of Brooks consistently overpredicted the concentrations at Sooke and several other sites. In addition all the models take some “site specific” data to work.

Page 35, last paragraph of Conclusions, express a preference for copper over creosote. This would assume that the benefits of either treatment are the same. That is not true for Alaska, where creosote has a much longer service life for most applications. However it does say, “the limited available information shows that, in some specific instances, the proper use of creosote-treated products may not impact ESA listed salmonids in a manner that can be meaningfully measured, detected or evaluated. “

Notes on WWPI comments
Since the attached WWPI comments address all the treatment methods discussed in the draft *guidelines* I copied two related to creosote that might be especially pertinent.

Page 12 [of guidelines]. When citing the Vines et al. (2000) study, which found adverse effects on herring spawn associated with creosote treated wood, the report omits reference to Goyette and Brooks (1998, 2000), which found that spawn from mussels growing directly on the creosote treated piling developed normally to the trochophore stage. While it is true that fish (vertebrates) and invertebrates (with planktonic early life stages) face different contaminant pathways and therefore different challenges, we recommend that either (1) both reports should be discussed or (2) neither report should be included. We are aware that there are some concerns being raised about the protocols used in the Vines et al. study.

Page 13. We believe the Threshold Effects Level (TEL) and Effects Range Low (ER L) are not appropriate sediment quality benchmarks. Washington State has published EPA approved marine Sediment Quality Criteria (SQC) in WAC 173 204 and is currently developing freshwater Sediment Quality Values (WDOE 2002, 2003). Goyette and Brooks (1998, 2000) conducted a detailed assessment of the efficiency and protectiveness of a range of possible SQC applicable to the Sooke Basin Study. Similar to WDOE (2002, 2003) they found that the TEL and ER   L were unacceptably inefficient because they predicted far too many toxic effects in Sooke Basin Sediments when the very large bioassay database generated in that study did not find toxicity. Goyette and Brooks (1998, 2000) found that the arithmetic mean of the TEL and the Probable Effects Level (PEL) and/or the Washington State SQC were both protective and efficient. Other SQC are available, such as the Consensus SQC proposed by Swartz (1999) and we recommend that NMFS should review these standards and consider them for inclusion in the guidelines. The reports of Goyette and Brooks (1998, 2000) are particularly appropriate for consideration here because they apply to the mixture of PAH that accumulates in sediments in association with the use of creosote treated wood.

Appendix F, Risk Assessment Models

For a large complicated project where creosote piles were the best design option, if the screening risk evaluations described in Chapter 9, were not sufficient, a more formal risk assessment would be needed. This would likely require consultants in many fields and be a large expense and time commitment for the project. However, by assuming that is the levels of PAH in the water column and sediment that are unlikely to be harmful to sensitive marine life, there are several models, all by Dr. Brooks, that may be useful. In Appendix B we discuss level of sediment PAH and note that the Washington State SQG are generally accepted and, based on the Sooke Basin studies, conservative.

For structures less than 100 piles, the WWPI model, Table C of Treated Wood in Aquatic Environments provides a useful conservative model. Its default assumptions are for warmer water, and it has other conservative assumptions. However, it provides an answer with only two input parameters, maximum current speed and depth to the reduction-oxidation discontinuity. The former is generally known to the designers, the later is often taken as the depth at which the sediment changes from light brown or grey to black, or where the sediment begins to smell of hydrogen sulfide. More exact standards for determining the redox potential discontinuity are available. The WWPI model indicates if the currents are very slow or the sediments anoxic, further risk assessment is needed. Thus, if the structure is greater than 100 piles or the WWPI model indicates it, a risk assessment is needed.

The most expedient risk assessment model is available from the WWPI in two files:
And Excel sheet: http://www.wwpinstitute.org/researchdocs/creosote/creorisk.XLS
And a pdf file which has the derivation of the model and some explanation.
http://www.wwpinstitute.org/mainpages/documents/01creo497.pdf
The model in the spread sheet is set up with two piles set two meter apart. The sediment concentrations are derived from linear superposition of the second pile on the first. Since the concentrations fall off rather quickly, working with the model can quickly yield sediment concentrations for any number of piles by superposition. However, in general, if the sediments are aerobic, Dr. Brooks notes:

> The model assumes that contaminants are dispersed in a 30 degree cone downcurrent from each piling. To assess complex projects involving numerous piling, one simply needs to superimpose the footprint of one piling on another. The further apart the piling are in a bent, the less effect one piling has on the next. The [WWPI] model does that for several piling. For more - you need to do it as you suggest [superposition] However, based on the Sooke Basin Study and other risk assessments, PAH appear to be restricted to the area within about 7.5 to 10 meters from even dense clusters of piling. Therefore, if piling are say 4 meters apart, then one would only need to consider the interaction of three piling. (Brooks 2009)

Thus, using Dr. Brooks heuristic or superposition of the entire structure, a maximum sediment concentration can be derived. Note in the overall risk evaluation of the project, if there are no TES or the area of the project will not diminish an EFH, the area under a large structure may be discounted, that is, assumed to be lost to the environment or habitat. For most EFH issues, it would need to be a very large structure or be in an very critical location to make any difference to the fishery.

Other models

Dr. Brooks and others are working on a book about wood preservatives and this has chapters that present risk assessment models for creosote, not only from piles, but also from overhead structures, such as bridges, and other wood treatments, such a ACZA. The likely title and authors are: “Managing Treated Wood in the Environment” by J.J. Morrell, K. Brooks, T. Ledoux, and D. Hayward, which has a chapter titled, *Modeling migration of preservatives under varying regimes*, which this author reviewed and noted it was very complete. That book should be available soon.

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List of Acronyms

Acronyms and Abbreviations

AAC	Alaska Administrative Code
ACZA	Ammoniacal Copper Zinc Arsenate
ADOT	Alaska Department of Transportation and Public Facilities (ADOT) AAC
AMOP	Arctic and Marine Oilspill Program
APA	Administrative Procedures Act
ANS	Alaska North Slope
AMH	Alaska Marine Highway
ATSDR	Agency for Toxic Substances Disease Control
AWPA	American Wood-Preservers' Association
BaP	benzo[*a*]pyrene
BMPs	best management practices
BOD	Biochemical oxygen demand
CCA	Chromated copper arsenate
CZMA	Coastal Zone Management Act
DOL	Department of Labor
EFH	Essential Fish Habitat
EPA	Environmental Protection Agency
ER-L	Effects Range-Low
ER-M	Effects Range-Median
ESA	Endangered Species Act
EFH	Essential Fish Habitat
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
HAPC	habitat areas of particular concern
HPAH	heavy PAH
kg	kilograms
Koc	Organic carbon partition coefficient
LD	Lethal dose
LC	Lethal concentration
LC50	Concentration lethal to 50% of the organisms
LPAH	Light PAH, two or three rings
LOEC	lowest observable effects concentration

LPAH	light PAH
MFO	Mixed function oxidase
mg	Miligrams
MSA	Magnuson-Stevens Act
NAS	National Academy of Science
NIOSH	National Institute of Occupational Safety and Health
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOEC	no observable effects concentration
NOEL	no observable effects level
O&M	Operations and maintenance
OC	organic carbon
OSHA	Occupational Safety and Health Agency
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PEL	Probable Effect Level
ppb	parts per billion
ppm	parts per million
ppt	parts per thousand
PWS	Prince William Sound
RED	Reregistration Eligibility Decision
RPD	redox potential discontinuity
RCRA	Resource Conservation and Recovery Act
RQs	risk quotients
SOP	Standard Operating Procedure
SPMDs	semipermeable membrane sampling devices
SPME	solid-phase microextraction
SQGs	sediment quality guidelines
SQC	sediment quality criteria
SUNY	State University of New York
TEL	Toxicity Effect Level
TES	Threatened and endangered species
TOC	total organic carbon
TPAH	total PAH
U.S. EPA	U.S. Environmental Protection Agency
USFS	Forest Service
USDA	USDA

USFWS	U.S. Fish and Wildlife Service
WAC	Washington Administrative Code
WWPI	Western Wood Preservers Institute

Volume II

Creosote Treated Timber in the Alaskan Marine Environment: a Report to the Alaska Department of Transportation and Public Facilities

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Draft Final Report
Report No. INE/AUTC 09.10

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1. Best Management Practices. Descriptive brochure. Includes general information and information not specific to creosote.
2. Best Management Practices. More technical than 1.) above. In specification format.
3. Treated Wood in Aquatic Environments. Semi-technical document. Has section on selection of preservative with retention recommendations. Also has WWPI risk matrix.

Volume II
Section I
Catalog Cuts from Vendors

- This section contains URLs to catalog cuts from vendors. The cuts were selected to be illustrative. The author intends no specific endorsement of these vendors – there may be other vendors of similar products that are comparable. The URLs given in the text and below are moving targets at best. In addition, some vendors sites require visitors to register.

In order:

1. Plastic piles and structural members, cuts from Trelleborg Plastic piles and timbers, some made from recycled plastic, are used for structures and fender piles. One brand features a pile that is filled with recycled plastic with fiberglass reinforced plastic rebar and a UV light and abrasion resistant outer skin. These are available in both pile and beam shapes. http://www.trelleborgms.com/catalogue_1.aspx?id=1:30038&cat=1:469203&pagenum=1&pagesize=20 for plastic piles and http://www.trelleborgms.com/catalogue_1.aspx?id=1:30038&cat=1:469282&pagenum=1&pagesize=20 for a plastic beam.
2. Plastic pile coating, a specification from Schrader Marine. This is another method of plastic encapsulation is to coat a pile with plastic before it is installed. Spray on polyurea ("truck bed liner") is one type of plastic used [3] and the finished coat may be 250 mil (1/4 inch) thick. http://www.schraderco.com/pdf/poly1.pdf for a These are generally applied over a treated wood to reduce transfer of the treating chemicals to the environment and the coating is not structural.
3. Plastic products that attach to the outside of piles. This brand features a petrolatum mat that lays between the plastic and the wood, that, when compressed, seals the wood preventing oxygenated water from reaching the wood and thus preventing marine borers. See http://www.tapecoat.com/marine_pages/seriesr.htm
4. Epoxy. Another retrofit method that should work with installed piles is an epoxy grout that will bond to wet wood (or concrete or steel). A metal form sleeve is placed around the pile and the mixed epoxy is placed in the form. http://www.schraderco.com/pile_res.cfm
5. Supplier of ACZA, a water-born copper-based preservative Chemonite® ACZA should contain approximately 50% copper oxide, 25% zinc oxide, and 25% arsenic pentoxide dissolved in a solution of ammonia in water
6. Stainless steel fasteners or a plastic sleeve for steel fasteners are recommended for ACZA.See http://www.archchemicals.com/Fed/WOLW/Products/Preservative/Chemonite/hardware.htm

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Section II
Stratus Creosote Report and Comments

Documents in order

1. Federal Register announcement of report and request for comments
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Section II

Stratus Creosote Report and Comments

1. Federal Register announcement of report and request for comments

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[DOCID:fr03mr06-33]

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DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

[I.D. 013006H]

Availability of Two Reports: Treated Wood in Aquatic Environments: Technical Review and Use Recommendations; and Creosote-Treated Wood in Aquatic Environments: Technical Review and Use Recommendations

AGENCY: National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Notice of availability; request for comments.

SUMMARY: NMFS is providing this notice in order to allow Federal and state agencies and the public an opportunity to review and provide comments on two reports, prepared for NMFS by an independent consulting firm, regarding the use of treated wood products in aquatic environments. The intent of the reports is to ensure NMFS is informed of relevant studies and recommendations when making decisions related to the use of treated wood in aquatic environments. This information may be used for future development or revision of NMFS treated wood-use guidelines. NMFS is soliciting public comment on whether the treated wood documents sufficiently summarize the existing body of knowledge concerning copper and creosote treated wood products,

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including the fate and transport of leached materials, the appropriate use of treated wood products, and the potential effects on living marine resources and their habitats. In addition to this public comment opportunity, the reports will also be subject to independent peer review.

DATES: Public comments must be received by 5 p.m., Pacific standard time May 2, 2006.

ADDRESSES: Comments on these reports may be submitted by mail to the National Marine Fisheries Service, 777 Sonoma Avenue, Suite 325, Santa Rosa, CA 95409, Attn: Water Quality Coordinator/Treated Wood Comments. Comments concerning the Treated Wood in Aquatic Environments report may be sent via facsimile to (301) 427-2538. Comments concerning the Creosote-Treated Wood in Aquatic Environments report may be sent via facsimile to (301) 427-2540. Comments may also be submitted electronically. For comments regarding the Treated Wood in Aquatic Environments report, please e-mail your comments to SWR.CopperWood@noaa.gov. For comments regarding the Creosote-Treated

swr.nmfs.noaa.gov/ or may be requested by calling or emailing the contact person listed below. Please include appropriate contact information when requesting the documents.

FOR FURTHER INFORMATION CONTACT: Joseph Dillon, Southwest Region Water Quality Coordinator at 707-575-6093 or by email, Joseph.J.Dillon@noaa.gov.

SUPPLEMENTARY INFORMATION: The purpose of the technical review documents is to present a summary of existing literature, prepared independently by Stratus Consulting, Inc. for NMFS, that analyzes the potential effects and mitigations for the use of treated wood products in aquatic environments. The documents focus on copper treated wood, primarily ammoniacal copper zinc arsenate (ACZA), as this is the most prominent material used on the west coast of the United States and in Alaska, and creosote treated products.

These products are being examined by NMFS to determine the risks generated by their usage to the living marine resources that NMFS is responsible for managing. These include anadromous salmonids managed by NMFS under the Endangered Species Act (ESA), as well as other marine fishery resources including Essential Fish Habitat (EFH) as identified and described under Federal fishery management plans pursuant to Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act). The use of treated wood in or near aquatic environments commonly requires a permit issued by the U.S. Army Corps of Engineers pursuant to the Clean Water Act and the Rivers and Harbors Act of 1899. Under the ESA, Federal agencies must consult with NMFS pursuant to section 7 of the statute to ensure that any action authorized, funded or carried out by the Federal agency does not jeopardize the continued existence of any threatened or endangered species or result in the destruction or adverse modification of designated critical habitat. Federal action agencies are also required by the Magnuson-Stevens Act to consult with NMFS on any action that may adversely affect EFH. In issuing this permit, the U.S. Army Corps of Engineers will have to conduct an EFH assessment pursuant to 60 CFR 600.920(e) to determine whether the proposed permitted action will adversely affect EFH.

Effects of treated wood that need to be examined under the ESA and Magnuson-Stevens Act regulations include direct, indirect, and cumulative effects. An example of direct effects includes the acute and sublethal impacts of copper and polycyclic aromatic hydrocarbons to salmonids and the EFH of managed species. An example of an indirect effect includes the adverse impacts to the prey base upon which ESA listed and EFH managed species depend. An example of a cumulative effect includes the impacts of multiple structures and contaminants in an area with or without additional loading from urban sources, historic mining, smelters, ships' hulls or any other source. The synthesis of these effects to habitat and to individuals, coupled with local environmental conditions and specific species of concern, defines the risk of a project proposing the use of treated wood.

Since the use of treated wood materials in situations that may expose aquatic ecosystems is widespread along the west coast of the United States and in Alaska, development of guidelines from the information presented in these reports should help to streamline the review of permitting processes as well as the permitting processes themselves. These reports may be used in the future to create new or update existing NMFS policies regarding treated wood.

Dated: February 27, 2006.

James W. Balsiger,
Deputy Assistant Administrator for Regulatory Programs,National Marine Fisheries Service.

[FR Doc. E6-3048 Filed 3-2-06; 8:45 am]

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Volume II

Section II

Stratus Creosote Report and Comments

2. Comments of David A. Webb, Administrative Director, Creosote Council III

CREOSOTE COUNCIL III

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May 2, 2006

National Marine Fisheries Service
777 Sonoma Ave., Suite 325
Santa Rosa, CA 95409

Attn: Water Quality Coordinator/Treated Wood Comments

Re: Comments on draft Stratus Consulting report entitled, *Creosote-Treated Wood in Aquatic Environments: Technical Review and Use Recommendations* (Oct. 17, 2005)

Dear Sir:

On February 27, 2006 the National Marine Fisheries Service (NMFS) issued a notice, published at 71 Fed. Reg. 10957 (March 3, 2006), announcing availability of, and soliciting public comment on, two Stratus Consulting Inc. reports, each dated October 17, 2005, regarding use of treated wood in aquatic environments. One of those reports, *Creosote-Treated Wood in Aquatic Environments: Technical Review and Use Recommendations* (hereinafter "*Technical Review*"), is the subject of these Creosote Council III ("Creosote Council") comments.[1]

The Creosote Council is the national, non-profit product stewardship organization for the U.S. creosote industry. Creosote is a highly beneficial, federally registered, industrial wood preservative used primarily for pressure treatment of railway ties, utility poles, and marine pilings. In addition to sponsoring all of the scientific studies that the United States Environmental Protection Agency (EPA) has required for reregistration of creosote under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), the

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[1] The other Stratus Consulting report, confusingly entitled *Treated Wood in Aquatic Environments: Technical Review and Use Recommendations*, pertains primarily, if not exclusively, to waterborne wood preservatives, particularly CCA, ACZA, and ACQ.

Council often comments on federal or state legislative or regulatory matters that affect the nation's creosote producers, creosote wood treaters, or industrial/commercial users of creosote-treated wood products.

NMFS consideration of possible guidelines relating to use of creosote-treated wood in Pacific coastal aquatic environments, and specifically the technical review which the NMFS Southwest Regional Office engaged Stratus Consulting Inc. to conduct in connection with development of such guidelines, is a matter of substantial interest and concern to the Creosote Council. For the reasons discussed below, Stratus' supposedly independent and objective creosote *Technical Review* exceeds the proper bounds of a scientific analysis, reflects the NMFS Southwest Regional Office's own patent bias against use of creosote-treated wood, and contains numerous outcome-driven assertions and conclusions that are inaccurate, misleading, or scientifically unwarranted. As a result, the Stratus creosote *Technical Review* utterly fails to fulfill its stated objective, which NMFS indicated "was to establish a solid scientific basis from which guidance development and implementation could proceed." NMFS Statement of Work for Center for Independent Experts (CIE) at 2.

GENERAL COMMENTS

1. Draft Status of *Technical Review*

In response to the Creosote Council's concerns that the Stratus report be released in *draft* form for public review and comment, Dr. William T. Hogarth, Director of NOAA Fisheries, indicated in a February 2, 2005 letter to the Council that "*[d]rafts* of Stratus' treated wood summary documents will be released for public comment *prior to finalization*" (emphasis added). Similarly, Dr. Hogarth wrote to the Council on October 12, 2006, reconfirming that "NMFS will release the *draft* literature review and synthesis reports from Stratus for public comment" (emphasis added).

Despite Dr. Hogarth's written assurances to the Creosote Council, nothing on the face of the Stratus *Technical Review* of creosote-treated wood indicates that it is a draft. Instead, the creosote *Technical Review*, whose printed color cover is dated October 17, 2005, gives every appearance of being a final document. Further, the document is posted on the NMFS Southwest Regional Office's web site under "Items of Interest" without any indication that it is a draft, and the document is never referred to as a draft in the NMFS March 3, 2006 *Federal Register* notice. Even worse, the Council's understanding is that overly zealous NMFS personnel have been disseminating the creosote *Technical Review* to other federal agencies' personnel as if it were a final document rather than cautioning that it is merely a draft and subject to revision following public comment and peer review.

Given that NMFS has submitted the creosote *Technical Review* for peer review, the document necessarily must be treated as a draft. *See* Office of Management and Budget (OMB), *Final Information Quality Bulletin for Peer Review* (Dec. 16, 2004), at 3 ("Peer review involves the review of a draft product by specialists in the field who were not involved in producing the draft."). To help rectify the misleading impression that NMFS and Stratus have created, the Creosote Council requests NMFS to promptly take the following actions: (i) stamp the cover and each page of the creosote *Technical Review* as a "DRAFT"; (ii) substitute the DRAFT-stamped document on the NMFS Southwest Regional Office web site and indicate that the draft creosote *Technical Review* is subject to public comment, peer review, and revision; (iii) publish a supplemental *Federal Register* notice clarifying that the October 17, 2005 creosote *Technical Review* is a draft, and subject to public comment, peer review, and revision; and (iv) advise all cognizant NMFS personnel that the creosote *Technical Review* is a draft document subject to public comment, peer review, and revision, that they must explain this fact whenever disseminating the draft, and that they may only disseminate the DRAFT-stamped version of the document.

2. <u>Peer Review Procedures</u>

The March 3 *Federal Register* notice states that the Stratus reports "will also be subject to independent peer review." 71 Fed. Reg. at 10958. More specifically, NMFS unilaterally determined—without any stakeholder input—that peer review of the Stratus creosote *Technical Review* (and the Stratus companion report on wood treated with waterborne preservatives) would be conducted by the Center for Independent Experts (CIE), which operates under the auspices of the Cooperative Institute for Marine and Atmospheric Science, a University of Miami–NOAA Fisheries joint institute. As a threshold matter, the Creosote Council believes that consistent with traditional peer review practices within the scientific community, NMFS should have sought stakeholder input in advance regarding subjects such as whether the CIE is the best suited organization to conduct an expert and independent peer review of the Stratus reports; what the specific experience and qualifications of the peer reviewers, and the pertinent conflict of interest considerations, should be for this particular peer review; and what the peer review process should entail. Instead, NMFS acted unilaterally in selecting CIE and devising the Statement of Work (including the Terms of Reference), so as to foreclose any stakeholder input.

The Creosote Council is especially concerned NMFS determined that the CIE peer review—which the Statement of Work describes as merely a "letter review"—should not be conducted in an open, transparent manner, and without any opportunity for stakeholder input directly to the peer reviewers, whose identities and qualifications still remain unknown to stakeholders and the public. NMFS apparently referred the Stratus reports to the CIE for peer review at least one month before they were released for public comment. Under the NMFS Statement of Work, each of the three (unidentified) members of the CIE peer review panel is to spend a maximum of only five days working individually on the project. There does not appear to be any opportunity for the peer reviewers to interact with each other, much less receive and consider comments from outside scientists, stakeholders, or the public. In fact, the Statement of Work requested that the peer reviewers' individual (non-consensus) reports be submitted to NMFS by April 14, 2006, more than two weeks prior to the May 2, 2006 deadline for public comments on the Stratus reports. As far as the Creosote Council knows, the CIE peer reviewers' reports (which presumably now have been forwarded to NMFS) have not yet been released to the public, and thus, the Council must hereby reserve (indeed, insist upon) a timely opportunity to comment on the CIE creosote peer review reports after NMFS finally makes them available.

CIE's procedures certainly allow for a peer review panel to conduct a meeting at which stakeholders can speak and/or submit written comments directly to the panel in connection with a NOAA-related issue, and to meet and confer in executive session following such a meeting, before each peer reviewer prepares his/her own independent report. *See, e.g.*, CIE's Groundfish Peer Review (reports describing CIE process utilized in that peer review are posted at www.rsmas.miami.edu/groups/cie/cierevlnks.htm.) The OMB *Final Information Quality Bulletin for Peer Review* states as follows:

> Public comments can be important in shaping expert deliberations. . . . there are situations in which public participation in peer review is an important aspect of obtaining a high-quality product through a credible process. . . .
>
> Public participation can take a variety of forms, including opportunities to provide oral comments before a peer review panel or requests to provide written comments to peer reviewers. Another option is for agencies to publish a "request for comment" or other notice in which they solicit public comment before a panel of peer reviewers performs its work.

OMB *Bulletin* at 21. Rather than utilizing any such open procedure here, NMFS mandated a limited, closed, paper procedure in which the anonymous peer reviewers are insulated from any outside criticisms of the Stratus reports, and apparently even the ability to confer with each other. This abbreviated "behind closed doors" peer review process might suit NMFS's purposes, but it violates the spirit of the OMB *Bulletin*. It strongly suggests that the NMFS Southwest Regional Office has attempted to rig the peer review process in order to obtain a quick rubber stamp of approval from the peer reviewers, not a fully informed, independent scientific evaluation of the Stratus reports.

3. NMFS Consideration Of Stakeholder Comments

The Creosote Council's understanding is that NMFS has contracted with Stratus to review stakeholder comments on the Stratus reports (such as these Creosote Council comments), and to prepare written responses to those comments. In addition to Stratus' review of the comments, the Creosote Council believes that it is extremely important for NMFS to review and consider all comments independently of Stratus. This is especially true for comments, like the Creosote Council's comments, which criticize the scope, content, and quality of the Stratus *Technical Review*. Of course, it also is important for both NMFS and Stratus to consider the peer review reports.

4. Nature and Utilization Of Potential NMFS Guidelines

As the Creosote Council noted in its September 13, 2005 letter to Dr. Hogarth, it is imperative for NMFS and its personnel, especially in the regional offices, to understand that any NMFS regional (or national) "guidelines" regarding use of, or issuance of permits for, creosote-treated wood in aquatic environments, must be regarded merely as non-binding guidance. Any such guidelines will *not* be regulations, will *not* have the force and effect of law, will *not* have to be utilized by NMFS personnel when consulted on particular types of projects or individual projects, and will *not*, as a matter of law, govern review or approval of permit applications by any federal, state, or local agency.

Further, while the Creosote Council acknowledges NMFS' consultative, permitting, and other functions under the Endangered Species Act and Magnuson-Stevens Act, the Council wishes to emphasize that through FIFRA, Congress has vested EPA with the primary authority to regulate the use of creosote, before, during, and after its application to wood products such as marine pilings. FIFRA's fundamental purpose is to protect health and the environment. Consistent with that mandate, EPA is nearing conclusion of a comprehensive, objective, non-biased, science-based FIFRA reregistration review of creosote (as well as conducting reregistration reviews of waterborne wood preservatives and numerous other pesticidal active ingredients). Under reregistration or other FIFRA review processes, EPA will determine, at the appropriate time, what restrictions, if any, should be imposed in connection with use of creosote-treated wood in aquatic environments. Although the consultative and/or permitting activities of NMFS, the Fish and Wildlife Service, and the U.S. Army Corps of Engineers are important, they are ancillary to EPA's primacy regarding how use of creosote-treated wood should be regulated, including in aquatic environments.

SECTION-BY-SECTION COMMENTS

Title of report — The title "*Creosote-Treated Wood in Aquatic Environments: Technical Review and Use Recommendations*" is inaccurate since the creosote report (unlike the separate Stratus waterborne wood preservative report) does not make any specific recommendations regarding use of creosote-treated wood products in aquatic environments. Accordingly, the phrase "Use Recommendations" should be deleted from the title, which instead should be *Creosote-Treated Wood in Aquatic Environments: Technical Review*. Similarly, the penultimate sentence in section 1.1, which incorrectly asserts that Chapter 4 of the report includes "recommendations to minimize the environmental risks of toxic chemicals in aquatic environments" should be deleted.

Section 1.3 ("Types of Oil-borne Wood Preservatives") — The last sentence of the first paragraph asserts that "[t]o protect wood from these organisms, preservative formulations must be toxic to the wood-degrading organisms." This statement is incomplete at best. To be effective, wood preservative pesticides need only establish a zone of wood pest inhibition at susceptible sites on treated wood. Contrary to the Stratus creosote report, efficacy as a wood preservative does not depend on production of adverse effects in wood-degrading organisms. This distinction may be esoteric to some, but goes to lack of objectivity in the Stratus draft and suggests bias against wood preservative pesticides.

Section 1.4 ("Creosote Composition") — This section of the Stratus creosote *Technical Review* attempts to describe in summary fashion the composition of coal tar creosotes used to treat wood. The point of the section seems to be that despite an acknowledged composition that ranges widely and includes a large number and variety of components, the Stratus draft would take creosote to be a small collection of PAH compounds, primarily those regulated by EPA as carcinogenic. The main citation in the Stratus draft for this position is the World Health Organization (WHO) International Program on Chemical Safety (IPCS) document on Coal Tar Creosote (WHO, 2004). The Stratus draft points to the WHO document (and to a lesser degree on a 2000 publication by Eisler) as an authoritative source for a presentation on creosote physical properties and chemical composition. The draft goes on to state that the WHO publication includes creosote compositional analyses from eight studies including creosotes from the United States, Britain, Germany, and the former Soviet Union.

It is quite unlikely that the WHO document includes analytical information developed on a North American creosote. Table 3 of the WHO document does present compositional information on eight creosote samples from around the world and claims that one of these eight is an AWPA P1 creosote. The source of this data is a Tar Industries Services report prepared in 1990 for an International Tar Conference. It is unlikely that the creosote analyzed for the 1990 International Tar Conference originated in North America or even conformed to AWPA specifications for P1/P13 creosote since complete compositional analysis of AWPA P1/P13 and P2 creosotes was not reported until 1994. Likewise, the Stratus draft merely acknowledges North American creosote and cites only EPA's summarization of North American creosote compositional data.

Actual compositional data for North American creosote are never presented in the Stratus draft. The absence of the most complete and reliable analytical characterization of creosote is more than an example of a mere omission of detail on a complex topic: it is a flaw in the foundation of the way the overall analysis was conducted. If an assessment of the environmental effects of creosote and creosote-treated wood is to be made on the basis of what is known about individual components of creosote, the lack of cogent comprehensive compositional information on creosotes detracts greatly from the validity of the assessment. This is the case with the Stratus draft assessment despite the availability of compositional and physical property analyses on certified samples of North American P1/P13 and P2 commercial creosotes.

The Creosote Council does not agree with the approach taken by Stratus to evaluate creosote risk by summing available information on the hazards of creosote components. However, once taken, that approach is susceptible to the uncertainty in quality and incompleteness of the analytical information relied upon by Stratus. Despite the assertion in the last sentence of section 1.4[2] in their analysis of creosote, Stratus moved quickly through the complexities and differences of creosote composition to reach a position of equating creosote with a select group of polyaromatic hydrocarbons (PAHs). The Stratus draft points out that EPA has classified 7 PAHs as probable human carcinogens (Group B2) but does not point out that the most recent and complete studies

[2] That "[w]hen considering the environmental impacts and toxicity of leached creosote in this report, we often will refer to the contaminants in leachate as 'PAHs' for simplicity, though we in fact mean 'PAHs, phenolics, heterocyclics, and other contaminants.'"

of creosote-exposed populations fail to show an association between creosote and cancer incidence (Wong and Harris, 2005, J Occup Environ Med 47:7, 683-97). Moreover, hazard assessment of complex mixtures must take into account the interactions of the components of the mixture. This was largely undone by Stratus in the present exercise.

Taken together, the points outlined above suggest that the Stratus draft report on creosote captured only a limited portion of the compositional information available on North American creosotes. There are at least two consequences to this: (1) the creosote hazard assessment offered by Stratus can be no more reliable than the Stratus view of what creosote actually is; (2) the creosote hazard (and risk) assessments of Dr. Kenneth Brooks which are based on assessment of actual creosote exposures are far more relevant and reliable than the assembled component assessment of Stratus.

Section 1.5 ("Creosote Regulations and Policies") — This section of the report is outside the scope of a technical review of scientific literature and should be deleted. Furthermore, the so-called regulatory discussion is highly selective, incomplete, and inaccurate. It reflects a pronounced bias against use of creosote and creosote-treated wood, which seriously undermines the credibility of the entire report.

The following additional comments relate to section 1.5:

(a) The reference to the "absence of federal guidelines" incorrectly implies that there is no federal regulation of creosote from the viewpoint of protecting the aquatic environment. As discussed in the General Comments above, the use of creosote, from both human safety and environmental viewpoints, is primarily and comprehensively regulated by EPA pursuant to FIFRA.

(b) The fact that nonprofessional use of creosote is "banned" in Europe, as it is in the United States, is irrelevant to use of commercially produced, creosote-treated wood products in aquatic environments.

(c) The assertion that "Table 1.4 provides some examples of creosote regulations and policies that *have been enacted* in the past few years and demonstrates the *consistency of approaches* toward creosote use in aquatic environments" (emphasis added) is inaccurate and misleading. For example, the New York creosote bill that Gov. Pataki carefully considered and then vetoed *twice* obviously is not a creosote-related regulatory measure that has been "enacted," and therefore should not have been included in the table. Further, the small number of agency policies identified in the table are not consistent with each other, much less representative of the vast majority of states and local governments, which do not prohibit or restrict the use of creosote-treated wood in aquatic environments.

(d) Section 1.5 states that "[t]he U.S. EPA published a risk assessment, described below, that will be used by the agency to decide whether creosote will be re-registered as a pesticide." The Stratus creosote *Technical* review cites, quotes from, and comments on EPA's 2003 ecological effects risk assessment, but fails to explain that the document, which is part of EPA's FIFRA creosote reregistration review, is a *preliminary* risk assessment and subject to revision or refinement following EPA's consideration of public comments. *See* 68 Fed. Reg. 68042 (Dec. 5, 2003) (announcing availability of EPA's preliminary risk assessments on creosote, soliciting comment from interested parties, and explaining that revised risk assessments will be prepared). In addition to the Creosote Council and other interested parties, NMFS submitted extensive written comments on EPA's preliminary ecological effects risk assessment, including a summary of research and peer-reviewed references that NMFS deems relevant to EPA's reregistration review. Further, NMFS recently met with EPA to provide technical assistance in connection with the FIFRA reregistration review. In view of NMFS' direct input to EPA on creosote-related ecological effects issues, it serves no useful purpose, and is counterproductive, for the Stratus report to comment on the preliminary risk assessment.

Section 2 ("Models of PAH Leaching from Treated Wood and Environmental Exposure") — The Creosote Council endorses and supports the comments of Dr. Kenneth M. Brooks on this section of the Stratus draft report. The Council knows of no one with greater experience and insight in this area of science than Dr. Brooks.

Section 3.1 ("Toxic Components of Creosote") and **Section 3.3.3** ("Carcinogenesis") — The assertion in the second paragraph of section 3.1 that there is "little information concerning the interactive effects of creosote components" is incorrect. The most serious application of this misimpression by Stratus occurs in their description of carcinogenicity in section 3.3.3 of the draft. The Stratus draft points out that mechanisms of the chemical induction of cancer are similar in mammals and fish. In its review of the literature on this topic, Stratus focuses on studies in which a PAH, usually BaP, was dosed to fish (dose levels never stated) and internal organ tumors or genetic lesions are described. For purposes of these comments, the Council notes that in the Stratus draft report these effects are then ascribed to creosote. Stratus places heavy emphasis on biomonitoring specific enzyme induction products (CYP1A protein) as means of gaging carcinogenicity. While there is strong evidence about the activation of the AHH receptor and subsequent regulation of transcription and translation, the ultimate outcome of this homeostatic sequence is not so well established, particularly with regard to neoplasia. The paragraphs below illustrate this point.

The hydrocarbon components of creosote do consist of planar fused ring compounds termed polyaromatic hydrocarbons (PAH), nitrogen and sulfur-containing hetereocyclic compounds and nitosubstituted aromatics. PAHs vary considerably in their biological activity. PAHs are indirect-acting or promutagens, meaning that genotoxicity is expressed following metabolic conversion of the PAH to an active species. The mechanism by which PAHs are thought to induce tumor formation is via interaction with genetic material within target cells; either frank mutagenicity or interference with normal genetic biology as a result of PAH-adduct formation with nuclear material. Photomutagenicity, or the property of enhancing the mutagenicity of non-ionizing radiation, has been reported for PAH mixtures and can account for the observation of a lack of mutagenicity in highly carcinogenic neutral PAH mixtures.[3] [4] The presence of PAH antimutagens has also been suggested to account for the difference in activity observed between isolated components of a PAH mixture and the intact mixture.[5]

The use of individual PAH components of a mixture, or any individual component, as a surrogate for the mix is fraught with possibilities for mistake. There is no validated method for tracking or otherwise characterizing the fate of mixtures of variable composition through the use of an indicator molecule. The National Research Council Report from the Board on Environmental Studies and Toxicology stated in their report on *Complex Mixtures – Methods For In Vivo Testing*,[6] indicator molecules have been used to assess mixtures based on the behavior of a constituent on the assumption that the behavior of the constituent is representative of the mixture. In judging this approach, the Committee cited the example of BaP. The committee reviewed independent research from six investigators, which collectively indicate that the BaP

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[3] Selby, C. P., et al., 1986. Chemical basis for photomutagenicity in synthetic fuels and correlation with carcinogenicity. Mut Res. 188:4, 287-299.

[4] Mahlum DD, 1983. Initiation/promotion studies with coal-derived liquids. J Appl Toxicol 3(1):31-34.

[5] Dasenbrock, C. et al., (1996) The carcinogenic potency of carbon particles with and without PAH after repeated intratracheal administration in the rat. Toxicol.Lett., 88: 1-3, pp 15-21.

[6] NRC, Complex Mixtures: Methods for In Vivo Toxicity Testing. National Research Council Committee on Life Sciences, page 13, National Academy Press, Washington, DC, 1988.

content of two complex mixtures, one of which was coal tar pitch volatiles, failed to correlate with the end points associates with that mixture. The National Research Council report concludes that BaP is at best is a crude indicator of the carcinogenic potential of complex mixtures. Direct testing of the role BaP can play in pulmonary carcinogenesis has demonstrated in inverse relationship between BaP and tumor formation. The relationship was also inversely dose-related, meaning that the greater the amount of BaP administered with the PAH mixture, the lower the incidence of lung tumors.

Environmentally and occupationally exposed cohorts have been examined for biomarkers of PAH exposure.[7] [8] [9] [10] The majority of this work has concentrated on DNA adduct formation in circulating white blood cells or the presence of micronuclear bodies (MN) in white blood or other readily available cells. The work has shown the method to be characterized by great individual variability and subject to major change from nontarget influences. For example, the magnitude of the difference between the occupationally exposed and nonoccupationally exposed groups was small compared to as much as a 13-fold increase seen in the local general population between summer and winter heating. In the case of PAH biomarkers diet and personal habits such as smoking are considered important source of marker interference.[11] [12] Surprisingly, DNA adduct formation and MN are not sensitive to cigarette smoking.

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[7] Eder, et al., (1999) Mutation Research, Vol. 424(1,2) pp. 249-261, Intraindividual variation of DNA adduct levels in humans.

[8] Jacob, et al., (1996) (Pure Appl. Chem., Vol. 68(2) pp, 301-8, The significance of polycyclic aromatic hydrocarbons as environmental carcinogens.

[9] Karahalil, et al., (1999) Mutation Research, Vol. 442(1) pp. 29-35, The micronucleus assay in exfoliated buccal cells: application to occupational exposure to polycyclic aromatic hydrocarbons.

[10] Kriek, et al., (1998) Mutation Research, Vol. 400(1,2) pp. 215-231, Polycyclic aromatic hydrocarbon-DNA adducts in humans: relevance as biomarkers for exposure and cancer risk.

[11] Kubiak, et al., (1999) Mutation Research, Vol. 445(2) pp 175-180, Biomarkers of carcinogenesis in humans exposed to polycyclic aromatic hydrocarbons.

[12] Lewtas, J. et al., (1997) Mutation Research, Vol. 378(1,2) pp. 51-63, Air pollution exposure – DNA adduct dosimetry in humans and rodents : evidence for non-linearity at high doses.

The carcinogenic/mutagenic effect of specific PAHs are not reliable indicators of the effect of PAHs in a complex mix like creosote. BaP or other specific PAHs are not reliable surrogates for biological activity of a complex hydrocarbon mixture containing PAHs.

<u>**Section 3.3.7**</u> ("Other effects") — The reference to the work of Borthwick and Patrick (1982) should be amended to state that the work does not identify the nature (identity and purity) or source of the creosote used for testing and relied on the addition of an organic solvent to test system to facilitate introduction of the "creosote" test substance. The solvent greatly enhanced toxicity.

<u>**Section 3.4.2**</u> ("Biological effects concentrations - sediment") — This section of the draft document should reflect the many source sources of PAHs in sediment, both natural and anthropogenic sources, that are not related to creosote or creosote-treated wood. A list of these sources and their PAH contribution to sediment can be found in the US Department of health and Human Services Agency for Toxic Substances and Disease registry (ATSDR) Toxicology Profile for Polycyclic Aromatic Hydrocarbons, Chapter 5, Potential for Human Exposure.[13]

<u>**Section 4.3**</u> ("Laboratory and Field Studies") — The first paragraph of the conclusions to this portion of the draft report (section 4.3.5) states that

> the degree of PAH accumulation to sediment associated with these structures appears to be relatively minor in many settings, particularly in well-circulated waters and over time. PAH accumulation also appears to be relatively limited spatially (within approximately 10 meters of the structure) and has not generally been associated with measured, significant, biological effects except in close proximity to the structures. The duration of any biological effects also appears to become attenuated within several months of construction (the time period when leaching rates are likely to be highest).

In the paragraph which follows in the draft report the authors claim that several factors exist which suggest application of what they term the "precautionary principle." The first of these factors is the claim that aquatic species assessment was conducted at the community or population level rather than the individual level. The draft document also states that hazard assessment was conducted on tolerant life stages of aquatic organisms

[13] ATSDR Toxicology Profile for PAHs, US DHHS, Public Health Service, August, 1995.

rather than critical life stages. Following anything other than a "drive-by" (i.e., superficial) review of the extant literature, these statements are unsupportable. In looking at aquatic toxicity literature developed on creosote there are no less than 30 studies addressing effects on the aquatic plants (vascular and nonvascular), invertebrates of several species, crustaceans, and vertebrate species. These studies include laboratory investigations employing small numbers of a single species that in no way can be considered community or population studies but are in fact single specie bioassays. In addition there are well-documented field studies on creosote that do cover community effects but that also assess all life stages including critical life stages of target organisms. If this were not enough to establish a proper hazard assessment of creosote and creosote-treated wood, then the approach taken by Stratus could come into play: the approach of assessing creosote by evaluation of isolated PAH components. In this approach the number and variety of toxicity studies are nearly legion. In the realm of single PAH studies it is impossible not to find reports of Early Life Stage toxicity testing of aquatic species. Two easily located examples are:

Wassenberg and DiGiulio, (2004) Synergistic Embryotoxicity of Polycyclic Aromatic Hydrocarbon Aryl Hydrocarbon Agonists with Cytochrome P4501A Inhibitors in Fundulus heteroclitus, EHP, 112:17.

Barron, et al., (2004) Evaluation of Fish Early Life Stage Toxicity Models of Chronic Exposures to Complex Polycyclic Aromatic Hydrocarbon Mixtures. Tox Sci 78: 60-67.

In the face of existing relevant publications and technical reports the conclusion that there is a need to invoke the "precautionary principle" is specious. Evocation of the Precautionary Principle under these circumstances is dangerously close to what Dr. Bernard Goldstein, Dean of the University of Pittsburgh Graduate School of Public Health, has recently described as abuse of the precautionary principle not warranted by toxicological science and risk assessment.[14]

Section 4.4 ("Factors to be Considered in Aquatic Risk Assessments") — The Creosote Council strongly objects to the final two paragraphs in the Stratus creosote *Technical Review*, which far exceed the proper boundaries of a scientific report and should be deleted in their entirety. Stratus sloppily asserts (without discussing Gov.

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[14] Goldstein, B., (2005) The Precautionary Principle: Is It a Threat to Toxicological Science?, International J of Toxicology, 25:3, 3-7.

Pataki's vetoes or the reasons for them) that the New York Legislature is an "agency" that has "begun replacing and restricting the use of creosote-treated wood." Then the report falsely generalizes that "regulatory agencies are increasingly recognizing that creosote treatments in marine environments can cause ecological harm under common enough circumstances that new structures should avoid the use of creosote-treated wood, and creosote should be isolated from the environment wherever it is used." The creosote *Technical Review* then concludes with the assertion—apparently Stratus' preordained conclusion—that "precautions to avoid creosote-treated wood where practical, and measures to isolate potential toxic effects appear to be justified," and recommends that "similar precautions be implemented by regulating agencies throughout the United States."

NMFS should not allow these and similar statements to be included in the Stratus creosote *Technical Review*. They not only are scientifically unwarranted, but also imply that Stratus, a private consulting firm, somehow has been delegated regulatory authority by NMFS (authority which NMFS itself for the most part does not possess) to determine whether creosote-treated wood should be allowed in aquatic environments, and if so, under what conditions. According to the March 3 *Federal Register* notice, "[t]he purpose of the technical review documents is to present a summary of existing literature, prepared independently by Stratus Consulting, Inc. for NMFS, that analyzes the potential effects and mitigations for the use of treated wood products in aquatic environments." 71 Fed. Reg. at 10958. The personal biases, opinions, and recommendations of the authors of the Stratus creosote *Technical Review* have no place in that document.

References —The Stratus creosote *Technical Review* contains a References Section, but it is unclear if the list of references cited in that section is coextensive with the creosote bibliography assembled by NOAA Fisheries for this project. The *Technical Review* could be improved by the addition of a master bibliography listing all references identified by NOAA Fisheries and stakeholders as well as those references identified by Stratus. The *Technical Review* should identify which of the citations in the master bibliography were actually cited in the Stratus *Technical Review*.

Sincerely,

David A. Webb
Administrative Director, Creosote Council III

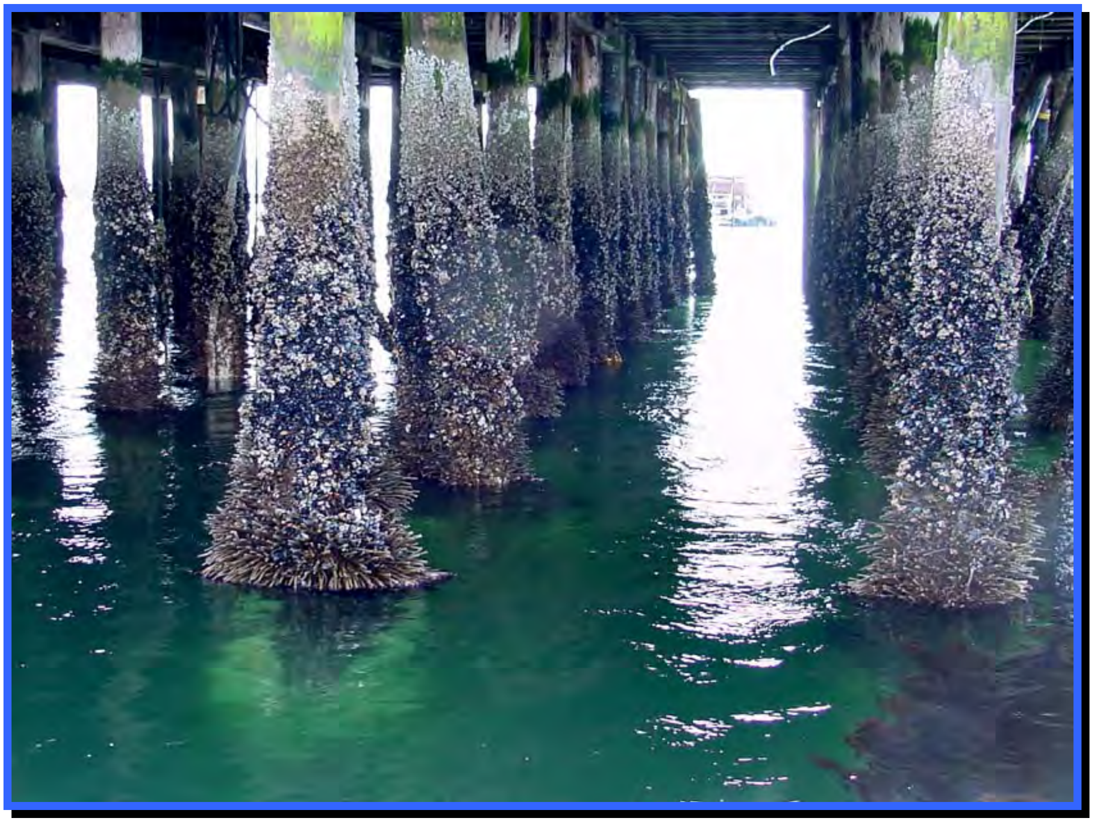
cc: John H. Butala, D.A.B.T.
Lawrence S. Ebner, Esq.

Volume II
Section II
Stratus Creosote Report and Comments

3. Comments of Dr. Kenneth M. Brooks produced for the Western Wood Preservers Institute

Comments regarding Stratus Consulting's document

Creosote-Treated Wood in Aquatic Environments: Technical Review and Use Recommendations



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March 6, 2006

Comments regarding Stratus Consulting's document

Creosote-Treated Wood in Aquatic Environments: Technical Review and Use Recommendations

1. Introduction: Dr. Brooks discussed the creosote models and several publications he has produced with Dr. Fry and Ms. Susan Humphries of Stratus on numerous occasions. However, the interaction was far less intense than occurred during production of the Stratus waterborne report. The result is apparent in the two documents. It should be emphasized that the creosote model (Brooks, 1997) was produced using data that was available at that time. Creosote is a complex mixture containing many compounds. Sparacino's (1999) report of compounds representing >0.5% of the content of P1/P13 and P2 creosote produced in North America accounted for 95.9% (99 compounds) and 92.2% (129 compounds) respectively of the two mixtures. The most common compounds reported in commercially produced creosotes by Sparacino (1999) are summarized in Table 1. Stratus was made aware of this most recent and thorough creosote evaluation and why they chose to ignore it in favor of older documentation is uncertain.

The risk assessment and model of Brooks (1997) and subsequent evaluations of actual creosote treated wood projects (Brooks, 2000, 2003, 2004 and Goyette and Brooks, 1998, 2001) have focused on EPA's 16 priority pollutant parental PAH because their physicochemical properties and toxicology are well studied. This emphasis is not unique to predictions regarding the environmental response to creosote. Regulatory benchmarks, such as Washington States sediment quality criteria (WAC 173-204) focus on these priority pollutant PAH as do numerous attempts to define sediment quality values (Smith *et al.*, 1996; Ingersol *et al.*, 1996; Long *et al.*, 1995 and BCMWLAP, 2005).

Most analyses, including Brooks (1997) assume that the suite of PAH in creosote pressure treated wood is the same as the mixture in the raw oil. That is not true. Goyette and Brooks (1998) compared the composition of raw creosote oil used to treat the Sooke Basin piling with the suite of PAH expressed from the wood following treatment. Naphthalene, which represented 23.8% of new creosote oil was reduced to 10.6% of expressate after treatment. It was hypothesized that this most soluble of the PAH compounds in creosote was preferentially lost during post treatment steaming of the products. This is important because naphthalene is more soluble (32 mg/L) and bioavailable than other PAH indicating that studies using whole creosote oil in bioassays will likely overestimate the mixture's toxicity in comparison with the suite of PAH that migrate from creosote treated wood products into aquatic environments. Stratus was made aware of this information but chose to ignore its implication in their review.

Dr. Brooks acknowledges that the creosote risk assessment model is ten years old and that a significant body of information has accumulated to better inform the model since it was first written. Because of the complexity of both the preservative and receiving environments, numerous assumptions were and will continue to be necessary to estimate the environmental response to the use of these products. The model was built on worst case assumptions, a fact that Stratus has failed to acknowledge. Numerous studies and evaluations by others over the last 10 years have failed to identify significant flaws in the models which generally predict more PAH accumulating in sediments and much higher concentrations of dissolved PAH in the water column than are actually observed in the real world.

Table 1. Comparison of the percent, by weight of the total mixture, of North American P1/P13 and P2 with European Types B and C creosote oils. The percent composition of all 16 parental PAH and other organic compounds representing ≥ 0.5% of at least one creosote mixture as determined by Sparacino (1999) are provided.

Compound	North American P1/P13	North American P2	European Type B	European Type C
Naphthalene	9.0	8.0	5.3	0.1
Acenaphthene	6.1	6.6	4.4	2.0
Acenaphthylene	0.3	0.2	0.1	0.2
Fluorene	4.2	4.9	3.3	5.5
Phenanthrene	12.2	12.6	9.9	18.5
Anthracene	2.2	2.1	0.5	1.1
Sum of low molecular weight parental PAH (ΣLPAH)	**34.0**	**34.4**	**23.5**	**27.4**
Fluoranthene	6.8	6.5	4.3	9.8
Pyrene	6.0	5.7	2.8	6.3
Chrysene	1.5	1.5	0.1	0.1
Benz[a]anthracene	0.5	0.5	0.1	0.2
Benzo[b]fluoranthene	0.8	0.3	0.0	0.0
Benzo[k]fluoranthene	0.3	0.2	0.0	0.0
Benzo[a]pyrene	0.5	0.5	0.0	0.0
Benzo[e]pyrene	0.4	0.4	0.0	0.0
Ideno(1,2,3-c,d)pyrene	0.1	0.1	Not listed	Not listed
Benzo[ghi]perylene	0.05	0.05	Not listed	Not listed
Sum of high molecular weight parental PAH (ΣHPAH)	**16.95**	**15.75**	**7.3**	**16.4**
Total parental PAH (ΣPAH)	**51.0**	**50.2**	**30.4**	**43.8**
Acridine	0.2	0.1	0.5	1.1
Indene	0.9	0.7	Not listed	Not listed
Quinoline	0.8	0.8	Not listed	Not listed
2-Methylnaphthalene	5.1	4.6	8.0	0.3
1-Methylnaphthalene	2.3	2.1	4.5	0.2
1,1'-Biphenyl	1.2	1.2	2.1	0.1
1-Ethylnaphthalene	0.5	0.5	Not listed	Not listed
Dimethylnaphthalenes (1,3- & 2,6 plus 2 isomers)	1.9	2.1	0.4	0.0
Dibenzofuran	3.1	3.7	3.2	2.1
Methyldibenzofuran	0.7	1.3	Not listed	Not listed
Dibenzothiophene	1.3	Not listed	Not listed	Not listed
9H-Carbazole	1.2	1.2	0.9	1.4
Methylphenanthrene	0.7	0.7	Not listed	Not listed
2-Methylphenanthrene	0.8	0.8	Not listed	Not listed
4H-Cyclopental[def]phenanthrene	1.8	1.7	1.7	3.1
1-Methylphenanthrene	0.8	0.5	Not listed	Not listed
2-Phenylnaphthalene	0.5	0.5	Not listed	Not listed
Benzonaphthofuran + Azapyrene	0.6	0.6	Not listed	Not listed
Benzo(a)fluorene	0.9	0.9	0.5	1.0
Benzo(b)fluorene	Not listed	Not listed	0.5	1.1
2,3-Benzofluorene	1.1	1.1	Not listed	Not listed
Phenylmethylnaphthalene	0.5	0.4	Not listed	Not listed
Acepyrene	0.5	0.5	Not listed	Not listed
2,3-Benzanthracene	1.5	1.6	Not listed	Not listed
Dibenzocarbazole (isomer)		0.8	Not listed	Not listed
Other compounds > 0.5%	**28.7**	**28.3**		
Percent of mixture accounted for by those at > 0.5%	**79.7%**	**78.5%**	**52.4%**	**50.9%**
Compounds detected	**99**	**129**	**22**	**21**
Proportion of total mixture accounted for	**95.9%**	**92.25%**	**53.39%**	**55.09%**

models were not designed to precisely predict the environmental response, but rather to provide conservative estimates of the expected response. In response to the predictions made by the original creosote risk assessment model (Brooks, 1994), NMFS (1996) scientists predicted, based on their own theoretical considerations, sediment PAH concentrations of 1,695 to 16,949 μg ΣPAH/kg dry sediment downstream from a single creosote treated piling. In fact, field studies have found concentrations ranging from non-detectable concentrations (Brooks, 2005) to a few tens of μg ΣPAH/g in the worst cases (Goyette and Brooks, 1998). At most sites, sediment concentrations have been <10 μg within a meter of the piling and in no case have significant biological effects been observed in macro-invertebrate communities. The reader is reminded that all of the epifaunal organisms inhabiting the pilings in the cover photograph settled there as sensitive larval stages – not as robust adults.

2. Specific comments: Stratus notes in the introduction that NMFS is ". . . .developing guidance on the use of treated wood in aquatic environments inhabited by NMFS trust resources. NMFS trust resources include commercially important marine species and their habitats, as well as threatened and endangered (T&E) marine species and their habitats." This includes all marine environments adjacent to the United States to a distance of 200 miles and those freshwaters used by several species and stocks, including salmon. By extension of the NMFS interpretations for salmon, this could include all anadromous species like menhaden, eels and shad. In other words, if, as the NMFS has proposed, this process leads to national guidance, the results may be applied to all marine waters and many freshwater systems with significant economic and social implications for the entire country. Restrictions on treated wood products should not be based on *effects per se* and/or *perceptions* that treated wood structures threaten aquatic resources. They should be based on empirically demonstrated adverse effects that threaten populations of these resources. The assertion in Stratus (2006) that NMFS manages T&E resources on an individual versus population basis is simply untrue. If that assertion were true, then mixed stock salmon fisheries would not be allowed because all of the T&E individuals returning to a small watershed could be captured in a single purse seine set . In addition, the stress imposed on individual T&E fish caught in hook and line fisheries far exceeds the stress (if any) imposed by the small amounts of polycyclic aromatic hydrocarbons released from creosote treated piling. Obviously, if NMFS was managing T&E stocks of salmon on an individual basis, no fishing of any kind would be allowed anywhere these stocks might be found, including the Pacific Ocean, Puget Sound and the Columbia River. Fishing has continued in all of these waters since the stocks were listed, making it obvious that NMFS has not managed T&E species on an individual basis.

- **Page 2-5, Non-detected compounds.** The most likely reason that HPAH were not reported in the Kang *et al.* (2003) study is for the same reason that they were not detected by Ingram *et al.* (1982). The concentrations of these highly insoluble compounds were less than detection limits at flow rates of 1.2 and 3.3 cm/sec. There is no basis for Stratus's assumption that they would have been detected in the absence of "volatilization, biodegradation, sorption to organic matter, or other route." Goyette and Brooks (1998) reported the results of dissolved PAH determinations in Sooke Basin by the Battelle Marine Science Laboratory in Sequim Washington using Semi-Permeable Membrane Devices (SPMDs). Four ring PAH were observed in concentrations of 0.002 to 0.61 ng/L (parts per trillion). The sum of the carcinogenic HPAH in tissues from mussels growing on the piling ranged between 0.39 and 3.92 ng/g (parts per billion) on day 14 following construction and were all below the method detection limit of 20 ng/g 1540 days following construction. The point being that all of this data suggests that HPAH were likely not observed at the flow rates examined by Kang *et al.* (2003) because their concentrations were exceeding low (below detection limits).

o **Page 2-5, Becker *et al.* (2001).** Brooks (2006) conducted leaching studies on CCA-C using TCLP tests of ground wood, TCLP tests of seven mm cubes, tests of 19 mm cubes (AWPA E11-907) and commodity size samples (2”x6”x24”) in static and dynamic tests. Loss rates using the small cubes were initially an order of magnitude higher (2.3 versus 22.61) than observed in the dynamic leaching studies. In large part this is believed to be associated with the high ratio of end-grain to surface-grain associated with the small samples (2:4) in comparison with the larger samples (0.00096) associated with a 16’ long 2”x6” plank. This problem is exacerbated when estimating environmental loss rates from oil-borne pressure treated wood because the open end grain provides a direct pathway for migration of the unfixed preservative into the diluent. Stratus (2006) acknowledged this problem.

o **Page 2-7, Xiao *et al.* (2002).** As a point of interest, Goyette and Brooks (1998, 2000) hypothesized that PAH, other than the more water soluble compounds such as naphthalene, migrated from the surface of the piling as microdroplets dislodged by currents and/or wave action. The Xiao *et al.* (2002) observation that loss rates were greatest in warm and turbulent water is consistent with this *particulate transport hypothesis.*

o **Page 2-8 Stratus Figure 2.2.** It is the long-term accumulations of PAH in sediments that constitute the primary risk to aquatic organisms associated with the use of creosote treated wood and the text on page 2-7 and Stratus’s Figure 2.2 are misleading. Figure 1 (from Brooks 2005a) describes, more fully, the results from Kang *et al.* (2004). Stratus was provided with a copy of the report and was aware of Kang *et al.* (2004). Note that PAH migration rates quickly converged to a single set of values following 10 days of immersion. It is the long-term migration rates that are important to predicting sediment concentrations of PAH, not short term rates as asserted by Stratus in Figure 2.2.

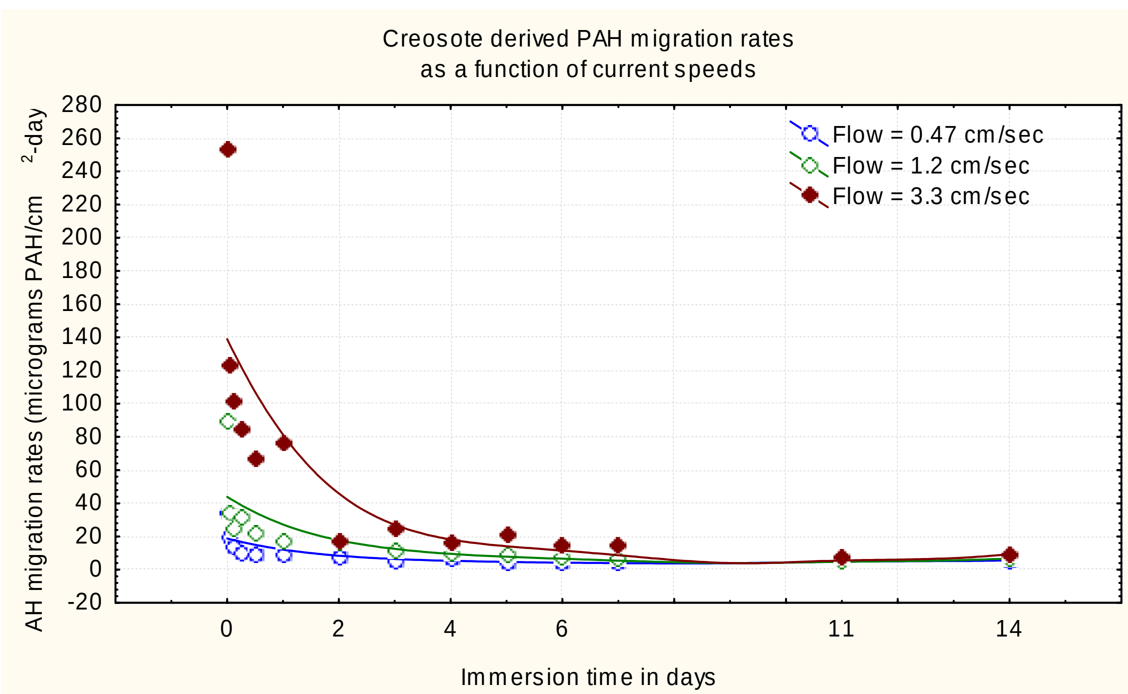

Figure 1. Creosote derived PAH migration rates from pressure treated wood (192 kg/m^3) into freshwater flowing at 0.47, 1.2 and 3.3 cm/sec (Data from Kang *et al.* (2004); graph from Brooks (2005a)).

- **Page 2-9, Whiticar *et al.* (1994) – *Concentrations of individual PAHs.*** As previously noted, naphthalene is a dominant PAH in creosote oil prior to treating. However, the high temperature, high humidity (steam) and low pressure environments used in the post treatment processing of creosote treated products preferentially removes more soluble and volatile naphthalene from the product; significantly reducing its presence in treated wood. The suite of PAH present in the pressure treated product is what migrates into the environment; not the suite of PAH found in creosote oil.

- **Page 2-11, (iv) Environmental factors – first paragraph.** Dr. Brooks agrees that theoretically, abraded wood particles would increase the leaching surface area from which creosote migrates to an aquatic environment. He also agrees that this can occur. However, he has surveyed dozens of creosote treated wood structures and has observed significant abrasion in only one instance at a pin piling on a personal use float. The abrasion was quickly and easily eliminated by installation of vertically placed HDPE wear strips within the intertidal zone. Stratus has presented no evidence substantiating abrasion as a common or significant problem associated with pressure treated wood. For this assertion to be credible, it must be based on something more than a perception.

  Epoxy is not, ". . .applied to cut ends of samples (in leaching studies) to minimize the effect of disturbance and abrasion as confounding factors." as asserted by Stratus. Epoxy is applied because laboratory studies unrealistically expose high end-grain in comparison with the surface grain. This unrealistically exposes the interior of cell walls to the diluent. Consider for example that one end (with exposed end-grain) of a piling is typically driven ten or more feet into the substrate and the other end is located above the receiving water. In the real world, the ratio of surface leaching area to exposed end-grain is therefore nearly infinite for piling. The procedure has nothing to do with abrasion.

- **Page 2-11, (iv) Environmental factors – second paragraph.** Wood preservatives are constantly being redistributed within lumber, timbers and pilings in response to diffusion gradients. Creosote migrating from near the surface of piling is constantly being replenished from deeper within the wood. This is the reason that historic assessments based on measuring the remaining preservative in pressure treated wood are of little value. In many cases, more preservative was observed at some depths after many years in service than was present at the time of treatment.

- **Page 2-12. Section 2.2.1. Model descriptions – Brooks CREOSS model.** A description of the assumptions used in constructing these *worst case models* was published in *Estuaries* (Brooks, 1996). In the near future, the creosote model will be revised to reflect the knowledge that has accumulated since it was first constructed and that model will be published in a peer reviewed journal.

  Unfortunately, there are no comprehensive studies describing PAH migration from creosote as a function of time, temperature, retention and salinity. These limitations are fully discussed in the Brooks (1997) introduction to the model. Algorithms describing the influence of each of these factors were segregated in the model's intermediate output because each factor was based on different studies and it was hoped that new data would be obtained to improve each algorithm. The PAH Migration Rate (M) is defined in Brooks (1997) as follows and Stratus's assertion that the model does not predict migration rates is erroneous. The model must predict migration rates in order to function.

$= (24.4 + 0.78*\text{temperature} - 0.55*\text{salinity})\exp^{(\text{-age in years}/10)}\exp^{(\text{-actual retention}/22.4 - 1)/2}$

- **Page 2-15, Section 2.2.2. Applicability and limitations of leaching rate models.** Dr. Brooks is unaware of what Stratus is referring to when the author(s) state that the risk assessment model asserts that different leaching rates are used for LPAH and HPAH. At page 26 of Brooks (1997) clearly states that, "For purposes of this model, we will assume that HPAH and LPAH migrate from the piling in the same proportions in which they are found in whole creosote." This statement is repeated several times in Brooks (1997). The model only predicts total PAH migration rates. Their proportion in water and sediments is then assumed to be equal to the proportion observed in the whole oil. The *Water Partition Coefficient* can be used to account for the low solubility of HPAH. Stratus did not specify where in Brooks (1997) it is asserted that different migration rates are used for LPAH and HPAH. If they will identify the statement's location, the statement will be removed. The source of data for developing each empirically derived algorithm are clearly identified in Brooks (1997). The basis for those algorithms that were developed in the absence of empirical data is also provided. The lack of specificity in the assertions made in this paragraph makes it difficult or impossible to respond.

- **Page 2-15, Section 2.2.2. Applicability and limitations of leaching rate models 2nd paragraph.** The empirical data from Xiao *et al.* (2002) has been incorporated in the Timber Bridge Model (Brooks, 2005) and will be incorporated in the next version of the creosote risk assessment model. However, as previously noted, it is expected to have little effect on sediment concentrations of PAH because the differences in PAH migration rates, as a function of flow speeds, converge to single values describing all flows within about 10 days.

- **Page 2-15, Section 2.2.2. Third and forth paragraph.** Dr. Brooks is confused by the Stratus comment that, "Regardless, it is unclear whether data from these studies were used to develop or calibrate the CREOSS model, or if the studies were cited for comparison." Brooks (1997) at Table 12, page 40, gives the data upon which the basic migration rate as a function of temperature and salinity was developed and the preceding text includes several paragraphs describing the results of the linear regression analysis upon which the algorithm is based. The availability of a comprehensive set of leaching studies on commodity size creosote treated wood products over a realistic real world range of temperatures, salinities and retentions, such as that reported by Brooks (2005b) for CA-B preservatives would enable development of a better model. However, data of that quality is not yet available for creosote. The question that should be asked by Stratus is, does Brooks (1997) lead to reasonable estimates of environmental concentrations of PAH in association with the use of creosote treated wood products. As will be seen in a later section of this response, the models do provide reasonable predictions and therefore, while the algorithms may not all be as well founded in empirical data as Dr. Brooks would like, the end result is useful (as acknowledged by Stratus).

- **Page 2-15, Section 2.2.2. Last paragraph.** It is unclear how Stratus concluded that Ingram *et al.* (1982) used WWPI BMPs in their study. These procedures were first developed in 1994, over a decade after the Ingram *et al.* (1982) study was conducted.

- **Page 2-16, First paragraph after Figure 2.4.** As previously noted, all of the models developed by Dr. Brooks are based on *worst case assumptions.* This was especially true for the Creorisk model because of the marginal dataset upon which it is based. However, as described in Table 12 of the model documentation, the algorithm was based primarily on Ingram *et al.*

(1982) and included data from Miller (1977) and Graham (date unknown). Given the paucity of high quality data, the over-prediction of PAH from creosote treated wood was intentional. A *Water Partition Coefficient* is provided to account for the low solubility of HPAH.

- **Page 2-17, Section 2.3.1, first paragraph.** The Creorisk Model (Brooks, 1997) was originally developed for use in harmonically driven current regimes typical of marine environments. Consistent with the worst case approach taken in these models, it estimates water column concentrations of PAH within half an hour either side of slack tide. The geometry is cylindrical around the piling in very poorly flushed environments. However, as current speeds increase, the PAH is forced into the downcurrent direction by a Geometry Factor. During these periods anticipated slow current speeds, turbulence is assumed to disperse PAH within the specified geometry. That geometry is defined by assuming a period of 12 hours and integrating a harmonic function having maximum amplitude equal to the maximum tidal speed observed on an exchange to mean low water (MLW) from t = -30 minutes to t = +30 minutes around slack tide. That integral is $0.0645*V_{maximum}$. During slack tide $\pm$ 30 minutes, turbulence is assumed to disperse migrating PAH into an ellipse equal to $0.0645*V_{maximum\ (cm/sec)}*1800$ seconds (30 minutes x 60 sec/min). Those who have done drifter studies in harmonically driven marine environments know that the drifters don't stop during slack tide. They move in random motions associated with eddy currents created as the tides change direction. There is no mechanistic basis for the approach taken. It is simply a model that is expected to provide minimum reasonable dilution volumes that are predictable in harmonically driven systems.

- **Page 2-19, last paragraph.** Stratus's conclusion that the transport is based on advection only is incorrect. The model discusses the small influence that molecular diffusion has on the dilution of PAH in the water column and exclusion of this as a factor is considered in keeping with the *worst case assumptions* driving development of the model. Diffusion is discussed at page 30 of Brooks (1997). Advection is not included in the determination of water column PAH concentrations because the highest concentrations are anticipated to occur within half an hour of slack tide when currents are exceptionally slow and chaotic. This is explained in detail in the model documentation. However, based on Stratus's inability to understand the text, it will be rewritten in the next version in a manner understandable by those unfamiliar with modeling. The model fully explains how advective transport is determined during sedimentation.

- **Page 2-20, first paragraph.** The pathway for developing the dilution factor in the Creorisk model is described at page 45 of Brooks (1997) under Model Output where it is stated that:

"Worst case scenarios occur within half an hyour of slack tide in areas where there are no steady state currents. **By integrating equation (2) from half an hour before slack tide to half an hour after slack tide we find that the average tidal speed during this period is 0.06451 x $V_{maximum}$." (Emphasis added)** Contrary to the comment by Stratus, the time is specifically identified.

- **Page 2-20, second paragraph.** Stratus states that, "In addition, dimensional analysis of the equation shows inconsistent units." Stratus did not query Dr. Brooks in this regard. The author incorrectly assumed that this could be worked through by those interested. Obviously that is not the case and the following text will be included in the model's next version.

$$PAH_{water}\ (ng/L) = WPC*10^6*2\pi*R_p*GF*M*1\ hour/[24\pi((1800*V_{model} + R_p)^2 - R_p^2)$$

Numerator

WPC = Water Partition Coefficient = non-dimensional
10^6 converts ml to liters and μg ΣPAH to ng ΣPAH = $(10^3 cm^3/L)*10^3 ng/\mu g$
2π is dimensionless
R_p = piling radius (cm)
GF = geometry factor which is dimensionless
M = PAH migration = $\mu g/cm^2$-day
1 hour = the time that PAH migrate (half an hour before to half an hour after slack tide)

Denominator

24 = 24 hours/day
π is dimensionless
1800 = seconds
V_{model} = cm/sec
R_p = cm/sec.

Combining these dimensions gives:

$$ng/L = \frac{cm^3*ng*cm*\mu g*hr}{L*\mu g*cm^2\text{-}day} \quad \frac{day*}{hr*((sec*cm/sec + cm)^2 - cm^2) = hr\ cm^2}$$

$$ng/L = \frac{cm^2*ng*hr}{L\text{-}day} \quad \frac{day}{hr\text{-}cm^2} = ng/L$$

For those who have not carefully reviewed or cannot understand the creosote risk analysis, this may seem somewhat obscure. However, the dimensions are correct and Stratus's comment is without merit.

- **Page 2-20, Last full paragraph.** The exclusion of post-deposition redistribution of sediment PAH associated with bioturbation and or mechanical disturbances such as erosion, turbulence during high current flows, propeller wash, etc. is intentional because it cannot be predicted. In addition, this would detract from the *worst case assumptions* upon which these models are based. For some reason, Stratus has refused to acknowledge at any place in their document Dr. Brooks' assertion that the models are based on *worst case assumptions.* Nor have they rebutted those assumptions other than to assert, without documentation in the form of empirical evidence, that abrasion of treated wood may significantly increase environmental loading of PAH.

- **Page 2-21, *Model predictions*, first paragraph.** Stratus asserts that, "The model predicts a water column concentration of 0.003 ppb total PAH. The volume of water containing this concentration and the length of time that this concentration persists are not specified, but it appears that the concentration is an average that might not be representative of instantaneous concentrations at a particular location." As has been previously described in this critique, the model documentation clearly states that water column concentrations of PAH are predicted as an average during the period within half an hour either side of slack tide. The concentrations are predicted to be lower at other times as harmonically driven current speeds increase. The volume of water within which the concentration is predicted is precisely defined as a cylinder with radius equal to 1800 seconds * 0.0645*$V_{maximum}$. Thus the concentration is assumed to persist for one hour and if $V_{maximum}$ 2 cm/sec, the radius of the cylinder would be 2.3 meters.

- **Page 2-23, *Model predictions.*** It should be pointed out that Brooks (1997) includes an Excel™ spreadsheet useful for predicting the ΣTU described by Swartz *et al.* (1995). Furthermore, procedures for using this utility are provided on page 52 of Creorisk and an example is given in Table 16 on page 53. It is curious that Stratus failed to mention the availability of this in Brooks (1997).

- **Page 2-26, (ii) Goyette and Brooks (1998, 2001), second paragraph.** Stratus asserts that, "In this study, the modeled total PAHs included all PAHs leached from creosote, but the measured total PAHs included only 17 measured PAHs potentially underestimating the total." This statement is incorrect. Most of the data used to estimate migration rates from creosote treated wood were taken from Ingram *et al.* (1982) and as stated at page 39 of Brooks (1997), "In each experiment, the leachate was examined at the end of three days for the presence of **15 major PAHs."** Emphasis added. The migration rates used in the Creorisk Model are based, in large part on the 15 PAHs that Ingram *et al.* (1982) was able to detect. Similar to the results of Xiao *et al.* (2000), they were not able to detect compounds heavier than benz(a)anthracene, The model assumes that the distribution of PAH within the migrating suite of compounds is similar to that found in creosote. This should not introduce significant errors because as seen in Table 1, priority PAH heavier than benz(a)anthracene comprise only 2% of creosote meeting AWPA Standard P2. Therefore, predicting total PAH migration based on the 15 compounds detected by Ingram *et al.* (1982) leads to a maximum error of 1/0.98 = 1.02 or 2 percent. However, the *particulate transport hypothesis* developed by Dr. Brooks suggests that the insoluble PAH do not dissolve in the water column, but are transported to sediments as microdroplets of PAH. If this is true then the 15 compounds detected by Ingram *et al.* (1982) likely do characterize the dissolved suite present in the receiving water. This is another example of inaccurate analysis and reporting by Stratus.

- **Page 2-26, (ii) Goyette and Brooks (1998, 2001), second paragraph.** One of the site selection criteria for Phase II of Environment Canada's creosote evaluation was that the site support a healthy macrobenthic community. Numerous potential sites were eliminated from consideration because they had historically been used for log storage. Initial site investigations indicated that the accumulated organic debris had resulted in anaerobic conditions and depauperate macrobenthic communities. Sooke Basin was chosen in part because the sediments were aerobic and supported a vibrant macrobenthos. Initial modeling indicated that the creosote treated dolphins would result in exceedances of adverse biological effects benchmarks due to the site's very slow currents and the dense clusters of treated pilings – despite the fact that the sediments were aerobic. Stratus has avoided reviewing the large biological databases including macrobenthic community assessments and bioassays included in Goyette and Brooks (1998,

2000) and Brooks (2000, 2003). This is curious because these data provide significant insight into the environmental response to creosote treated wood. Contrary to the assertion made by Stratus, the requirement for aerobic sediments and a healthy macrobenthic community is considered absolutely necessary for a worst case evaluation. Conducting the studies in anaerobic conditions with a depauperate macrobenthos would have denied any ability to detect biological effects.

- **Page 2-26, (ii) Goyette and Brooks (1998, 2000).** Figure 29 in Goyette and Brooks (1998) describes PAH as a function of depth in sediment cores. Concentrations declined exponentially as a function of depth. Why Stratus chose to ignore this section of the report and instead stated that, "Sediments above the RPD are oxic, which increases the rate of PAH breakdown, and sediment samples for PAH analysis were routinely collected from the top (0-2 cm) layer during the study." is curious and demonstrates a consistent trend to unsubstantiated criticisms rather than to accurately and completely reporting the results of many of the studies..

$$PAH_{\text{BMP dolphin as a function of sediment depth}} = 30.24*\exp^{-0.691*\text{sediment depth (cm)}} \qquad R^2_a = 0.998$$
$$PAH_{\text{WP dolphin as a function of sediment depth}} = 14.43*\exp^{-0.378*\text{sediment depth (cm)}} \qquad R^2_a = 0.983$$

- **Page 2-27, first paragraph.** During installation of the dolphins, the pile driver was anchored offshore to avoid contamination of sediments in the predetermined up- and down-current directions. The twelve creosote treated piling used to construct the two dolphins were also rafter there. Considering the amount of debris on the pile driver and the piling rafts located offshore from the dolphins, elevated PAH concentrations there were expected, but not considered indicative of the short or long-term environmental response to PAH derived from the structure, which was the purpose of the study. Dolphins are structures constructed of densely packed piling arranged like the poles in a teepee. The small area inside the dolphin was considered a *technozone* (European term) and it was not part of the study. PAH concentration inside the dolphin were not modeled and therefore the observed concentrations were not higher than model predictions as asserted by Stratus. The observed mean concentrations observed outside the interior of the dolphin were all lower than those predicted by the model.
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- **Page 2-27, first paragraph after Table 2.7.** The model makes predictions of the maximum PAH accumulation in sediments. Stratus's assertion that the concentrations reported in their Table 2.7,"occurred somewhat sooner than predicted, giving the appearance of model under-prediction earlier in the experiment followed by over-prediction later in the experiment" is unsupported. It is possible to numerically solve the infinite series presented in Equation 16 of Brooks (1997) to predict sediment concentrations as a function of time post installation. Brooks (2004) did that for the Sooke Basin data collected through day 1530. The results for a distance of 0.5 m downcurrent, normalized to the highest value reported, are provided in Figure 2. The normalized data for Day 14 is higher than the predicted value, but all other predictions are very close to predictions through Day 720 when it appeared that the concentrations peaked. These results suggested that during the first four years following immersion, the observed concentrations peaked slightly earlier and declined more quickly than was predicted by the model. This was particularly surprising because the sediments were anaerobic at that time and the model predicted much higher concentrations of PAH under the zero RPD conditions observed near the dolphins at the end of the study. The author is unaware of how Stratus could arrive at their stated conclusion as they did not present any supporting analysis.

- **Page 2-27, last paragraph.** Considering even the biased and selective way in which Stratus has used the available data, their conclusion that, "The results of these comparisons of modeled to measured PAH concentration data are not sufficient to make any specific quantitative conclusions about the accuracy of the model in predicting actual sediment concentrations" is curious. At the Westham Island Bridge (Stratus Table 2.6), the model predicted 0.56 μg ΣPAH/g dry sediment at 0.5 meters and the observed concentration was 0.17 μg ΣPAH/g. Similarly, the model predicted slightly higher concentrations at 2.0 m (0.17 predicted versus 0.03 μg/g observed) and 5.0 m (0.08 predicted versus 0.07 μg/g observed) than were actually observed. At Belcarra Bay the model predicted more PAH at one meter distance than was observed (9.0 predicted and 4.0 observed) at 3 and 5 meters distance the model predicted 5.5 and 4.0 μg/g and 10.0 and 8.5 μg/g were observed. In Sooke Basin the model predicted 24 μg ΣPAH/g dry sediment at 0.5 m distance and a mean of 16.1 μg ΣPAH/g were observed. Predicted values in Sooke Basin were generally higher than observed. Model predictions were not developed for the *Technozone* existing within the center of the dolphin. In Dr. Brooks' opinion, these results are excellent, especially when compared with the NMFS prediction of1,695 to 16,949 μg ΣPAH/g dry sediment downstream from a single piling. As explained in Brooks (1997), there is significant uncertainty in several of the algorithms used in the predictions due to a lack of empirical data. In addition, because the complexity of receiving environments, particularly harmonically driven marine environments, the models are based on worst case assumptions.

  Past models have only considered contributions of PAH from immersed portions of treated structures. Stormwater runoff from overhead structures also contributes PAH to receiving environments. Large industrial structures like those found at Belcarra Bay and the Westham Island Bridge contribute PAH from above the water. Recent rainwater runoff data generated by Oregon State University has allowed Brooks (2005a) to predict PAH loading from above water and immersed portions of treated wood structures. When that document completes peer review, the results will be incorporated in a new version of the creosote risk assessment model. Final judgment with respect to the reasonableness of the predictions make by the Creorisk Model will be left to other reviewers of the Stratus report and this response.
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- **Contributions from overhead structures.** Contributions of PAH from overhead structurs are incorporated in the recently completed timber bridge model (Brooks, 2005a) produced for the U.S. Forest Service. Three wooden bridges were modeled and then assessed in that effort. Concentrations of PAH under and adjacent to the 53 year old Anderson Creek Bridge were predicted to range from 11.05 μg ΣPAH/g dry sediment within 15 cm of the 53 year old bridge's creosote treated bulkheads to 1.84 μg ΣPAH/g dry sediment at a distance of 20 m downstream. Observed concentrations steadily decreased from 1.59 μg ΣPAH/g under the bridge to 0.30 μg ΣPAH/g at 20 m downstream. Anderson Creek is a salmon spawning stream and the evaluation occurred in fall before winter rains increased typically low summer flows. The much lower sediment concentrations observed under the bridge in comparison with those predicted was likely associated previous annual high flows that diluted and redistributed the PAH downstream. In addition, sediments in the sandy-silt sediments under the bridge were aerobic, facilitating microbial catabolism of sedimented PAH.

  The Seabeck Lagoon Bridge was evaluated on October 19, 2004, 15 years after it was last reconstructed. Predicted sediment concentrations at this 183.5 foot long bridge spanning a poorly flushed tidal lagoon varied from 1.7 μg/g under the bridge to 3.87 μg ΣPAH/g at 3 m and

0.14 μg ΣPAH/g at 6 m downcurrent. Equal abundance and much higher diversity was observed under the bridge in comparison with the reference location.

- **Page 2-27, last paragraph.** Contrary to the assertion by Stratus to the contrary, both the number and density of pilings can be considered using the model of Brooks (1997), it simply takes more insight than was achieved by Stratus. It is unfortunate that they did not request that information if it was of concern to them.

- **Page 2-28, Section 2.3.3.** The author agrees with Stratus that aquatic systems are complex and difficult to model, but is reminded of a comment by Dr. Crawford Revie in considering future sea lice models in British Columbia. "Models don't have to be right to be useful." Dr. Brooks also agrees that environmental modeling of any kind is fraught with complexity and uncertainty. The models attempt to simplify this complexity by using *worst case assumptions.* For some reason, Stratus has failed to acknowledge this or to attack any of the assumptions because they do worst case. Field verification studies completed to date suggest that despite the uncertainties in many of the algorithms, the models *are useful.* Ultimately, their usefulness will be determined by experience and peer review.

- **Page 2-29, third full paragraph.** The next *incarnation* of the creosote risk assessment model will incorporate the results produced by Xiao *et al.* (2002) and Kang *et al.* (2004). This information was not available in 1997. It has been included in the Timber Bridge Model (Brooks 2005a). The data are of particular interest to Dr. Brooks they support his *particulate transport hypothesis* which has not yet been adequately tested.

- **Page 3-2, first paragraph.** Goyette and Brooks (1998) analyzed all sediment samples for 17 parental and 19 alkylated PAH plus dibenzofuran. The concentrations of alkylated PAH in Sooke Basin sediments under and near the creosote treated dolphins were very low. In the absence of definitive toxicity information and because the concentrations were so low, the data was included in the report's database, but was not analyzed. However, it is available for others to use.

- **Page 3-3, first paragraph.** Tissue PAH burdens in somatic and gonadal tissue were low throughout the *in-situ* mussel studies in Sooke. They were even lower in mussels growing directly on the Sooke Basin piling and on three creosote treated structures reported in Brooks (2003). The author is unaware of information supporting the assertion by Meador *et al.* (1995) that the "metabolic capacity" of PAH in bivalves is very limited.

- **Page 3-5, first paragraph.** As previously noted, the results of studies using whole creosote oil (Sved and Roberts, 1995) are useful for understanding the environmental responses to industrial spills but cannot be applied to the response to treated wood. Note that Sved and Roberts (1995) observed naphthalene comprising 21% of the resolvable PAH in their study of sediments contaminated with whole creosote oil. As previously noted, naphthalene is the most water soluble (and therefore bioavailable) PAH in creosote. However, Goyette and Brooks (1998) observed that much of the naphthalene present in the creosote oil used to treat the Sooke Basin BMP dolphins was absent in expressate from the treated piling. This is consistent with the frequent observation of high naphthalene in groundwater historically contaminated by discharging contaminated water flushed from retorts to unlined ponds at treating plants.

o **Page 3-13, second paragraph.** Stratus's statement regarding the in-situ mussel bioassay in Sooke Basin is misleading. Mussels growing within 15 cm of the newly installed piling grew significantly more slowly than those at further distances. However, all of the following important information was intentionally or unintentionally excluded by Stratus:

- Note that Battelle found only 22.9 ng dissolved ΣPAH/L at a distance of 0.25 m from the downcurrent side of the dolphin and that the sum of toxic units (ΣTU) determined using the method of Swartz *et al.* (1995) was 0.031.
- Mussel tissue PAH concentrations were very low at all times. Prior to placement in the test, mussel tissues held 16.15 ± 2.2 ng ΣPAH/g wet tissue. Tissue concentrations were highest on Day 14 following construction (47.0 to 68.1 ng/g) in comparison with 44.1 ± 8.1 ng/g at the open control. On Day 384, tissue concentrations of PAH were lowest immediately adjacent to the BMP piling (8.29 ± 0.85 ng/g) in comparison to 11.1 ± 1.2 ng/g at the open control.
- On Day 185, mussel condition factors were higher at all treated wood stations (0.200 ± 0.009 to 0.244 ± 0.036) than at the open control (0.177 ± 0.035).
- Mussel survival was 79 ± 0.7% at the BMP 0.5 m station, which was not significantly different from the open control (80 ± 4.5). Mussel survival was higher at other stations near the BMP dolphin varying between 88 ± 6% at 2.0 m to 81 ± 7.9% at 10 m and it was highest (88.7 ± 5.6%) at 0.5 m from the weathered piling in comparison with the control cohorts. These are all exceptionally high survival rates at the end of one year with no indication of toxicity associated with PAH released from the creosote treated wood..
- While Stratus emphasized that mussels grew significantly slower near the piling, they failed to report that the final valve lengths for the three replicate cohorts of 100 mussels at each station was 59.3 ± 2.4 mm immediately adjacent to the BMP piling and 64.2 ± 0.9 mm adjacent to the weather piling dolphin in comparison to 69.5 ± 0.8 mm at the open control. This growth, which was achieved over the winter months, was exceptional for all of the cohorts..
- Lastly, Stratus failed to report that no significant differences were observed in development of eggs to the trochophore stage in reproductive studies involving all of the cohorts of mussels..

A more holistic assessment of this data would have concluded that mussels survived and grew exceptionally well in all cohorts evaluated in Sooke Basin; that they bioconcentrated small amounts of PAH during the first 14 days; but that they effectively catabolized PAH after that leading to lower values in the mussels growing on the piling than was observed before the test began and tissue burdens in mussels growing on the piling were lower than observed at the open control. No significant adverse effects were observed in any of these cohorts. The fact that the large number of animals evaluated (300 at each distance) enabled the detection of small differences in their lengths at the end of 384 days is also noteworthy.

o **Page 3-14, first paragraph.** It should once again be emphasized that the suite of PAH in whole creosote oil is not the same as the suite migrating from pressure treated wood. If studies are intended to assess the biological or environmental response to the pressure treated wood product, then they need to use expressate from the wood, which will contain much less naphthalene that the raw oil. Otherwise, these studies are comparing apples and oranges.

- **Page 3-15, Table 3.1.** Note that all of the biological effects concentrations reported in this table are 100 to 6000 times greater than the maximum of 30 ngΣPAH/L measured at Sooke Basin. Low concentrations of dissolved PAH associated with the creosote treated piling was further substantiated by the low concentrations of PAH observed in mussels growing directly on the treated structures and by the fact that all of the 124 taxa representing the 4,236 invertebrates collected in six 0.0225 m^2 samples from creosote treated piling in Puget Sound settled there as sensitive larval stages.

Page 3-18, last paragraph and page 3-19. Much of the NMFS emphasis on setting a 1.0 µg ΣPAH/g standard has been based on the work of NMFS scientists Johnson *et al.* (1994) and Horness *et al.* (1998). The following critique was supplied to Stratus but no mention of the problems in these papers is presented in their report. They are provided here for information to other reviewers. These two papers are considered together because they both relied on essentially the same data. Both papers also relied heavily on the assertion that observance of a biochemical response to PAH implies physiological impairment. The inappropriateness of this assertion is discussed in Brooks (2003b). Enzyme induction is a sign of physiological response – not necessarily a sign of stress or physiological impairment.

The most significant flaw in Johnson *et al.* (1994) and Horness *et al.* (1998) is that they significantly underestimated sediment PAH exposure – at least in Elliott Bay where they reported 10 mg ∑PAH/kg in contrast to Department of Ecology (WDOE 1995) reports of 111.3 to 593 µg ∑PAH/g. Johnson *et al.* (1994) and Horness *et al.* (1998) reported 6 µg ∑PAH/g) in the Duwamish Waterway and 90 µg ∑PAH/g in Eagle Harbor. In reality, Eagle Harbor sediments contain as much as 6,461 mg ∑PAH/kg (Swartz *et al.*, 1989) and the Puget Sound Environmental Atlas (PSWQA, 1992) indicated sediment ΣPAH levels at numerous locations in the Duwamish Waterway >21 µg ΣPAH/kg. In general, higher contaminant concentrations are found in shallow nearshore areas associated with Seattle's intensely urbanized upland and with numerous waterfront docks and industrial facilities. Concentrations of ∑PAH decline in the middle and outer reaches of Elliott Bay (PSWQA, 1992). Sediments in these Puget Sound industrial areas also contain high levels of PCBs and metals. Misitano *et al.* (1994) reported much higher concentrations of both high and low molecular weight PAH in these areas than reported by Johnson *et al.* (1994) and Horness *et al.* (1998).

Juvenile English sole (*Pleuronectes vetulus*), which were the subject of Johnson *et al.* (1994) and Horness *et al.* (1998), are found in shallow water in the intertidal zone where sediment concentrations of all contaminants are highest. As they grow, English sole move into deeper water, but tend to seasonally migrate from deep water in the winter to shallow water in the spring. In British Columbia, English sole are known to make extensive migrations of at least 700 miles (Hart, 1973). The point is that English sole in Elliott Bay and the Duwamish Waterway are exposed to a variety of sediment conditions including ∑PAH concentrations that greatly exceed (by one to two orders of magnitude) those described in these two reports.

Both papers are based on the assumption that the English sole subjected to histopathological examination were exposed to a single sediment concentration of ∑PAH. That simply is not true and while the study does suggest a correlation between exposure to ∑PAH (and the mix of other contaminants found in these industrial areas) and hepatic lesions, it is not appropriate to attempt to quantify the degree of exposure without significant additional study and documentation of the actual PAH exposure experienced by the fish. Furthermore, while the intermediate metabolites of some high molecular weight PAH can create chromosomal lesions, some metals and other organic compounds found in these contaminated sediments are also associated with cancer. Correlation analysis can never be used as unequivocal evidence of a cause and effect relationship. Both reports are analogous to examining chemical plant workers for signs of disease in their locker rooms and collecting air samples at the same time. Most responsible researchers would not assume that the low concentrations of chemical in the locker room was responsible for any observed disease.

To summarize, Johnson *et al.* (1994) and Horness *et al.* (1998) noted some of these problems in their own work. The authors suggested that the results warranted a closer look at the protectiveness of existing sediment quality criteria. Lastly it is important to note that the author's could not demonstrate any adverse effect on the population of English sole in their study. Poston (2001) summarizes other critical reviews of these papers.

- **Page 3-19.** Stratus has not presented a defensible argument for a sediment effects concentration of 1 ppm ΣPAH as a reasonable screening value for use in the evaluation of potential creosote applications. To the best of the author's knowledge no jurisdiction, anywhere in the world has adopted the sediment standard or screening level proposed by NMFS Northwest Science Center. Such standards must be applied to all activities. In this case, a sediment standard of 1.0 μg ΣPAH/g would essentially shut down all sewage treatment plant outfalls; all stormwater discharges to surface waters; and many industrial discharges. The implications of uniformly applying a standard that is exceeded naturally in some areas to all activities in North American would likely be to shut down modern society. Application of this standard to only treated wood is arbitrary and this author believes that based on the lack of empirical evidence, it should also be considered arbitrary..

- **Page 4-2, Section 4.2 Risk Assessments Using PAH Leaching Models.** Stratus is in error in reporting that the recommendations of Brooks (1995) were based on a TOC of 1.9%. The text on page 7 of Brooks (1995) clearly states that the PAH predictions were based on a TOC of 1.0 percent. The rationale for reducing the input from 1.9% to 1.0% in making recommendations for the Columbia River is discussed in the paper. It appears that Stratus did not read the report.

- **Page 4-3, first paragraph after Table 4.1.** Both Poston (2001) and Brooks (1997) rely on the ΣTU methodology of Swartz *et al.* (1995) to assess water column toxicity. Stratus did not present any convincing arguments in Chapter 3 that would discredit the work of Swartz *et al.* (1995).

- **Page 4-3, second paragraph.** Stratus has presented no information suggesting that the numerous benchmarks described in Table 3.2. are inadequate to protect biological resources. In addition, Stratus has ignored the exceptionally large bioassay and benthic community databases reported in Goyette and Brooks (1998, 2000) and in Brooks (2000 and 2003a). Washington State proposed changes in its marine PAH SQC after publication of the NMFS describing *effects per se* at ΣPAH concentrations <1.0 μg ΣPAH/g. The proposed revisions will decrease the SQC for HPAH from 960 to 900 μg ΣHPAH/g TOC and increase the SQC for LPAH from 370 to 593 μg ΣLPAH/g TOC (WDOE, 1999). The proposed change will increase the sum of the two classes 1,330 to 1,493 μg/g. For sediments containing one percent TOC that equates to a SQC of 14.93 μg ΣPAH/g dry sediment – not the 1.0 μg/g proposed by the Northwest Science Center.

Washington State is also developing freshwater sediment quality criteria. Table 3-11 of Michelsen (2003) gives as an example, a freshwater PAH SQC of 6.6 μg LPAH/g dry sediment and an HPAH SQC of 31.0 μg/g. The total is 37.9 μg ΣPAH/g, which is far above the 1.0 μg/g proposed by the Northwest Science Center.

British Columbia (BCMWLAP, 2005) has recently defined sediment quality criteria for managing contaminated sites. This document includes *Sediment Quality Criteria for Sensitive Contaminated Sites ($SedQC_{SCS}$).* These sensitive sites include habitats used by endangered or threatened species, or species of special concern under the Canadian *Species at Risk Act.* The $SedQC_{SCS}$ for PAH includes 7 LPAH and 6 HPAH. The stipulated suite of PAH includes phenanthrene, fluoranthene, pyrene, chrysene and benzo(a)anthracene – the most abundant PAHs found in sediments near creosote treated structures. The newly adopted TPAH value in British Columbia is 10 μg ΣPAH/g dry sediment – not 1.0 as has been proposed by NMFS.

Goyette and Brooks (1998) contained a detailed evaluation of the efficiency and protectiveness of the numerous sediment quality benchmarks available at that time based on a very large database consisting of a suite of sediment bioassays with same sample chemistry. They found that the Washington State SQC and the mean of the TEL and PEL were both protective and efficient.

The development of SQC by Washington State and other jurisdictions has been based on careful deliberation and documentation and none of the evolving criteria are consistent with the Northwest Science Center's standard of 1.0 μg ΣPAH/g. Stratus has been very selective in its discussion of sediment effects and regulatory criteria. Their conclusion that the NMFS recommended sediment quality criterion of 1.0 μg ΣPAH/g is an appropriate benchmark is no better substantiated in their document than it has been by the Northwest Science Center. Almost none of this information is provided in the Stratus Report.

- **Page 4-3, last paragraph.** Stratus's assertion that, "Depending on the specific field application, the laboratory-based leaching models appear to be more likely to under-predict than over-predict leaching under field conditions, . . ." is based on conjecture with no empirical evidence supporting it. To the contrary, the field verification studies of Goyette and Brooks (1998, 2000) and Brooks (1997 and 2005a) indicate generally lower concentrations of PAH in the water column and in sediments near creosote treated structures than are predicted by the model. A credible report by Stratus would have relied more on a thorough review instead of their selective review and it would have documented empirical evidence supporting the numerous unsubstantiated assertions made in their document.

- **Page 4-5 and 4-6.** The report of Katz (1998) indicated that average dissolved PAH concentrations near the Navy pier when bilge water was being discharged was 1.1 μg/L (N = 36). The Navy stopped discharging bilge water and removed 50% of the creosote treated piling. Concentrations of dissolved PAH then declined by an order of magnitude to 0.12 μg/L at the piers and 0.06 μg/L at non-NAVSTA sites. It is agreed that some low and intermediate weight PAH migrating from creosote treated wood are dissolved in the water. At Sooke Basin, concentrations of dissolved PAH within 25 cm of the six piling dolphins varied between 0.018

and 0.031 mg/L in comparison with a concentration of 0.013 μg/L at the open control. Dr. Brooks was a navy carrier pilot for 20 years and spent time on carriers in San Diego Bay. He has seen the oil sheens associated with the discharge of bilge water from ships. He has also seen the very dense assemblages of creosote treated piling at Navy piers in the 1960's and 1970's. An alternate and more rational assessment of the Katz (1998) results would be that ending bilge water discharges was primarily responsible for the decrease in dissolved PAH at the NAVSTA because with half the creosote treated piling still in place, the increase in dissolved PAH was only 0.06 μg/L above background.

- **Page 4-7, first paragraph.** Sediment samples reported in Goyette and Brooks (1998) were carefully collected from the upper 2.0 cm of the sediment column in accordance with recommendations in the Puget Sound Estuary Protocols (PSEP, 1996). Why Stratus would assert that they were collected at the "top 2.0 to 2.5 cm" is unclear.

- **Page 4-7, Table 4-2.** It is unclear where Stratus got the values used in Table 4-2. A single sample was collected inside the BMP dolphin next to one of the six closely spaced piling on Day 384. The concentration of PAH was 30.8 μg ΣPAH/g not 47.4. On Day 14, the mean PAH concentration at 0.5 m from the BMP dolphin was 7.86 μg ΣPAH/g – not 105 μg/g. Sediment PAH was measured at 105 μg/g at the Weathered Piling (WP) dolphin on Day 14. However, high concentrations were not observed there on other days (14.1 μg/g was observed on Day 180 and 10.8 μg/g on Day 384) or at other distances (the concentration at 2.0 m distance on Day 14 at the WP dolphin was 2.9 μg ΣPAH/g). The anomalously high sample was most likely associated with pile driving and dolphin fabrication. A more rigorous review by Stratus would have reported the above relationships.

The mean sediment PAH concentration at 0.5 m distance from the BMP dolphin on Day 180 was 8.8 μg/g (not 14.4 or 17.8) and it increased to 18.9 μg/g on Day 384. Numerous other errors are evident in Table 4-2 of the Stratus Report. Stratus has over-emphasized the high sediment concentration of PAH observed in the Sooke Basin study and overstated concentrations at the BMP dolphin. This is the dolphin that should be emphasized because it is BMP piling that are being used today, at least on the west coast.

Figure 2, 3 and 4 are provided to better place the PAH concentrations observed in the Sooke Basin Study in better perspective. Note in Figure 2, that 3 samples were collected at the BMP site that exceeded 30 μg ΣPAH/g. One of those was from inside the dolphin and the other two were both at 0.5 m distance. One additional sample was observed with a concentration of 18 μg/g and the remaining samples were all ≤ 10 μg/g. The results of sampling an offshore transect (where the pile driver was anchored) on Day 384 are provided on the right side of Figure 2. Note that while sediments collected next to the piling had 69.3 μg ΣPAH/g, the oil was restricted only to that area and the concentration was 2.85 μg/g at a distance of 2.0 m and it was essentially at background at 5.0 and 10 m (0.68 and 0.66 μg ΣPAH/g). Figures 3 and 4 are histograms describing the frequency of observation of classes of PAH concentrations to put Stratus's review in better perspective.

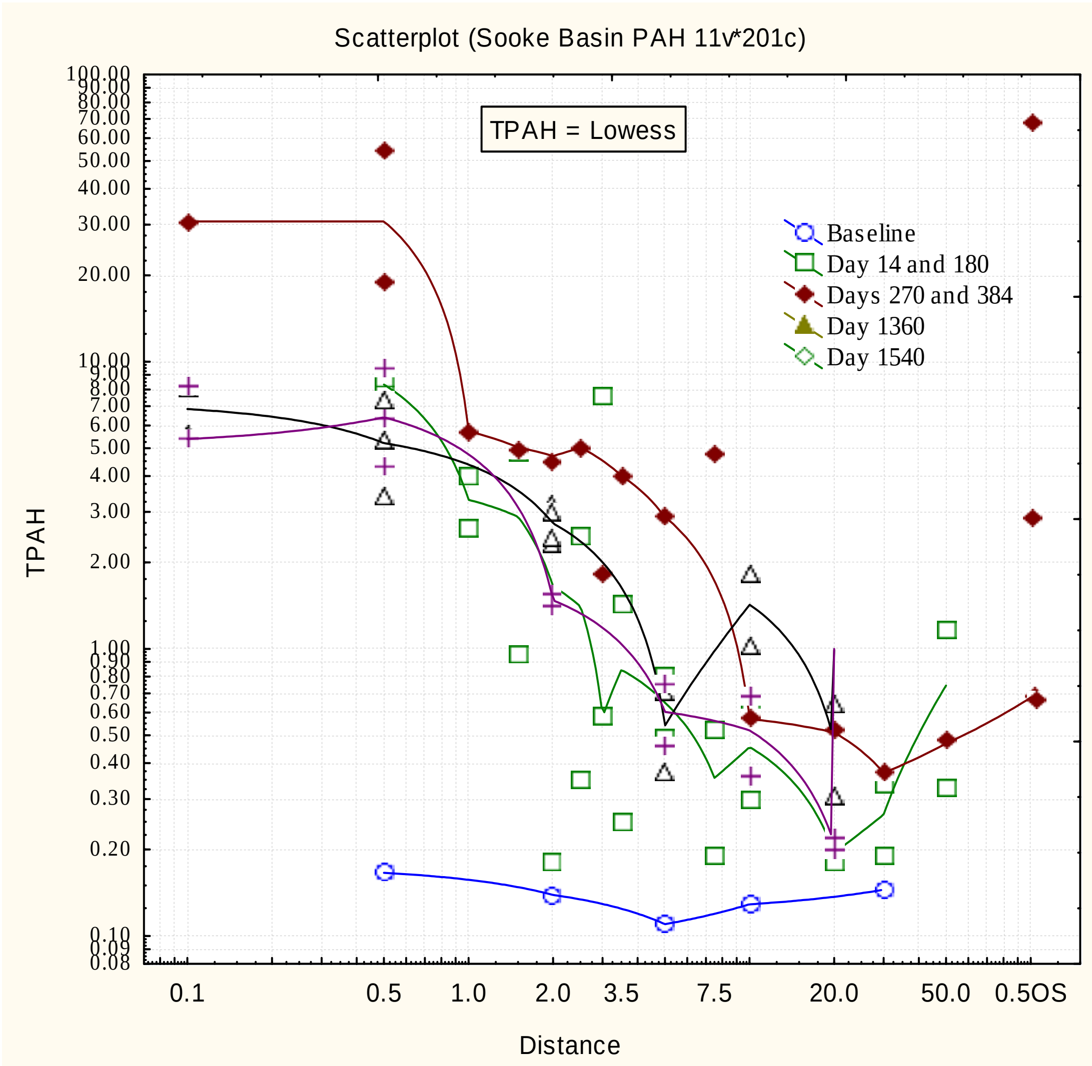

Figure 2. Summary results describing ΣPAH concentrations in surficial (0 – 2 cm) sediments as a function of distance from the Sooke Basin creosote treated dolphins.

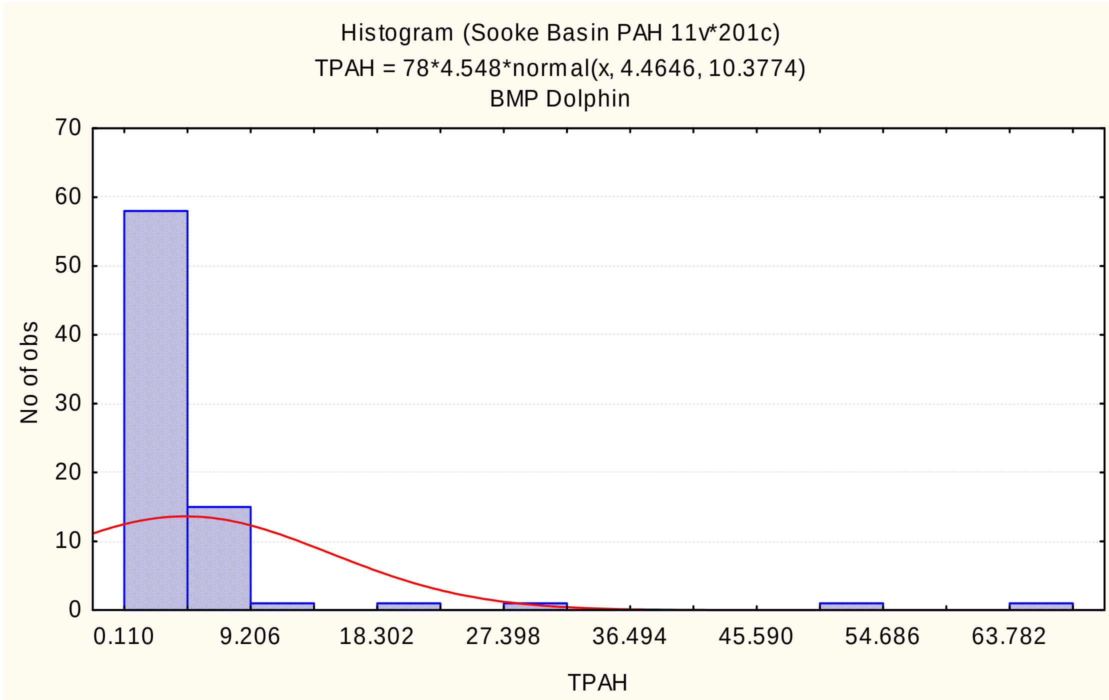

Figure 3. Frequency of observation of PAH concentrations at the Sooke Basin Best Management Practices (BMP) dolphin. Data from Goyette and Brooks (1998, 2000)

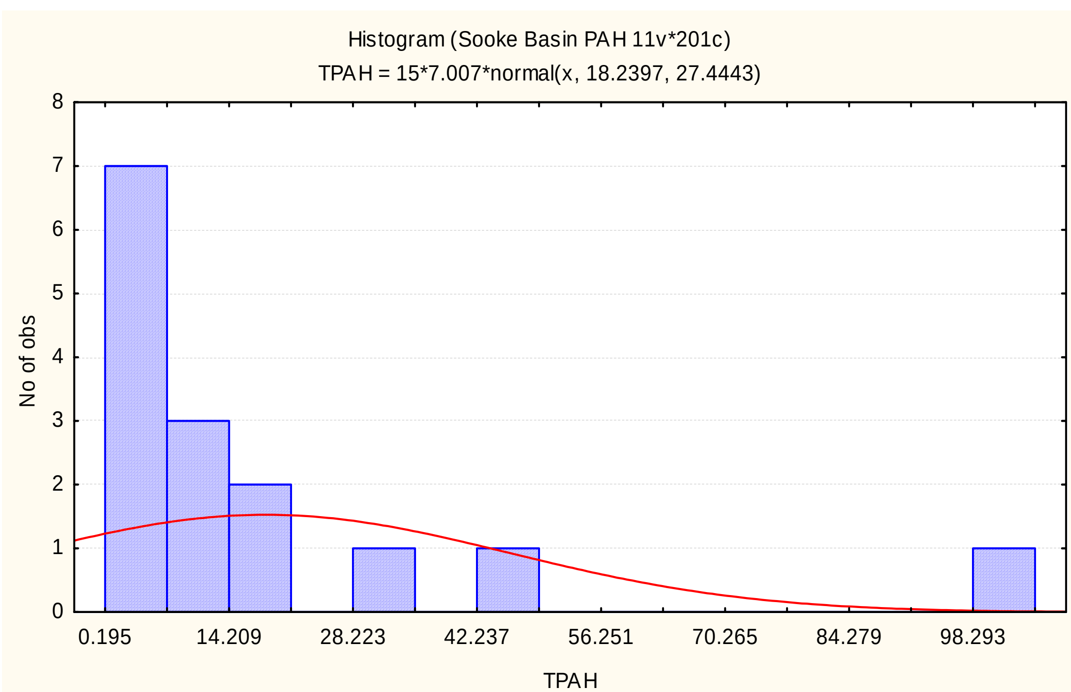

Figure 4. Frequency of TPAH concentrations observed in sediments at the Sooke Basin Weathered Piling dolphin. Data from Goyette and Brooks (1998, 2000)

Environmental studies are fraught with variability and it is important to put that in proper context. For instance, sediment concentrations of 7.6 and 20.0 μg ΣPAH were recorded 5.0 m from the Mechanical Control dolphin on Day 14. There were no creosote treated piling or sources of PAH other than the pile driver at this site. It should be also noted that Stratus was provided with all of the Sooke Basin data.

- **Page 4-9, first paragraph.** Stratus asserts that "elevated PAH concentrations remaining over a year after installation and extending up to 50 m from the pilings." That statement is not true. Table 2 describes sediment data collected at the 30 and 50 m stations from the BMP dolphin on Day 384, together with concentrations for the Mechanical Control and Open Control sites on the same day. Concentrations were highest at the Mechanical Control site, where there were only untreated Douglas fir piling, and lowest at the Open Control. PAH concentrations at distances $\geq$30 m from the BMP dolphin were intermediate. However, the null hypothesis that the three means were equal was not rejected.

Table 2. a) Surficial (0 to 2.0 cm depth) sediment ΣPAH concentrations observed at distances $\geq$ 30 m from the BMP dolphin and at the Mechanical Control (MC) and Open Control sites in Sooke Basin on Day 384. b) Analysis of variance assessing the significance of differences in mean ΣPAH concentrations at the three sites.

Breakdown Table of Descriptive Statistics (Sooke Basin PAH)
N=14 (No missing data in dep. var. list)

Site	TPAH DAY 384 >29 m Means	Confidence -95.000%	Confidence +95.000%	TPAH DAY 384 >29 m N
BMP	0.434	0.317	0.551	5.000
MC	0.500	0.008	0.992	6.000
OC	0.203	0.067	0.340	3.000
All Grps	0.413	0.229	0.597	14.000

Analysis of Variance (Sooke Basin PAH)
Marked effects are significant at p < .05000

Variable	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
TPAH DAY 384 >29 m	0.179	2.000	0.090	1.141	11.000	0.104	0.865	0.448

- **Page 4-9, first bullet.** As shown in the preceding paragraphs, Stratus misrepresents the results of the Sooke Basin study in this bullet. True, that sample was elevated on that Day 14. However, the concentration of the ΣPAH was high only at that location on that particular day. To put this result in perspective, Stratus should have noted that the concentration was 2.9 μg/g at 2.0 meters on the same day and it was 15.9 μg/g and on Day 180 and 16.1 μg/g on Day 384. The surrounding data strongly suggests that a piece of debris from the pile driving operation was included in the Day 14 sample and that this concentration did not characterize conditions at other locations near the WP dolphin on the same day or on following days. The Stratus assertion is a misuse of the data.

- **Page 4-9, last bullet.** This statement is misleading. Mussel tissue burdens of PAH were low at all times in the Sooke Basin study. They were significantly higher in mussels at the 0.5 m station on Day 14 in comparison with mussels at the Open Control. Differences in body burdens of PAH were not significantly different among the five cohorts on Day 185 and they were significantly lower in mussels grown adjacent to the BMP pilings when compared with control mussels on Day 384. Protocols for these *in-situ* bioassays are clearly detailed in the report and it is puzzling that Stratus concluded that the mussels that grew slightly slower were in contact with contaminated sediments. In fact, the mussel cages were placed at a depth of 1.5 meters or about 8 to 9 meters above the sediments, which they were never in contact with.

- **Page 4-10, last paragraph.** The Fort Worden site is not, "A long wharf" as described by Stratus. As noted in Table 1 of Brooks (2003a), this wharf consists of 801 Class "A" creosote treated piling packed into an area of 2,115 m^2 and it was chosen because it is one of the densest assemblages of creosote treated piling, located in a rural area away from other sources of PAH, that the author could find in the Pacific Northwest. In addition to the piling, the wharf's deck is supported by a numerous creosote treated beams and cross braces. The sample referred to by Stratus was collected in the center of the densest cluster of tightly packed piling that could be negotiated within this complex. The mean of the three samples collected there was 27.6 μg ΣPAH/g and the next highest sample collected at Fort Worden contained 17.57 μg ΣPAH/g. This represents yet another instance in which Stratus has described results in a non-representative way. A more balanced summary by Stratus would have included the fact that when normalized to sediment organic carbon, not a single sample collected within the Fort Worden complex was greater than the Washington State SQC or that the number of macrobenthic taxa immediately adjacent to the creosote treated wave fence was equal to or greater than observed at either of two reference locations and that the abundance of macrofauna was three to six times higher at all distances within 7.5 m of the creosote treated structures at Fort Worden when compared with these reference stations.

- **Page 3-14, 4.3.5 Conclusions.** All researchers agree that creosote migrates in small quantities from pressure treated wood and that it can accumulate in sediments and Dr. Brooks agrees with the first paragraph of Stratus's conclusions. However, despite a century and a half of high usage in transportation and marine systems across America, there are few records of environmental damage created by the use of creosote treated wood structures.

- **Page 3-14, 4.3.5 Conclusions, second paragraph.** The Precautionary Principle, as stated in Article 15 of the Rio Declaration (UNCED) is, "*the precautionary approach should be widely applied and that, where there are **threats of serious or irreversible damage**, lack of full scientific certainty should not be used as a reason for postponing cost-effective measures to prevent environmental degradation.*" The first paragraph of Stratus's conclusions indicates that they found no threats of serious or irreversible damage associated with the use of creosote treated wood products. Despite the uncertainties inherent in managing any human activity, including the use of wood that has been preserved using creosote, there is a great deal known regarding the migration, transport and fate of creosote derived PAH. As shown in the papers reviewed by Stratus, there are a number of tools available including risk assessment models and production and construction *Best Management Practices*, to enable society to effectively and deliberately manage the use of these commodities. These resources significantly reduce the need for a *precautionary approach* leading to USACE denials, based on advice from NMFS, of the public's right to use these minimally impacting, inexpensive and renewable wood products for projects constructed where federal permits are required. It is puzzling that NMFS and Stratus invoke the *precautionary approach* to the use of treated wood products, for which the environmental risks and their management are well characterized, in favor of alternative materials such as concrete, steel and plastic, for which similar detailed knowledge is not available. Based on conversations with Dr. Fry (personal communication), in which he expounded at length on the significant risks associated with the use of steel and plastic products in aquatic environments, it is puzzling that none of this information was included in the final version of the Stratus report. Because of the lack of information, it is these products to which the *precautionary approach* should be applied.

- **Page 3-14. 4.3.5. Conclusions, second paragraph.** Stratus states that, "First, the above studies typically have evaluated responses at the community level (e.g., the benthic invertebrate studies) or to tolerant life stages (e.g., adult oysters and mussels)." Most benthic invertebrates have planktonic larval stages that recruit into sediments or onto treated piling as more sensitive larvae or juveniles. Therefore, the composition of these communities integrates environmental effects at nearly all life stages. Stratus completely ignored the inventory of invertebrate communities resident on creosote treated piling that were presented in Brooks (2003a). The Stratus statement also ignores the results of the mussel (*Mytilus edulis edulis*) reproductive bioassays that found no significant differences in development to the trochophore stage as a function of distance from the BMP dolphin. As previously noted, NMFS does not manage listed salmon stocks at the individual level. If they did, there would be no mixed stock or hook and line fisheries allowed anywhere in the Pacific Ocean, particularly near the Columbia River or in Puget Sound, Washington.

Lastly, most of the pressure treated wood risk assessments have been conducted in worst case environments involving slow moving bodies of water and high densities of treated wood. However, Brooks (2000) assessed the risks associated with bridges treated with pentachlorophenol crossing salmon spawning streams in Washington State and Oregon and Brooks (2005a) assessed sediment PAH concentrations under the creosote treated Anderson Creek Bridge in Washington State. Anderson Creek is also a salmon spawning stream. Sediment concentrations of pentachlorophenol and/or PAH were well below any biological effects concentration at all of these sites – even within 15 cm of piling and/or bulkheads supporting the bridges. Stratus did not discuss any of these studies, even though they were provided copies of them. The studies are important because they directly assess conditions in salmon spawning streams and demonstrate a lack of effects. Why Stratus chose to ignore reports directly assessing effects in salmon spawning streams is puzzling.

- **Page 4-14, Section 4.4 Factors to be Considered in Aquatic Risk Assessments.** The first sentence in this section, asserting that, ". . . .PAHs that leach from creosote-treated wood have the potential to accumulate in abiotic media and aquatic biota and to cause toxicity to biota." is misleading. While the potential may exist, of all the reports reviewed by Stratus, the only case in which adverse biological effects were observed was in sediment bioassay tests conducted within ca. 0.65 m of the Sooke Basin dolphin. No adverse effects were observed in macrobenthic communities in any of the other studies or in bioassays at any site other than Sooke.

- **Page 4-15, second and fifth bullets.** Dr. Brooks agrees that site specific risk assessments should be conducted where current speeds are <1.0 cm/sec (first bullet). With respect to creosote, site specific risk assessments should also be conducted where sediment redox is negative or where the reduction oxidation potential discontinuity is < ~1.0 cm. WWPI (2002) provides specific guidance for when a site specific risk assessment is required. Based on the results of Brooks (2000 and 2005a) there is no reason to arbitrarily require a site specific risk assessment for the use of creosote treated wood in areas where the larvae and/or juveniles of T&E species are found. Imposition of this requirement should only be based on empirical evidence demonstrating a real risk in these situations.

- **Page 4-15 and 4-16, remaining bullets.** The remaining bullets should be applied to all construction activities and commodities – not just to pressure treated wood.

- **Pages 4-16 and 4-17.** It is uncertain how the actions of a very few of the thousands of federal, state and local jurisdictions that use and/or permit the use of pressure treated wood has to do with the science of this subject. At this point Stratus leaves science and enters the realm of politics – leaving the door open for others to respond. It is curious that Stratus has not included comments and responses from the U.S. Forest Service regarding the use of pressure treated wood. That agency's Forest Products Laboratory has far more expertise and credibility than NMFS in understanding and predicting the environmental response to pressure treated wood and yet Stratus failed to solicit their comments or those of the hundreds of port authorities that continue to use pressure treated wood to advantage.

- **Page 4-17, last paragraph.** At page 4-14, Stratus concludes that, " . . . and has not generally been associated with measured, significant, biological effects except in close proximity to the structures." As previously stated, even this statement is misleading in that biological effects have generally not been detected and where they have, they have been associated with a proliferation of life on and around the piling. How Stratus uses even their own conclusion to assert in the last paragraph of their report that, ". . . . ., and environmental levels of contaminants originating from creosote-treated wood are often toxic, precautions to avoid creosote-treated wood where practical, and measures to isolate potential toxic effects appear to be justified." is incomprehensible.

Conclusion. Dr. Brooks has seldom encountered a scientific review that has been as poorly written and biased as this document. Despite Stratus's selective extraction of material and misrepresentation of the results of numerous studies, even their own review does not substantiate the conclusions reached. In the end, because empirical evidence did not support the desired conclusions, they reverted to a political argument in asserting that because a few jurisdictions have institute restrictions that others should follow. It should be emphasized that standards in a democratic society must be uniformly applied. Restrictions on a single commodity are not justified. If NMFS feels that a sediment PAH criterion of 1.0 μg ΣPAH/g is needed, they should submit their proposal to EPA for consideration. Obviously a standard of 1.0 μg ΣPAH/g, if applied equally to all activity, would essentially shut down all societies. No stormwater discharges, no atmospheric deposition associated with fireplaces or electrical power generation, no sewage treatment plant discharges, etc. The pressure treated wood industry has a right to be treated equally with other elements of society and the application of this standard to only pressure treated wood cannot be viewed as anything but arbitrary. If such a standard is applied universally within America, then certainly, the treated wood industry would have to comply.

The lack of scientific rigor and the bias evident in this report means that other reviewers will be forced to examine the volumes of available literature to achieve a true perspective. In that regard, it is unfortunate that Dr. Brooks has not submitted some of his numerous studies to journals for peer review and publication. The basic model for CCA-C Brooks (1996) was peer reviewed and published as have Brooks (2000a, 2000b, 2004b). Brooks (2005a) is in-review. An effort will be made in the near future to submit other key publications. From that perspective, the Stratus report has been valuable in that it points out sections of Brooks (1997) that need amplification to assist those unfamiliar with modeling and environmental risk assessment.

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Volume II

Section II

Stratus Creosote Report and Comments

4. Transmittal by Chris Risbrudt of the Forest Service

United States Department of Agriculture
Forest Service
Forest Products Laboratory
One Gifford Pinchot Drive
Madison, WI 53726-2398
Phone: 608 231-9200
Fax: 608 231-9592
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File Code: 4000
Date: April 26, 2006

NOAA Fisheries, Water Quality Coordinator, Treated
Wood Comments
National Marine Fisheries Service
777 Sonoma Avenue, Suite 325
Santa Rosa, CA 95409

Dear Water Quality Coordinator:

I am respectfully submitting the attached comments on behalf of the USDA Forest Service concerning two documents that have been posted in the Federal Register by the National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NMFS).

We understand NMFS is in the process of developing guidelines for the appropriate use of preservative-treated wood in aquatic environments. As part of this process, NMFS contracted with a consulting firm to interpret the existing science on preservative leaching and environmental impacts and to make recommendations to NMFS on guidelines for appropriate use. The consulting firm produced two reports, which have been posted to allow comments by the public, as well as by Federal and state agencies.

Forest Service scientists have reviewed the reports and have noted that the recommendations have the potential to significantly impact construction projects conducted by the Forest Service and other government agencies. In several cases, the recommendations in the reports do not appear to be well-supported by the relevant science. We have enclosed a review that summarizes our primary concerns with the content and recommendations in the reports. Thank you for your time and consideration.

Sincerely,

/s/ Robert J. Ross (for)
CHRIS RISBRUDT
Director

Enclosure

cc: Robert J Ross
Stan Lebow

Gordon E Blum

Volume II
Section II
Stratus Creosote Report and Comments

5. Memo from Stan Lebow, PhD, of Forest Service to Chris Risbrudt that contain Forest Service comments

Date: April 26, 2006

To: Dr. Christopher Risbrudt, Director
USDA Forest Service, Forest Products Laboratory
1 Gifford Pinchot Dr.
Madison, Wisc. 53726-2398

From: Stan Lebow, PhD., Research Forest Products Technologist

Subject: Comments on Stratus Consulting Reports on use of Preservative-Treated Wood in Aquatic Environments

Background

The National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NMFS), is in the process of developing guidelines for the appropriate use of preservative-treated wood in aquatic habitats that are, or have been, utilized by threatened or endangered species. NMFS is primarily concerned about the impacts of copper released from waterborne preservatives and of polyaromatic hydrocarbons (PAHs) released from creosote-treated wood. The purpose of the proposed guidelines is to identify the types of construction projects that present acceptable risks and those that might warrant further study. To assist with developing these guidelines, NMFS contracted with Stratus Consulting to interpret the existing science on preservative leaching and environmental impacts and to make recommendations to NMFS on guidelines for appropriate use. The task included comparing treated wood to alternative construction materials such as concrete, steel, and plastic.

The Forest Service shares NMFS's desire to utilize construction materials in a manner that is compatible with our natural resources. To that end, the Forest Service has conducted and/or funded studies on the environmental impacts of preservative-treated wood. These studies have indicated that treated wood can be used for most Forest Service construction projects without posing unreasonable risks to the environment. Recommendations in the Stratus Consulting reports appear to offer a more restrictive view of appropriate uses for preservative-treated wood. If these Stratus-proposed recommendations are incorporated into NMFS guidelines, construction projects proposed by the Forest Service and other government agencies could be significantly impacted.

General Comments

Perhaps the most notable weakness of the reports is the apparent disconnect between the science presented in the bodies of the reports and the recommendations listed in the conclusions. A specific example is Recommendation #4 (page 7-4) of the report on waterborne preservatives (a similar recommendation is made on page 4-15 of the creosote report). The authors appear to be recommending that any treated-wood construction project, regardless of project size or stream flow, require a site-specific ecological risk assessment if the location is defined as part of critical habitat for NOAA Trust Resources. It is notable that, because the majority of Pacific Coast rivers, streams, and estuaries are considered critical habitat, adoption of this recommendation would require site-specific risk assessment for the majority of construction projects in or above water. Recommendation #4 appears to directly conflict with the authors' conclusions elsewhere in the report, that concerns are limited to projects involving large volumes of treated wood or poor water circulation (see page 7-1, for example). In fact, the recurring theme among the studies and models evaluated by Stratus is that small- to medium-sized construction projects in (or above) moving water do not rise to a level of concern that warrants further study. More specifically, the U.S. Army Corp of Engineers modeled the impacts of ACZA- and CCA-treated wood and concluded that no adverse impacts were likely to occur if average flows exceeded 1.0 cm per second and fewer than 100 piles were involved in a construction project. Using more conservative models, NMFS conducted a simulation with structures involving 300, 100, or 24 piles. Their models indicated acceptable copper concentrations in all scenarios involving 24 piles, or with current speeds in excess of 10 cm per second. Thus, blanket recommendations that all projects in areas designated as critical habitat require a site-specific biologic assessment appear to be unfounded.

The impact of implementing such recommendations on Forest Service construction projects alone could be substantial. Most Forest Service construction projects utilize much smaller volumes of treated wood than those modeled and often do not have any treated wood in direct contact with water. They are also typically constructed over well-circulated water. Requiring a full risk assessment in these situations would appear to be unnecessarily burdensome and an inefficient use of time and resources. The Stratus recommendation appears additionally incongruous because earlier in the text the authors point out the negative impact of a similar approach in a NOAA Fisheries Northwest Region draft guidance document. The following excerpt is copied verbatim from page 6-15 of the Stratus waterborne preservatives report:

"The draft guidance includes the statement that "While this guidance contains recommendations on project design and construction, in most settings, a site specific assessment will be needed to determine if the use of treated wood will be consistent with adequate protection of species covered by the ESA and the MSA, their prey base and habitat." This statement is significant because the desire to avoid a formal consultation for a treated wood project can lead an applicant to use alternative materials such as steel or concrete, even if the proposed use of treated wood products would not have exceeded water column or sediment guidelines."

Thus, it appears that the authors are well aware of costs associated with requiring unnecessary site-specific risk assessments.

It is also troubling that although the reports provide suggested parameters to evaluate in site-specific assessments, little guidance is offered on interpreting the results of those evaluations. This raises the concern that the suitability of treated wood for a specific application will remain unresolved even after the considerable time and expense of conducting an assessment.

Another area of the waterborne preservatives report that warrants comment is Chapter 5, Alternative Materials. The information presented in this chapter is inadequate to allow comparison of relative risks and benefits of alternative construction materials. The authors do briefly note that concrete, steel, and plastic products all contain and emit compounds that are potentially harmful to aquatic organisms. However, there is no attempt to model or quantify the rate of release of these components or their potential environmental concentrations. Thus, it is not possible to consider the risk associated with the alternatives relative to that of preservative-treated wood. Based on the Stratus reports, it appears that the science on environmental impacts of alternative materials is less advanced than that for treated wood. The lack of data on the alternatives is significant considering that the primary criticism of treated wood in the Stratus reports appears to be the degree of uncertainty associated with the existing models. If similar logic is applied to the alternative materials, this lack of environmental data should lead to a recommendation of a site-specific biological assessment for any project using any materials in any area designated as critical habitat. Any other recommendation would be difficult to defend based on the state of the science of the alternative materials relative to treated wood. The practical impact of Stratus Recommendation #4, then, may be to require a site-specific assessment for all construction projects regardless of the building material, size of project, or site conditions. This type of outcome would hinder the Forest Service's ability to build the infrastructure needed to access its lands for either forest management or public recreation purposes.

The Stratus waterborne preservatives report does present some information on the cost of treated wood piles relative to concrete, steel, and plastic piles, but the information does have some limitations. A small but important point is that the report uses a typical maximum service life of 15 years for treated-wood piles. Service life data are notoriously difficult to obtain, and in this case the 15-year value—apparently obtained from personal communication—is substantially below that expected by the treating industry and below that predicted by Forest Service exposure tests. The cost comparison also neglects an important consideration for many Forest Service construction projects that are in remote locations with limited vehicular access: The Stratus report notes that the heavier alternative materials are slightly more expensive to install but does not acknowledge that the difference in installation costs increases for remote locations. In locations without vehicular access, construction with alternative materials may simply be impractical. The economic comparison also does not include the cost of purchase or installation of any construction members other than piles. Piles compose only a small fraction of the volume of treated wood used in many construction projects, and particularly Forest Service projects. Most treated-wood members used in construction (joists, stringers, beams, and decking) are oriented horizontally. The cost of these members made of treated wood is generally lower than the cost of these members made of alternative materials, but an even greater difference is found in the ease and cost of installation. As mentioned above, the cost of installing heavier materials in remote locations can be prohibitive.

The lack of information provided for members other than piles in the Stratus reports is also a concern in the biological impact assessment. Neither report addresses release of preservative components from treated wood above water, even though this use constitutes the greatest volume of treated wood. Past publications and correspondence from NMFS (the 2004 Slopes III document, for example) indicate that NMFS is concerned with releases from all parts of a treated-wood structure, including those not in contact with water. Release of preservative from above-water members is primarily a function of precipitation. Because precipitation varies seasonally and geographically, estimation of preservative release from wood used above water is complex. Still, the value of the Stratus reports and their recommendations is diminished by the lack of data on contributions from a major portion of treated-wood structures. Although data on leaching from precipitation is limited in comparison to leaching rate data for submerged wood, some data are available, and the reports should be expanded to incorporate above-water members of both treated wood and non-wood materials.

In both reports, the authors convey the impression that previous studies and models are likely to underestimate actual rates of preservative release from in-service structures. In the report on waterborne preservatives, the authors expend considerable effort (see Table 2.5, for example) expounding on the theory that laboratory leaching trials are likely to underestimate leaching from treated wood in service. Although some of the authors' points may be valid, they are largely speculative. For example, no evidence supports the theory that static-renewal leaching procedures underestimate leaching rates. In essence, these tests are actually flow-through tests conducted in steps, and they will reach similar values if the test is carried to completion. There are numerous other reasons why laboratory tests may actually overestimate in-service leaching. First, many past laboratory studies have used samples with small dimensions and/or a high proportion of end-grain. These types of samples are intended to accelerate leaching and shorten the test period. By intent, these types of samples will overestimate release rates from commodity-size material in service. Forest Products Laboratory researchers have found that specimens treated in the laboratory may actually have a higher rate of preservative leaching than wood treated by commercial treaters. There are several reasons for this. First, laboratory treatments often use a "full cell" process with a lengthy initial vacuum, lengthy pressure period, and no final vacuum. This type of process is used to improve the uniformity of preservative penetration within the sample and minimize variability between treatment groups. However, the full cell treatment also maximizes uptake of preservative solution. Commercial treaters, in contrast, have the goal of using the minimum amount of preservative required while still meeting the treatment standards. Commercial treaters use an abbreviated initial vacuum, a short pressure period, and a lengthy final vacuum. As a result, commercial treatments typically deliver only about two-thirds the amount of solution that is delivered with a laboratory full cell treatment. In a recent Forest Products Laboratory study, leaching from laboratory-treated deck boards was compared to that of commercially treated deck boards purchased from several suppliers. In each case, less preservative leached from the commercially treated deck boards than from the laboratory-treated deck boards. Commercial treaters have extensive experience in using their equipment to minimize use of preservative and provide a clean surface. In many cases, laboratory researchers are less familiar with treating processes and may not achieve ideal treatment conditions. A common flaw with laboratory treatments is that researchers rapidly dry the specimens immediately after treatment. This rapid re-dry does not allow fixation reactions to proceed and may also result in surface deposition of preservatives on the specimens.

Laboratory tests may also overestimate in-service leaching when the tests are conducted using commercially treated specimens. Laboratory trials are often conducted with deionized water, which can cause higher rates of leaching of some types of preservatives than those found with natural waters. Leaching tests also assume full exposure of the product to the leaching medium, whether water immersion or simulated rainfall. However, in actual structures, much of the wood is only partially exposed to weather because it is protected by decking or other parts of the structure above it. Finally, laboratory tests are typically conducted until the rate of preservative release reaches a relatively stable level and then discontinued. The final release rate noted in the laboratory trial is then assumed to remain constant for the life of the product and is used to estimate long-term leaching. This assumption of constant release for an indefinite period is an overestimate because as the preservative is depleted from the wood, leaching rate will gradually decline. Thus, most published estimates of long-term release and environmental accumulation tend to overestimate long-term leaching.

In the creosote report, the authors claim (see bottom of page 4-3) that the models reviewed in the report are more likely to under-predict than over-predict PAH leaching under field conditions. This claim appears to directly conflict with the authors' own review of those same models earlier in the report. On page 2-25, the authors note that Poston felt that his model probably over-predicts water column concentrations of PAHs. A similar statement about the Poston model is made on page 4-3. Also on page 2-25, the authors noted that Brooks's model over-predicted environmental concentrations at all locations at the Westham Island Bridge location and both over- and under-predicted concentrations at the Belcarra Bay site. On page 2-26, the authors report that Brooks's model over-predicted water column concentrations at the Sooke Basin site and that it over-predicted sediment concentrations for all but one sampling event. Thus, it is unclear why the authors claim that these models underestimate leaching. Although there is uncertainty in both models, they appear more likely to over-predict than under-predict. In light of the number of parameters involved, the predictions made by the Brooks model are relatively close to environmental concentrations.

Another point of concern in the creosote report is the authors' derivation of what appears to be a completely new, and perhaps unrealistically low, threshold value for sediment PAH levels. In Chapter 3 (Section 3.4.2), the authors summarize various biological effects concentrations discussed in the literature. They note that the issue has been widely studied, and in Table 3.2 they summarize sediment quality guidelines and criteria that have been developed or used by various regulatory agencies as a result of this prior work. They then apparently disregard this previous work in favor of using the data of two NMFS scientists whose research is limited to PAH effects on English sole in Puget Sound. Utilizing this data, they derive a new threshold value (1.0 mg/kg) that is well below that previously utilized by any government agency. Considering the large body of scientific study and considerable expertise that were applied to establishing previous sediment criteria, such a large change based on very limited data does not appear prudent. Unfortunately, this 1.0 mg/kg is then used later in the report (see page 4-2, for example) as if it were a well-established and well-accepted PAH threshold for comparison with observed environmental concentrations.

Specific Comments

Other points in the waterborne preservative report that need clarification are discussed below in the order in which they appear in the text:

Page 2-2, 3rd paragraph—The authors state that the leaching of copper from CCA is typically higher than that of arsenic. This statement is true only for wood exposed in seawater (as cited by the author in Lebow et al. 1999). Most studies of leaching in freshwater, soil, or precipitation have reported that arsenic release is greater than copper release.

Pages 2-6 through 2-10—The authors discuss models developed by Dr. Brooks to assess leaching from CCA-, ACZA-, and CA-B-treated wood and leave the impression that Brooks feels that his models underestimate leaching. In fact, Brooks made this statement for the ACZA models only, and this statement does not apply to the CCA or CA-B models.

Chapter 2, Section 2—The authors comment that models developed to date suffer from variability and uncertainty. Although this criticism has some validity, this same comment could be made about all attempts to model natural phenomena. And the outcomes of models constructed by various authors using a range of testing conditions actually appear to be surprisingly similar. Considering the absence of any models offered for leaching from the alternative construction materials, the work presented in Chapter 2 appears rather robust. It is also unclear why or how the authors reach the conclusion that Dr. Brooks's models of CA-B release will underestimate long-term leaching rates "*by a factor of approximately 1.5 to 2 times*" (see page 2-15). The foundation for this claim is not obvious from the information provided, and as noted above, models such as this probably tend to overestimate long-term leaching because they assume that the rate of release does not decline over time.

Chapter 4, Section 2—On pages 4-2 and 4-3, the authors discuss a series of studies conducted by Weis and Weis or Weis et al. It should be noted that these studies involved use of wood that was treated with CCA to the highest marine retention (2.5 lb/ft^3). This retention is 4 to 6 times greater than that used for freshwater and terrestrial applications. This wood was also in contact with seawater, which has been shown to increase release of copper from CCA-treated wood relative to that in freshwater.

Chapter 6, Section 2—In this section the authors summarize content from a Forest Service publication titled "Guide for Minimizing the Effect of Preservative Treated Wood on Sensitive Environments." It should be noted that the last bullet point in this section misinterprets the Forest Service article in regards to the use of field-applied coatings. The Forest Service publication actually cautioned that the benefit of applying coatings or finishes over aquatic environments was probably not worth the risk of the potential impacts of the coatings themselves.

Page 7-7, final bullet point—The authors appear to suggest use of a preservative system that has not been standardized and has not been evaluated using accepted standard methods. It is important to reference only preservative systems that have demonstrated efficacy in their intended end use.

Other points in the creosote report that need clarification are discussed below in the order in which they appear in the text:

Page 1-5—The authors incorrectly state that copper naphthenate is not recommended for use in freshwater applications. It is standardized for use in freshwater, although at this time its usage is very low compared with that of other preservatives. The authors are correct that copper naphthenate is not standardized for use in seawater.

- *Page 4-10, 3rd bullet point*—It is unclear what toxicity threshold effects level the authors are referring to.

- *Pages 4-4 to 4-6*—Charlestown Navy Pier and San Diego Naval Station: The situation described in the Charlestown Navy Pier is an anomaly that occurred in 1987. The creosote re-treatment required by the National Park Service led to the high degree of leaching observed. It is misleading to state that the piles were treated to a retention that was "higher than the BMP's specified." It is not clear what BMPs the authors are referring to, because the current BMPs had not yet been developed at that time. The piles in that situation were certainly not treated to any type of modern BMP specification. The authors, conclusions based on the San Diego Naval Station study appear speculative. There are many sources of PAH in the environment, and as the authors state, the Navy had taken steps to reduce PAH contributions from multiple sources. The study does not establish what proportion, if any, of the PAH reduction in the harbor was attributable to removal of creosote-treated piles.

Page 4-17, final paragraph—This paragraph is out of place in a report whose intent is to summarize and interpret scientific literature. In the first sentence the authors appear to be expressing the opinion that policies should dictate science. The subsequent statement that "*…levels of contaminants originating from treated wood are often toxic*" conflicts with the majority of studies of creosote impacts. It also conflicts with the authors' own conclusions on page 4-14, where the authors state, "*However the degree of PAH accumulation to sediment associated with these structures appears relatively minor in many settings, particularly in well-circulated waters and over time.*" As a whole, this paragraph diminishes the credibility of the report and should be removed.

Positive Comments

Although there are problems with the Stratus Reports, they do make some recommendations that are worthwhile. For example, the recommendation that wood intended for aquatic environments be treated according to industry best management practices. Treatment of wood to these BMPs will reduce concerns about variability in treatment quality with respect to leaching. Recommendations about prefabrication, fabrication off site, and debris collections are also excellent. It should be noted that these practices are currently followed in most Forest Service construction projects, but further reinforcement of this concept is worthwhile.

Summary

There are several areas where the Stratus interpretations of the relevant science and their resulting recommendations are inconsistent and inadequate. The recommendations presented at the end of the reports conflict with data presented in the reports and with the authors' own conclusions earlier in the reports. Recommendations in both reports would require site-specific biological assessments for any construction project, regardless of volume of wood used, volume of water, or rate of circulation. This recommendation is not supported by the numerous studies and models that have indicated that projects involving moderate volumes of treated wood or rapidly moving water do not warrant further evaluation. Most Forest Service structures, for example, do not appear to warrant a site-specific assessment. The reports should be modified to include simple screening criteria (based on project size and current velocity, for example) that would exclude such projects from the site-specific assessment requirement.

The information provided for alternative construction materials is inadequate to allow comparisons with preservative-treated wood. Although the authors note that the alternatives do release potential toxicants into the environment, there is no attempt to estimate or model these releases. However, it appears that if the authors used logic similar to that used for treated wood, the lack of environmental data for these materials would lead to a broad recommendation of site-specific assessments for every project. The economic assessment of the alternative materials does not consider the additional costs of installing the alternative materials in remote locations and does not consider members other than piles.

Both reports focus almost solely on piles even though piles are absent from many treated-wood structures and constitute only a fraction of the volume of wood used in others. The reports should be expanded to include assessment of risks from above-water structures.

In both reports, the authors make statements that laboratory studies and modeling efforts are likely to underestimate in-service leaching. These statements are not supported by the data presented. In the case of the creosote models, the data appear to suggest that the models are more likely to overestimate environmental accumulations.

In essence, these reports provide very limited guidance. It is clear from these and other reports that although treated wood presents little concern in many projects, there are some situations where further evaluation is warranted. Instead of providing models or criteria that can be used to identify projects that may be of concern, the authors simply recommend that all projects be subjected to site-specific assessment.

Volume II

Section II

Stratus Creosote Report and Comments

6. Letter with comments from William B. Smith of Wood Products Engineering of SUNY Syracuse.

State University of New York
COLLEGE OF ENVIRONMENTAL SCIENCE AND FORESTRY
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May 2, 2006

Mr. Joseph J. Dillon
Water Quality Coordinator
National Marine Fisheries Service
777 Sonoma Ave., suite 325
Santa Rosa, CA 95409

via email and fax 301/427-2540

Dear Mr. Dillon:

I have recently obtained a copy and reviewed the draft report on *Creosote-Treated Wood in Aquatic Environments: Technical Review and Use Recommendations*, prepared by Stratus Consulting. It is my understanding that this report was prepared for the National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration (NOAA), and is intended to assist the NMFS in developing guidance on the use of treated wood in aquatic environments. Stratus has presented an extensive review of data and other information related to creosote, aquatic environments, and components of creosote such as PAHs. Unfortunately, as currently written, the primary conclusions and recommendations put forth in this report are not properly supported nor substantiated by the data reviewed. As such it would be inappropriate at this time for the NMFS to promulgate any policy, guidelines or restrictions based upon this document.

Stratus has correctly noted that the U.S. EPA is currently undertaking a scientific technical review and risk assessment of creosote treated wood, to assist in deciding whether creosote will continue to be registered as a pesticide. They have also reported, however, that despite pending federal review, many states have implemented their own regulations. What is left unsaid is that much, if not all, of the state regulatory activity has been without scientific justification. In New York State, for example, over the past several years legislative bills to restrict use of creosote treated wood have been vetoed by Governor Pataki, who in each case noted that the reasons for his veto included lack of supporting scientific data and that most appropriate action would best be addressed from the upcoming EPA review. The implication provided to an uninformed reader is that the individual state regulations have been necessarily implemented due to the absence of federal guidelines and restrictions, Aeditorially≅ implying that those regulations were in fact necessary. The Acircular logic≅ of this argument has no place in a scientific document, and its presence suggests strongly an inappropriate prejudicial bias on behalf of the Stratus authors. Such author bias subsequently serves to cast doubt on the confidence of other data, analysis, results and conclusions.

Stratus acknowledges that in 2003 the federal EPA, upon significant study, review and analysis of data, concluded that use of creosote-treated wood products does not result in excessive translocation of creosote or its components into the environment, nor does it result in acute or chronic toxicity to fish and aquatic invertebrates. Also included in this report are data noting that while some PAHs can migrate from treated wood structures into aquatic environments, the degree of PAH accumulation associated with such structures is relatively minor, particularly shortly after new installations, when products are produced, handled and installed in accordance to published BMPs (Best Management

Practices), in well circulated waters, and over time. Data of any PAH accumulation was also shown to be quite limited spatially to areas very close to structures, and yet was still not generally found to be associated with measured, significant biological effects on fish, invertebrates or other aquatic organisms. Duration of any reported biological effects appeared to specifically attenuate within a short time of construction, after which minimal, if any, effects were measurable.

Subsequent to the reporting of various data on creosote components and their possible presence and effect in aquatic environments, and that adverse biological effects from aquatic use of creosote-treated wood have not generally been substantiated or observed, it was concluded by Stratus that nevertheless, several factors suggest that a precautionary principle might be applicable to certain treated wood uses. I am not aware of how such a Aprecautionary principle≅ can be defined, nor what data would be properly used in its development, or how it could be appropriately implemented. For example, I can only presume that through use of the precautionary principle it would be appropriate for protection of aquatic environments to ban boating, swimming, or any human activity within hundreds of yards of such water. This concept clearly has no merit in a scientific document. It was also noted as part of the conclusions and recommendations that the level of environmental protections applied to threatened and endangered (T&E) species should occur at the individual rather than the population or community level. I am not aware of this being accepted procedure or protocol for toxicological or epidemiology studies, and again, I see no scientific justification to making such a statement.

The two current Stratus reports on both creosote- and copper-treated wood in aquatic environments have reviewed a considerable amount of data and reports of performance and biological activity over many years, and as such can provide a meaningful start to the NMFS as it addresses use of treated wood. Unfortunately, the use of inappropriate analysis, editorializing without scientific justification, and suggestions without merit that alternative materials such as steel or plastic pilings and timbers (which take considerably more energy, petroleum and other non-renewable resources to manufacture, are of considerably higher cost, and have questionable performance characteristics as compared to wood) would be better than treated wood, make the conclusions in these reports unusable and much of the rest of the information provided potentially suspect.

I very much appreciate your time and willingness to consider my review and comment upon both of these reports. Please call me at 315/470-6832 or 6880, or email to [illegible]@[illegible].[illegible] , [illegible] [illegible] [illegible] [illegible] [illegible]. [illegible] [illegible].

[illegible],

William B. Smith

[illegible] [illegible]. [illegible], [illegible].[illegible].
[illegible]

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Section II
Stratus Creosote Report and Comments

7. Peer Review comments by Timothy T. Townsend, PE, PhD, prepared by the University of Miami Independent System for Peer Review.

Review of

"Creosote-Treated Wood in Aquatic Environments:
Technical Review and Use Recommendations"

and

"Treated Wood in Aquatic Environments:
Technical Review and Use Recommendations"

Prepared by:
Timothy T. Townsend, PE, PhD

Prepared for
"University of Miami Independent System for Peer Review"

March 13, 2006

Executive Summary

Treated wood products by design contain toxic chemicals that are designed to prevent deterioration of the wood by organisms. Several treated wood applications involve submerged wood structures, and in these cases, preservative chemicals are known to leach from the wood products into the surrounding aquatic environment. Concerns have been raised as to the effect of leached preservative chemicals on non-target organisms. The National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration (NOAA) has such a concern with respect to the impact of treated wood on threatened and endangered species in NMFS trust fishery resources. As such, the NMFS is in the process of developing guidelines for the appropriate use of treated wood products in these habitats. The NMFS commissioned two technical documents for use in the development of this guidance, and this current report is a review of those documents.

The following two reports were reviewed: “Treated wood in aquatic environments: Technical review and use recommendations” and “Creosote-treated wood in aquatic environments: technical review and use recommendations.” The information covered in the two documents summarizes several different topic areas pertaining to treated wood in aquatic environments: leaching and transport, toxicity of preservative chemicals, risk assessment and evaluation, and best management practices for minimizing risks. This reviewer responded to specific review questions.

The two documents provide an excellent summary of currently available information regarding preserved wood in aquatic environments, specifically information regarding pollutant leaching, available models for predicting transport and fate of preservative chemicals, toxicity of preserved wood chemicals to aquatic organisms, factors to consider in conducting a risk assessment, and existing best management practices for treated wood usage in aquatic environments. These documents represent the most complete, up-to-date compilation of this information currently available. The documents further propose a set of use recommendations for assessing whether treated wood use is appropriate for specific construction projects in a given aquatic environment. These recommendations are warranted and their application is supported by existing data. Given the many uncertainties associated with the current available science on the impact of treated wood products on the aquatic environment, these recommendations should provide conservative protection to threatened and endangered species in NMFS trust resources.

One fundamental component of the use recommendations is the performance of a site-specific ecological risk assessment for projects identified as sensitive in a screening-level project evaluation. The documents provide elements that should be included in such assessments and the factors that should be considered. The documents do not, however, provide sufficient guidance or documentation to conduct a site-specific ecological risk assessment; this does not appear to have been part of the scope of work. Thus, NMFS should focus future guidance development on the production of detailed guidelines for conducting such a risk assessment. Based on past use by the reviewer of some of the existing leaching and transport models cited, these tools are not adequately reviewed, validated, nor documented to be of wide-spread use. NMFS guidelines should include detailed description of leaching and transport models, and should include a sensitivity analysis so that those conducting ecological risk assessments understand which factors most heavily influence the assessment. The guidelines should include very specific examples demonstrating the application of these models as part of a risk assessment; several examples should be provided, included those where results find that treated wood usage should be restricted and those where usage is not restricted. A logical component to such guidelines would be an easy-to-use software application.

1. Background

Treated wood products contain preservative chemicals specifically added for the purpose of preventing biological decay. The chemicals act as toxins (biocides) to organisms that would otherwise deteriorate the wood. The presence of these toxic chemicals raises natural concern when other non-target species may be impacted. An area of such concern is the use of treated wood structures in aquatic environments and the impact they may have on fish and aquatic invertebrates. Preservative systems are designed to remain active and retained in or on the wood structure for many years, but preservative chemicals do leach at relatively low concentrations over time when exposed to water. These chemicals have the potential to impact biota when dissolved in water and when accumulated in sediment.

The National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration (NOAA) are in the process of developing guidelines for the use of treated wood products in aquatic environments utilized by federal trust fishery resources. NOAA contracted with Stratus Consulting to prepare two technical reports that dealt with treated wood use in aquatic environments. One report focused on the use of creosote treated wood and the other focused on water-soluble preservatives (referred to herein as the "waterborne" report). The reports contain (1) background information on treated wood, (2) data on preservative chemical leaching in aquatic environments, (3) available toxicity information for a variety of biota and different preservative chemicals, (4) existing policies and best management practices for treated wood use in aquatic environments, and (5) recommendations for future projects that might involve the use of treated wood. The purpose of these reports is to assist NMFS and NOAA in future guidance development.

The present document provides a review of the above referenced reports by Timothy Townsend. Dr. Townsend is an associate professor in the Department of Environmental Engineering at the University of Florida in Gainesville, Florida. His area of specialization is solid and hazardous waste management. Much of his research has focused on the leaching of preservative chemicals from treated wood, particularly CCA-treated wood. Some of his research has involved evaluating the toxicity of treated wood leachates use in a variety of aquatic toxicity assays. Under agreement with the University of Florida, Dr. Townsend also provides technical consulting services to a variety of public and private organizations.

2. Review Activities

The following two reports were provided:

- "Treated wood in aquatic environments: Technical review and use recommendations" by Stratus Consulting, Inc., and Paladin Water Quality Consulting

- “Creosote-treated wood in aquatic environments: technical review and use recommendations” by Stratus Consulting, Inc., and Duke University

The reviewer read through each of these documents and prepared a review report based on specific questions that were posed.

3. Summary of Findings

This summary of findings is organized by restating the questions that were asked as part of the review (see original scope of work in Appendix A) followed by a detailed response.

Task Evaluate the synthesis and interpretation of the toxicology information, and state whether or not the conclusions regarding the potential effects to ESA and EFH regulated species and habitats are supported by the scientific evidence.

Toxicity information is provided in Chapter 3 of the waterborne preservatives report and in Chapter 3 of the creosote report. The report authors provide what appears to be a very complete and up-to-date compilation of aquatic toxicity data related to the wood preservative chemicals evaluated.

<u>*Surface water*</u>*: In the creosote report, the final section of the chapter (3.4) summarizes biological effects concentrations for surface water. In the waterborne report, US EPA water quality criteria for the preservative chemicals of interest are first summarized. Then in the detailed text that follows, the authors conclude that in most cases (cautions are noted) the water quality criteria are protective of regulated species.*

<u>*Sediment*</u>*. In the creosote report, the final section of the chapter (3.4) summarizes sediment quality guidelines from several different organizations. In the waterborne report, sediment toxicity thresholds for freshwater sediment were summarized, and it was concluded that these thresholds can serve as meaningful screening tools, but that site specific risk assessment may be needed in some cases.*

The report authors did a good job of synthesizing and interpreting the toxicological data. The conclusions reached on potential effects on target species are supported. Certainly the impact of preservative of chemicals on aquatic organisms is influenced by numerous factors and will be very site specific. It is very likely that in many cases no deleterious effects will be observed. But the existing toxicological data do suggest that in some circumstances, preservative chemicals can result in a negative impact to some species.

Task	Evaluate the synthesis and interpretation of fate and transport information and state whether or not the conclusions regarding potential effects to ESA and EFH regulated species and habitats are supported by the scientific evidence.

Fate and transport information is provided in Chapter 2 of the waterborne preservatives report and in Chapter 2 of the creosote report. Both reports review available data preservative leaching from submerged treated wood and review available models that have been proposed to predict leaching. Both reports also describe several transport models that have been developed to assess the fate of leached chemicals in a water body (water column concentrations and sediment concentrations). Finally each report describes available data that compare model predictions to actual measured data.

The authors conclude that the available models do provide a useful tool for predicting how different conditions and parameters impact preservative concentrations in the sediment and the water column, but that the caution must be used when evaluating the absolute magnitude of the modeled concentrations. Results from field measurements and model predictions were reported in most cases to be different.

The specific conclusions that are reached with regard to various aspects of fate and transport appear to be supported by the available data. More discussion on this question is provided in response to questions below.

Task	If the conclusions are not supported by the available evidence, please provide a detailed explanation and new conclusions.

See above. The conclusions provided by the authors are supported by the data.

Task	Did the review adequately characterize these models by addressing model assumptions, uncertainties, and their applicability to ESA listed salmonids and the habitats of NOAA's Trust Resources? If not, provide explanation(s) and how subsequent conclusions are affected.

The reports did a good job of describing the fate and transport models, but the level of review is not sufficient for someone to then apply the models. The reports were not prepared to the level of a users guide; this is assumed not to have been part of the work scope. Assumptions and uncertainties were adequately characterized. The applicability to ESA listed salmonids and trust resource habitats was adequately characterized in general terms. The reports did not provide sufficient detail and *examples for someone to apply the models.*

This reviewer has in the past tried to use some of the models referenced in the report. It is important to note that the models familiar to the reviewer were not peer reviewed, and often times the documentation was minimal and it was very difficult to understand why certain model steps were undertaken. The models (that the reviewer is familiar with) were not particularly user-friendly.

One recommendation is that additional work needs to be conducted to develop a new model (based on the same methodology already described in the existing models) or to take an existing model, peer review it, and provide better documentation, i.e., create a users guide. The authors of the two reports reviewed here did a good job of summarizing the models that exist, but a detailed critique/examination of the models was not presented (I assume this was outside their work scope).

The above recommendation does not imply that the authors made any false conclusion. The conclusions reached by the authors are appropriate.

Task The review concluded that most of the factors present in the models would lead to an increase in leaching in the field compared to that observed in the laboratory. Is this conclusion supported by the scientific evidence? Please explain in detail why the models do or do not result in an under prediction of leaching.

In my opinion, this conclusion is somewhat overstated. The authors of the waterborne report conclude that in-service conditions are "likely to produce much higher leaching rates" compared to laboratory studies. In response to the question above, this conclusion is not supported by the scientific evidence. But I do not believe that the authors were basing their conclusion on measured data as much as they were on plausible expectations.

If you look at table 2.5, the authors describe many factors that could result in more leaching to occur in the field than predicted in the lab. The primary reason provided is incomplete fixation and excess preservative material. While it is true that incomplete fixation might tend to be less of a problem in the laboratory (because of the controlled nature of the experiments), the authors imply that incomplete fixation is a common occurrence. It is not my understanding that incomplete fixation is that common of an occurrence; it certainly happens, but one could argue the other way. In some cases, wood is not treated to sufficient retention levels, and thus the concentrations in the field might be less than what is observed in controlled laboratory experiments. With regard to post-

treatment cleanup, yes, perhaps excess material might exist in a full-scale situation that might not exist in the lab, but again I am aware that this was a very common occurrence. And in the actual applications, there are also factors that could result in leaching already occurring before these products are installed. For example, after treatment, the wood is stored out doors, it is transported on open truck beds and it may be stored at the construction site. During this time period it might be exposed to rain thus washing off preservatives that would not be washed off in the lab.

So I agree that the factors in table 2.5 do suggest that in some cases the mass of preservative leaching per volume of water it comes in contact with may be greater in the field than predicted in the lab, but this concern seems to be overstated. The authors should provide more documentation that treated wood is not being properly fixed or post-treated if this is truly the case. It seems that the error introduced by this might be less than the error inherent in the other factors of the risk assessment. I do not suggest removing this discussion, but it should be thought through better and referenced, and it may need to be toned down accordingly.

Task Are these models sufficient to predict leaching concentrations for use in ecological risk assessments concerning ESA listed species and their habitat?

I believe the approach behind the models is sound and appropriate. In this respect they are sufficient. However these models are not available in a format that could be used routinely by different parties to conduct site-specific ecological risk assessments. In this respect they are insufficient. The models need to be reviewed for their scientific merit as part of a separate review, a user's guide with detailed explanations of terms and procedures needs to be developed, and detailed examples for different use scenarios need to be published. This type of modeling is something that lends itself well to producing easy-to-use software as well.

Task Are additional precautions required to add a margin of safety to the model predictions? Provide examples?

The steps described above are needed. As part of the review above, there should be a sensitivity analysis of the different parameters. This would enable one to recommend where it is appropriate to assign safety factors.

Task The risk evaluation chapters in both reports conclude with a list of factors to be considered in risk assessments concerning the use of treated wood. Are there any other factors missing from the lists?

The list appears complete. As noted elsewhere in the report, other water quality factors may impact toxicity, e.g., dissolved organic carbon *content. Perhaps these factors should be mentioned in this section as well.*

The variability of the current velocity and direction may also be important. Which velocity do you choose in the model? The average? Again, it would be helpful to see a sensitivity analysis to determine how important these choices are.

Under "size of proposed structure," does this include above water treated wood? If the piles are holding up a walkway, does the preservative leaching from the walkway after a rain and after abrasion matter? It is unclear whether this is included in the "surface area of the exposed wood." So in addition to "size of proposed structured," may also want to add information for "type of structure" and "proposed structure usage."

Task The copper treated wood report contains a chapter concerning alternative materials and includes a brief examination of toxicity considerations regarding these products. Are there any other considerations that are not mentioned in this chapter?

This is good information. It would be helpful to get a better handle of the proposed lifespan of different materials. This clearly has a strong impact on the annualize costs. The only life spans that are used are 15 and 20 years. It has always been my understanding that plastic can last a lot longer than treated wood. The authors should comment on how reliable these numbers are; limitations of the assumptions and the impact the results should be noted. Otherwise some alternative materials may be unduly dismissed from consideration on a project. A recommendation of getting site specific costs for all projects may be warranted.

Task The current regulations and best management practices (BMP) chapter in the copper treated wood report discusses BMPs put forth by the industry as well as several government agencies. Do you feel that the available scientific evidence warrants the use of these BMPs? Do you think that utilization of the BMPs, given consideration of the site specific factors listed at the end of the risk evaluation chapters, will provide protection to individuals of ESA listed species and to the habitat components of EFH?

The available scientific evidence does warrant the use of BMPs. Preservative chemicals do leach and they can be toxic. The data suggest that although the risk to biota should be low in many cases, there may be times when the risk is not acceptable. The use of proper BMPs can provide protection to ESA listed species. As described above, some components of the "tools" to be used as part of the BMPs need to be refined. A big component of the BMPs is conducting a site specific ecological risk assessment for sensitive sites. The guidance for *conducting this risk assessment needs to be strengthened.*

Task Do any of the BMPs or restrictions seem unwarranted or are there additional BMPs or restrictions which should be utilized? Please provide explanations to answers including any site specific factors that should be considered in making decisions regarding the use of treated wood products in aquatic environments.

The recommended BMPs provided in chapter 7 are appropriate. The institution of manufacturing/processing/production BMPs could make a very big difference. The conditions in the screening-level project evaluation review are appropriate and supported by existing information. Additional guidance needs to be provided on how to conduct site-specific ecological risk assessments.

4. Conclusions and Recommendations

The information summarized and presented in the two documents appears to be complete and thorough with respect to the topic of treated wood and its use in aquatic environments. The best management practices recommended are sound and would, if properly used, provide protection of ESA biota. The reports review existing models for determining fate and transport of preservative chemicals from treated wood used in aquatic environments that are conceptually correct and can be used as a tool in an overall risk assessment. Based on the reviewer's understanding of some of these models and the state of their documentation, validation and support, additional work needs to be performed to create a guide that can be used to conduct a site-specific ecological risk assessment of a proposed treated wood project on a potentially sensitive site. This guide should include detailed definitions and derivations of the equations used (with appropriate references), recommended tables for water and sediment toxicity thresholds (these are outlined in the existing report, but they need to be summarized in one spot), a sensitivity analysis, and several examples for different projects (outlined in a step by step fashion). Such a guide could also easily be accompanied by a spreadsheet or simple software package.

Appendix A: Statement of Work

Consulting Agreement Between the University of Miami and Dr. Timothy Townsend

February 20, 2006

Background

The purpose of the technical review documents requiring independent review is to present an analysis of the potential effects and mitigations for the use of treated wood products in aquatic environments. The documents focus on copper treated wood, primarily ammoniacal copper zinc arsenate (ACZA), as this is the most prominent material used on the west coast of the United States and in Alaska, and creosote treated products.

These products are being examined by NOAA's National Marine Fisheries Service (NOAA Fisheries) to determine the risks generated by their usage to the living marine resources which NOAA is responsible for managing, referred to as NOAA's Trust Resources. These include anadromous salmonids managed under the Endangered Species Act (ESA) and Essential Fish Habitat (EFH) as designated by the Magnuson-Stevens Fishery Management and Conservation Act. The use of treated wood in or near aquatic environments commonly requires a permit issued by the U.S. Army Corps of Engineers under section 404 of the Clean Water Act. Under the ESA, federal agencies are to consult with NOAA Fisheries to insure that any action authorized, funded or carried out by the federal agency does not jeopardize the continued existence of any threatened or endangered anadromous salmonids or result in the destruction or adverse modification of designated critical habitat. The issuance of this permit by the U.S. Army Corps of Engineers requires consultation under the ESA to determine whether its approval action would jeopardize Federally-listed species or adversely modify designated critical habitat, and requires an EFH assessment to determine whether its approval action would adversely affect EFH. Since the use of treated wood materials in situations that may expose aquatic ecosystems is widespread along the west coast of the United States and in Alaska, development of these guidelines should help to streamline the review of permitting processes as well as the permitting processes themselves. In some instances, these guidelines may be used to update existing policies regarding treated wood.

The purpose of the ESA is to provide a means whereby the ecosystems upon which endangered and threatened species depend may be conserved, to provide a program for the conservation of threatened and endangered species and to take steps that may be appropriate to achieve this conservation. Conservation is defined in the ESA to mean using, and the use of all methods and procedures necessary to bring any endangered or threatened species to the point at which the protections provided by the ESA are no longer necessary. It is the policy of Congress, as declared in the ESA, that all Federal departments and agencies shall seek to conserve endangered and threatened species and shall utilize their authorities in furtherance of the purposes of the ESA. ESA regulates an activity with an eye toward its impact to as little as a single listed individual. These guidelines are meant to clarify the extent to which these authorities need to be applied for the use of treated wood.

The Magnuson-Stevens Fishery Conservation and Management Act established procedures designed to identify, conserve, and enhance EFH for those species regulated under a Federal fisheries management plan. EFH regulates an activity with an eye toward its impact on habitat characteristics. EFH is defined as those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity. Waters include aquatic areas and their associated physical, chemical, and biological properties that are used by fish and may include aquatic areas historically used by fish where appropriate; substrate includes sediment, hard bottom, structures underlying the waters, and associated biological communities; necessary means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and "spawning, breeding, feeding, or growth to maturity" covers a species' full life cycle. Essential Fish Habitat for salmonids includes their saltwater and fresh water ranges.

Effects of treated wood that need to be examined under the ESA and EFH regulations include direct, indirect, and cumulative effects. An example of direct effects includes the acute and sublethal impacts of copper and polycyclic aromatic hydrocarbons to salmonids and EFH regulated species. An example of an indirect effect includes the adverse impacts to the prey base upon which ESA listed and EFH regulated species depend. An example of a cumulative effect includes the impacts of multiple structures and contaminants in an area with or without additional loading from urban sources, historic mining, smelters, ships' hulls or any other source. The synthesis of these effects to habitat and to individuals, coupled with local environmental conditions and specific species of concern, defines the risk of a project proposing the use of treated wood.

The objective of the technical review and use recommendations development was to establish a solid scientific basis from which guidance development and implementation could proceed, particularly concerning potential direct and indirect effects.

Objectives of the CIE Review

The information presented for review has been developed by a consulting firm under contract to NOAA Fisheries. The use of an independent firm was determined to be the best way to initiate and complete a thorough review of the best available science concerning effects of treated wood, effects of the most likely contaminants coming from treated wood, and policies and guidelines already developed and in use throughout the United States, Canada and/or other jurisdictions involving the use of treated wood products. A brief review of the economic aspects of treated wood and its leading competitors as well as engineering aspects of all these materials was also commissioned as part of the process.

The review panelist is required to review the following reports (*Treated Wood in Aquatic Environments: Technical Review and Use Recommendations* and *Creosote – Treated Wood in Aquatic Environments: Technical Review and Use Recommendations*), in particular, the aquatic toxicology, the fate and transport aspects of the suite of contaminants that may result from its use, and the modeling that is used in conducting risk assessments concerning treated wood. These sections make up the bulk of the submitted documents and have been an area of considerable debate for many years.

Specific terms of reference for the review include:

- Evaluate the synthesis and interpretation of the toxicology information, and state whether or not the conclusions regarding the potential effects to ESA and EFH regulated species and habitats are supported by the scientific evidence.
- Evaluate the synthesis and interpretation of fate and transport information and state whether or not the conclusions regarding potential effects to ESA and EFH regulated species and habitats are supported by the scientific evidence.
- If the conclusions are not supported by the available evidence, please provide a detailed explanation and new conclusions.
- Evaluate the review of the leaching and environmental concentration models presented in both of the reports.
  - A) Did the review adequately characterize these models by addressing model assumptions, uncertainties, and their applicability to ESA listed salmonids and the habitats of NOAA's Trust Resources? If not, provide explanation(s) and how subsequent conclusions are affected.
  - B) The review concluded that most of the factors present in the models would lead to an increase in leaching in the field compared to that observed in the laboratory. Is this conclusion supported by the scientific evidence? Please explain in detail why the models do or do not result in an under prediction of leaching.
  - C) Are these models sufficient to predict leaching concentrations for use in ecological risk assessments concerning ESA listed species and their habitat?
  - D) Are additional precautions required to add a margin of safety to the model predictions? Provide examples?
- The risk evaluation chapters in both reports conclude with a list of factors to be considered in risk assessments concerning the use of treated wood. Are there any other factors missing from the lists?
- The copper treated wood report contains a chapter concerning alternative materials and includes a brief examination of toxicity considerations regarding these products. Are there any other considerations that are not mentioned in this chapter?
- The current regulations and best management practices (BMP) chapter in the copper treated wood report discusses BMPs put forth by the industry as well as several government agencies. Do you feel that the available scientific evidence warrants the use of these BMPs? Do you think that utilization of the BMPs, given consideration of the site specific factors listed at the end of the

risk evaluation chapters, will provide protection to individuals of ESA listed species and to the habitat components of EFH?

- Do any of the BMPs or restrictions seem unwarranted or are there additional BMPs or restrictions which should be utilized? Please provide explanations to answers including any site specific factors that should be considered in making decisions regarding the use of treated wood products in aquatic environments.

Specific Activities and Responsibilities

The review panelist's duties shall occupy a maximum of 5 workdays (i.e., a few days for document review and a few days to prepare a Review Report). The review panelist will review the treated wood technical review and use recommendations documents and develop a review report in the context of responsiveness to the terms of reference. See Annex 1 for further details on report contents.

No later than March 13, 2006, the review panelist shall submit the Review Report to the CIE for review[1]. The CIE reports shall be addressed to "University of Miami Independent System for Peer Review," and sent to Dr. David Die, via e-mail to ddie@rsmas.miami.edu and to Mr. Manoj Shivlani via e-mail to mshivlani@rsmas.miami.edu.

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[1] All reports will undergo an internal CIE review before they are considered final.

ANNEX 1: Contents of Panelist Report

1. The report shall be prefaced with an executive summary of findings and/or recommendations.

2. The main body of the report shall consist of a background, description of review activities, summary of findings, conclusions/recommendations, and references.

3. The report shall also include as separate appendices the bibliography of all materials provided and any papers cited in the Panelist's Report, along with a copy of the statement of work.

Appendix B: Background material

Stratus Consulting, 2005. Treated Wood in Aquatic Environments: Technical Review and Use Recommendations. 160 pp.

Stratus Consulting, 2005. Creosote-treated Wood in Aquatic Environments: Technical Review and Use Recommendations. 104 pp.

Volume II
Section II
Stratus Creosote Report and Comments

8. Peer Review comments by Jason M. Weeks of Cefas

Reviewers Report on;
Treated Wood in Aquatic Environments: Technical Review and Use Recommendations
&
Creosote-Treated Wood in Aquatic Environments: Technical Review and Use Recommendations

By

Jason M Weeks
(Appointed by CIE)

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Contents of the Report

Objectives of the CIE Review

This review considers the information presented by a consulting firm working under contract to NOAA Fisheries. The consultants report was intended to be a complete and thorough review of the best available science concerning effects of treated wood in aquatic environments, providing both a technical review and use recommendations for wood treated with products other than creosote (see second review). The key focus of this work is to assess the likelihood of negative effects of the most likely contaminants coming from such treated wood on protected habitats and species. The documents focus on copper treated wood, primarily ammoniacal copper zinc arsenate (ACZA), as this is the most prominent material used on the west coast of the United States and in Alaska.

These products are being examined by NOAA's National Marine Fisheries Service (NOAA Fisheries) to determine the risks generated by their usage to the living marine resources, which NOAA is responsible for managing, referred to as NOAA's Trust Resources. These include anadromous salmonids managed under the Endangered Species Act (ESA) and Essential Fish Habitat (EFH) as designated by the Magnuson-Stevens Fishery Management and Conservation Act. The use of treated wood in or near aquatic environments commonly requires a permit issued by the U.S. Army Corps of Engineers under section 404 of the Clean Water Act. Under the ESA, federal agencies are to consult with NOAA Fisheries to ensure that any action authorized, funded or carried out by the federal agency does not jeopardize the continued existence of any threatened or endangered anadromous salmonids or result in the destruction or adverse modification of designated critical habitat.

This review also considers the information presented by a consulting firm working under contract to NOAA Fisheries. The consultants report was intended to be a complete and thorough review of the best available science concerning effects of creosote treated wood and the effects of the most likely contaminants coming from such treated wood.

Executive Summary

This document comprises a critical review of the reports "Treated Wood in Aquatic Environments: Technical Review and Use Recommendations" and "Creosote-Treated Wood in Aquatic environments: Technical Review and Use Recommendations". It reports on key areas addressed by the Terms of Reference and attempts to provide a holistic overview of the value of the report in terms of meeting its intentions. Several areas are highlighted where the reviewer believes the report fails to provide adequate guidance or make clear its judgements. The reviewer believes there are changes to the reporting style that would accelerate learning by the reader and provide greater assistance in providing use recommendations.

Key Recommendations

The following key recommendations are made; other suggestions are presented in the full text below.

- The structure of the report requires modification to include additional sections and commentaries on a series of issues not currently addressed by the consultants report.

- More recommendations are required, and key statements addressing the issues should be given, i.e. much evidence is presented, but few firm conclusions are extracted and made.

- The modelling sections do not fully highlight their associated uncertainty – the message requires more purpose in its reporting; what are the key recommendations from this report and where is the evidence for these decisions?

- The risk assessment section is weak and requires context and specific recommendations to be given.

- The report suffers from inadequate linking to the final protection goal, i.e. the species and habitats of concern.

- It further suffers from excluding international literature which could often strengthen ones point of view. Although the brief was clearly to use local examples for direct relevance much of the background information could be provided from other sources. This is also highlighted by the lack of consideration of global issues pertaining by way of example, say CCA and how policy makers are dealing with similar issues.

Creosote

- The structure of the report requires modification to include additional sections and commentaries on a series of issues not currently addressed by the consultants report.

- More recommendations are required and statements addressing the issues should be given, i.e. much evidence is presented but no firm conclusions are extracted and made

- The modelling sections are consistently ambivalent – the message is confused and requires more purpose in its reporting, what are the key recommendations from this report and where is the evidence for these decisions?

- ❖ The risk assessment section is weak and requires context and specific recommendations to be given.

- ❖ The report suffers from inadequate linking to the final protection goal, i.e. the species and habitats of concern

- ❖ It further suffers from excluding international literature which could often strengthen ones point of view. Although the brief was clearly to use local examples for direct relevance much of the background information could be provided from other sources.

Introduction

Wood preservation products based on a mixture of copper sulphate, sodium dichromate and arsenic pentoxide have been used for decades for the industrial pre-treatment of timber using pressure impregnation. The chemicals bind with constituents in the wood and are essentially ‘fixed’ to the wood in a form that is resistant to leaching out by water. The treated timber is used in areas where long term protection is needed and this resistance to leaching is particularly important in e.g. telegraph poles, motorway fencing and timber in cooling towers. Some treated timber is used in outdoor playground equipment.

It is well established that both inorganic arsenic compounds (such as arsenic pentoxide) and sodium dichromate can produce serious adverse health effects, in particular cancer, and both are regarded as human carcinogens. The concerns with arsenic specifically relate to skin and lung cancer, and in the case of dichromate, lung cancer when exposure is via inhalation.

There is no doubt that the components of CCA are hazardous. They are only used at industrial sites under strictly controlled conditions. The treatment process is in enclosed systems and any exposure to operators is minimal.

With regard to the treated wood, again normal handling and use does not result in any significant exposure because of the fixation of the compounds in a form which does not result in any exposure to the compounds of concern.

However, the application of such timbers in situations such as marine pilings may give rise to concern. This report undertaken by the consultants sets out to address this issue and report a series of recommendations and best use practise.

The objective of the technical review and use recommendations development was to establish a solid scientific basis from which guidance development and implementation could proceed, particularly concerning potential direct and indirect effects of treated timbers.

Creosote is a wood preservative used for commercial purposes only; it has no registered residential uses. Creosote is obtained from high temperature distillation of coal tar (itself a mixture of hundreds of organic substances), and over 100 components in creosote have been identified. It is used as a fungicide, insecticide, miticide, and sporicide to protect wood and is applied by pressure methods to wood products, primarily utility poles and railroad ties. The US EPA is currently reassessing creosote as part of its ongoing re-registration program for older pesticides. Federal law directs EPA to periodically re-evaluate older pesticides to ensure that they continue to meet current safety standards. Due to the smell (diesel-like) and feel (often sticky) creosote-treated timber is not generally used for residential or contact uses, but because of creosote's efficacy in protecting wood, creosote-treated timber is used in industrial applications in Australia and North America.

Creosote as a ``heavy duty wood preservative,'' was first registered in the United States in 1948 as a coal tar creosote active ingredient. Presently, 16 products are registered for use as industrial wood preservatives for above and below ground wood protection treatments, as well as treating wood in marine environments. Creosote wood preservatives are used primarily in the pressure treatment of railroad ties/crossties (about 70% of all creosote use) and utility poles/cross-arms (about 15-20% of all creosote use). Assorted creosote-treated lumber products (e.g., timbers, poles, posts and ground-line support structures) account for the remaining uses of this wood preservative in the US. The consultants report addressed the use of such creosote treated wood in aquatic environments through a report detailing technical and use recommendations.

Structure of the Report

The report provided for review follows a logical framework and is similar in structure to the report on Creosote Treated Wood in Aquatic Environments: Technical Review and Use Recommendations.

The report is based on a series of naturally linked chapters, with Chapter 1 providing a general introduction to the issue and a background to the types of wood treatment. Chapter 2 moves immediately to an examination of metal leaching potential from treated wood and the potential for environmental exposure, and is based around a series of 5 subsections examining metal leaching rates; Models of leaching rates; application of laboratory derived leaching results to field conditions, field trials; and attempts at Predicting Environmental Concentrations (PEC) of metals from leaching models. This is followed by a series of conclusions. Chapter 3 goes on to look at the toxicity of wood treatment chemicals to aquatic organisms and consists of 3 subsections: 1) examining water column exposure, 2) looking at sediment concentrations, and 3) dietary exposure. Chapter 4 undertakes a risk evaluation containing three subsections: 1) looking at predictive risk assessments, 2) laboratory and field studies, and 3) factors to be considered in aquatic risk assessments. Chapter 5, with 5 subsections examines the use of alternative materials or treatments to that of using wood and covers in section 1) material types; 2) toxicity considerations; 3) economic considerations of these alternatives and 4) a summary of costs for alternative piling treatments with section 5) presenting annualized costs for a hypothetical fender piling project. Chapter 6 examines in 4 sections current regulations and Best Management Practices (BMP) and looks at 1) the production and treatment of treated wood, 2) construction specifications, 3) when to use treated wood and 4) a set of conclusions of their use. Chapter 7 provides a section covering general conclusions and recommendations, followed by a set of references and appendices detailing information referred to in the preceding chapters.

Generic Comments on the overall report

The report is fairly well written and follows a useful framework. However, I would like to see the following additions;

1) An executive summary

2) A bulleted list of recommendations

3) Greater numeration of sections for ease of reference

4) A critical re-evaluation and set of conclusion(s) at the end of each section/ chapter or statement clearly identifiable from the remainder of the report and showing how chapter 7 was complied from such recommendations within the report – better road mapping

5) It would be useful to have a chapter providing an overview of the current legislative status of treated wood in an international context (see section below on other comments), comparing policy and guidance from e.g. US EPA with other sources such as Canada and Europe. This could be included possibly as part of chapter 6.

6) A summary at the end of each chapter addressing the key aspects.

7) A section detailing site specific risk assessment and the processes involved would be useful

Overall the report is written in a style that does not reflect the degree of uncertainty or evidence base for which some of the primary assertions are made. Greater relevance must be paid to the protection endpoints.

Chapter 1

Sets the objectives of the report and defines its protection goal as working towards setting recommendations that are protective of the habitats and species outlined in the section above. The report authors then go on to describe the different types of wood treatment.

Chapter 2

This section looks at models of leaching rates from metals. These models are largely empirical and based on the results of laboratory studies. The models reviewed demonstrate a high degree of variance suggesting that the models are inadequate for dealing with natural systems. The Brooks (2005) model, however, appears to provide fairly robust short-term predictions, but is unable to address chronic leaching which may be underestimated by as much as twice. This section leads on to more obvious statements and conclusions regarding the ability of models to predict environmental metal concentrations from leaching (2.4.3). The underlying assertion is that the available models are inadequate in predicting actual field metal concentrations because of the highly complex nature of individual site scenarios (this message is not as clear for the creosote report where the data and models are equally deficient). I concur with the authors. A list of conclusions is presented on page 2-27 and I would agree with each. I would further add that the prediction of a chemical in the environment is a measure of its potential to cause harm, but not necessarily one that says harm will occur. The uptake of metals is via metal-ion interactions and the result of available metal species in the aqueous and other phases. The underlying uptake of heavy metals is not considered in this report.

Chapter 3

This section deals with the toxicity of wood treatment chemicals to aquatic organisms through different exposure routes: Water, sediment, food and the implication of both direct and indirect toxicity. The section is fairly detailed using the consultants brief to pre-select examples only relevant for the US situation. However, what is missing from this entire chapter is a series of highlights, summaries recommendations and bullet points underlying the key interpretations of the data presented. Much more could be made of this section.

Chapter 4

This chapter addresses the risk(s) from metal impregnated timbers posed to the sensitive habitats and species required to be protected as described above. My comments on this chapter are repeated later for the creosote report. I regard this chapter to be the weakest of all within the review and to my mind (and I am a practicing risk assessor) does not address a formulative approach to risk assessment. The risk assessment process is not described; the chapter represents a series of case studies and scenarios with no clear outputs. The factors to be considered (section 4.3) are important but reflective issues to be considered during a risk assessment rather than dictating or driving the process itself – if you like - these factors all represent degrees of uncertainty that would be required to be addressed during a risk assessment process, and where it is not possible to do so they weigh heavily in the process as uncertainties. This section does not address a risk assessment methodology or process. Moreover the authors do not address the requirements to be protective of the species or habitats of concern; e.g. salmonids and their habitats. The list of factors to be considered in the Aquatic risk assessment (RA) is useful but not unexpected given the foregoing. I would like to see greater perception and understanding of the risk assessment process and the utility of site specific risk assessment prior to the use of metal treated timber products in each case – a clear requirement not addressed.

Chapter 5

This section considers alternative material in place of treated timbers. The comments below are repeated in my review of the creosote report also. Overall the report fails to consider alternative or more novel methods in place of treated timbers for the protection of the marine environment, including the use of naturally durable woods (e.g. those with high silica content species such as *Dalium*, *Parinari*, etc.) or wood species with natural resistance attributed to natural plant exudates e.g. *Euclyptus marginata*. Other considerations might be the use of other chemical preservation techniques: protection using physical barriers, e.g. plastic sheathing, plastic coatings for example, pile guard etc., fish oils or creosote floating collars etc. The use of dual treatments of creosote plus CCA/ACA is not mentioned. Novel treatments using the incorporation of other organic pesticides (fungicides, mollusicide and insecticides) are not covered and perhaps such warrant a brief mention as an alternative approach.

Chapter 6

This section looks at the different legislative and other guidance documents in existence for the protection of the environment from treated timbers during both the prior consideration of their use in different applications, through to guidance on construction techniques etc. Again, these BMPs and legislative guidance do not necessarily link to the described risk assessment process, a clearly designed tiered hierarchical risk assessment framework would be able to adopt or interchange relevant legislation and guidance for a given situation with a degree of confidence. Currently it is difficult to find a roadmap through this chapter with an underlying certainty of adopting the correct procedure. It is useful to note that the European Commission has prepared a draft proposal (Directive (76/769/EEC) to prohibit the use of copper chrome arsenic (CCA) as a wood preservative. This proposal is based on a potential risk to children's health from wood treated with preservatives containing CCA in playground equipment and risks to human health from the use of treated wood. The risks related to domestic household burning of CCA treated wood will also be addressed. The Commission's scientific committee (CSTEE) also reached a number of conclusions, in particular that the substance is both genotoxic and a well-known carcinogen, and that it may be appropriate to assume that no safe level exists. Based on this advice, the European Commission brought forward proposals to restrict the marketing and use of CCA.

It is this type of context that is missing from the current report, i.e. what is happening elsewhere and advances in other regions.

Chapter 7

I actually quite like this section and I concur with the statements, recommendations and conclusions drawn. One has to ask, however, where the authors were able to draw these conclusions from given the lack of summary evidence in the preceding chapters. If these conclusions are an accumulation of suggestions, recommendation and observations collated from the bulk of the document, then it is not transparent how or necessarily why several of these conclusions were reached. Again, a call for better road mapping through the document is made.

Other general comments

GLOBAL TRENDS IN THE WOOD PRESERVATION INDUSTRY

The following global trends in the Wood Preservation Industry have been identified which may have an impact upon the consultants report.

<u>The CCA issue</u>

CCA preservatives will not be used for treating timber destined for residential (domestic and contact) uses in the US and Canada after December 2003, and in the EU after June 2004. In addition to domestic uses, CCA preservatives will also not be used for timber destined for marine and most agricultural uses in the EU after June 2004. The Wood Preservation Industry estimates that the reduction in CCA applications may reduce the volume of CCA-treated timber produced in the US by about 80%, meaning that 52% of all treated timber will be treated with a different preservative. Due to the varying concentrations of preservatives in working solutions, the impact on the total volume of high risk chemicals being used (identified in the US as CCA, pentachlorophenol and creosote) may only be reduced by about 5%.

This trend away from CCA-treated timber has been driven by four factors.

1. The most recently completed risk assessment of arsenic, carried out by the Commission of the European Communities CSTEE (Scientific Committee for Toxicity, Ecotoxicity and the Environment) concluded that it is appropriate to consider that no threshold exists for the carcinogenic effect of arsenic. The US EPA and the Canadian Pest Management Regulatory Authority (PMRA) have not assessed that CCA-treated wood poses unreasonable risks to the public or the environment when used in accordance with normal handling procedures. The US EPA and the US Consumer Products Safety Commission are currently conducting a probabilistic assessment of potential cancer risks to children from exposure to CCA in residential settings.

2. Following from the CSTEE's risk assessment, the CSTEE concluded that it would be appropriate to apply the precautionary principle, and move to reduce the production of CCA-treated timber.

3. The US wood preservation industry perceived a consumer demand shift away from CCA-treated timber, driven by increased public awareness of arsenic risks, and media coverage of recent studies into the risk of preservatives leaching from treated timber playground equipment.

4. Viable alternative preservatives are now available on the market to replace CCA, and maintain the same level of hazard protection for the timber product. Alternatively treated timber costs between 8–15% more than CCA-treated timber, but this premium is expected to be diluted through economies of scale once production expands to fill the current CCA market.

INTERNATIONAL REGULATORY STATUS OF PRODUCTS CONTAINING CCA

There has been a significant level of action taken internationally in relation to the continued availability and use of CCA timber treatment products.

US Environmental Protection Agency (US EPA)

On 12 February 2002, US EPA announced a voluntary decision by industry to move away from timber treatments containing arsenic by December 31 2003, in favour of new alternatives. This transition affects virtually all residential uses of wood treated with CCA, including wood used in play-structures, decks, picnic tables, landscaping timbers, residential fencing, patios and walkways/boardwalks. US EPA will not allow CCA products to be used to treat wood intended for any of these residential uses from 1 January 2004.

The US EPA has not concluded that there is unreasonable risk to the public from these products, but is of the view that any reduction in exposure to arsenic is desirable. This action comes ahead of the US EPA completing its regulatory and scientific assessment of CCA.

United States Consumer Products Safety Commission (CPSC)

More recently (February 2003), a report by the United States CPSC raised further concerns about the potential health risks associated with CCA-treated timber in playgrounds.

PMRA Canada

Canadian regulatory authorities are working in collaboration with the US EPA to effect similar actions in Canada.

Commission of the European Communities

A risk assessment conducted by the EC Scientific Committee on Toxicity, Ecotoxicity and the Environment (CSTEE) noted that the main risks associated with CCA were those to human health from the disposal of timber treated with CCA and in particular risks to children's health from the use of CCA–treated timber in playground equipment. The CSTEE raised further concerns regarding the potential for children to be exposed to CCA through ingestion and/or inhalation of sand particles in playground equipment. They concluded that arsenic is both carcinogenic and genotoxic. The CSTEE also identified a risk to the aquatic environment in certain marine waters.

Structure of the report (Creosote)

The report provided for review follows a logical framework and is similar in structure to the previous report on Treated Wood in Aquatic Environments: Technical Review and Use Recommendations.

The report follows a general introduction, addressing the nature and use of creosotes their composition and current regulations, policies and Best Management Practises (BMPs). Chapter 2 moves to looking at the available models of PAH leaching from treated wood and consequences for environmental exposure. This chapter is broken into 4 sections examining: 1) Factors affecting PAH leaching from treated wood, 2) Models of PAH leaching, 3) Predicted environmental concentrations (PECs) of PAH resulting from treated wood, and 4) conclusions section. Chapter 3 goes on to examine the toxicity of creosote to estuarine organisms, and again is split into four sections, examining: 1) the toxic components of creosote, 2) routes of exposure, 3) toxicities, and 4) conclusions, including a discussion on biological effects. Chapter 4 provides a framework for a risk evaluation and again four sections describe: 1) previous risk assessments, 2) risk assessments based on PAH leaching models, 3) laboratory and field studies, and 4) factors to be considered in a risk assessment. There is then a section containing references.

In terms of overall layout, structure and readability, I feel the report could focus the reader by providing;

1) An executive summary

2) A list of recommendations

3) Greater numeration of sections for ease of reference

4) A critical re-evaluation and set of conclusion(s) at the end of each section/ chapter or statement clearly identifiable from the remainder of the report

5) It would be useful to have a chapter providing an overview of the current legislative status of creosote treated wood, comparing policy and guidance from e.g. US EPA with other sources such as Canada and Europe

6) A summary at the end of each chapter addressing the key aspects.

7) A "Recommended Use" section appears to be missing despite being part of the report title

8) A section detailing site specific risk assessment and the processes involved

9) A final conclusion, ways forward, recommendations section (as a separate Chapter 5)

Overall the report is written in a style that does not reflect the complexity of the subject matter nor the degree of uncertainty or evidence base for which some of the primary assertions are made. The focus is almost entirely on PAHs and not on creosote. There is also limited consideration of the endpoints dictated by the study objectives; i.e.

"The purpose of the ESA is to provide a means whereby the ecosystems upon which endangered and threatened species depend may be conserved, to provide a program for the conservation of threatened and endangered species and to take steps that may be appropriate to achieve this conservation. Conservation is defined in the ESA to mean using, and the use of all methods and procedures necessary to bring any endangered or threatened species to the point at which the protections provided by the ESA are no longer necessary."

Furthermore, … "The Magnuson-Stevens Fishery Conservation and Management Act established procedures designed to identify, conserve, and enhance EFH for those species regulated under a Federal fisheries management plan. EFH regulates an activity with an eye toward its impact on habitat characteristics. EFH is defined as those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity. Waters include aquatic areas and their associated physical, chemical, and biological properties that are used by fish and may include aquatic areas historically used by fish where appropriate; substrate includes sediment, hard bottom, structures underlying the waters, and associated biological communities; necessary means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and "spawning, breeding, feeding, or growth to maturity" covers a species' full life cycle. Essential Fish Habitat for Salmonids includes their saltwater and fresh water ranges".

The report suffers from the brief to use only literature examples from the US, there are many instances where work has been described elsewhere that could certainly fit the brief given. To this end may I suggest that the book by Peter Douben (Douben, 2003) be consulted? Furthermore, there is a complete lack of linkage of the chapter tasks to the need to link to the protection of particular species or habitats types (as detailed above).

Generic comments on the overall report

Chapter 2

Based on the overall simplicity and generic assumptions made in the development and application of models to predict leaching rates, the conclusions derived by the reviewers are relevant. However, the models presented are limited in the quality of their predicted outputs and thus appear at best to be poor substitutes for real data collected from water or sediments, or through the use of SPMEs. In my opinion, the utility of the models is over played by the paucity of the data presented. They appear to either grossly under/ or over estimate water and sediment PAH concentrations as a consequence of variable leaching rates. Mostly this is a consequence of the highly variable (noisy) environments that the applications are attempting to model. More effort invested in defining better model parameters would be time usefully spent. Again the focus of all the models is on predicting the fate and behaviour of only the PAH fraction of creosotes, as we recall creosote is a chemical mixture of up to 300 different compounds, including polycyclic aromatic hydrocarbons (PAHs) some of which are known carcinogens.

Chapter 3

Begins to examine the toxicity of creosote to estuarine organisms and again focuses largely on the impact of PAHs on biota. The chapter is largely effects based, rather than estimating the significance of any measured effects in terms of consequences for ecosystem harm. The chapter covers in fair depth a series of experimental studies in both lab and field and collates evidence form these. This evidence is not necessarily interrogated or criticised, for example, links between measured biomarkers and health of animal populations are not made – partly, I would imagine, because the evidence is absent. I wonder how the conclusion drawn on page 3-14 "…the response measures described in the preceding sections of this chapter appear to be appropriate and <u>reasonably</u> protective of aquatic receptors in evaluating wood-treating <u>projects</u>"(?), I presume that products should be substituted for projects. I see little evidence to justify this statement. Indeed there is not a chapter summary, detailed conclusion, or firm set of recommendations forthcoming from the literature review of this section.

Chapter 4

This chapter addresses the risk posed to the sensitive habitats and species required to be protected as described above. This chapter is the weakest of all within the review and to my mind (and I am a practicing risk assessor) does not address a formulative approach to risk assessment in any form. The risk assessment process is not described; the chapter represents a series of case studies and scenarios. The conclusions drawn (section 4.3.5) do not address a risk assessment methodology or process. Moreover they do not address the requirements to be protective of the species or habitats of concern; e.g. salmonids and their habitats. The list of factors to be considered in ARA is useful but not novel. I would like to see greater perception and understanding of the risk assessment process and the utility of site specific risk assessment prior to the use of creosote treated timber products in each case – a clear requirement is not addressed.

Other general comments

Overall the report fails to consider alternative or more novel methods for the protection of the marine environment including the use of naturally durable woods (e.g. high silica content species such as *Dalium, Parinari*, etc.) or wood species with natural resistance attributed to natural plant exudates, e.g. *Euclyptus marginata*. Other considerations might be the use of other chemical preservation techniques; protection using physical barriers, e.g. plastic sheathing, plastic coatings for example, pile guard etc., fish oils or creosote floating collars etc. The use of dual treatments of creosote plus CCA/ACA is not mentioned. Novel treatments using the incorporation of other organic pesticides (fungicides, mollusicide and insecticides) are not covered and perhaps such warrant a brief mention as an alternative approach. It is worthy of note that in December 2002, the largest creosote producer in the US, Kerr-McGee LLP, announced that it was leaving the forest products industry following several law suits involving harm caused by wood preservation plants using creosote. A factor in this trend is the availability of viable alternative materials, such as steel, composites and concrete, for the applications of creosote-treated timber. This was not considered in the consultants report.

Specific Comments addressing the points highlighted by the specific terms of reference (ToR)

Evaluate the synthesis and interpretation of the toxicology information, and state whether or not the conclusions regarding the potential effects to ESA and EFH regulated species and habitats are supported by the scientific evidence.

What is missing from this entire section is a series of highlights, summaries recommendations and bullet points underlying the key interpretations of the data presented. Much more could be made of this section. The issue of CCA is not explicit, many countries including the US are working towards banning such a timber treatment for marine and other applications.

Creosote

Serious ecological damage from PAHs has been recorded locally as a consequence of severe oil spills. Less dramatically leakages from offshore oil operations have also caused local pollution issues. Most reported harmful effects are from the physical action of the oil rather than the toxicity of PAHs. So although it has been relatively easy to demonstrate local short term effects of "oil" pollution establishing longer term effects on marine organisms or ecosystems has proved more difficult to demonstrate for PAHs, notwithstanding the persistence of PAH residues in sediments. In various studies outside of those cited (i.e. non-US situation), indicator organisms have been shown to demonstrate negative effects along a pollution gradient in the neighbourhood of an oil terminal. The impacts of PAHs were assessed using a suite of biomarkers. The study by Moore et al. (1987) and Livingstone et al. (1988) showed a strong correlation between tissue concentrations of 2 and 3 ring PAHs and health of marine mussels. Although this work may be criticised on the grounds that other contaminants could have followed the same pollution gradient, there was some supporting evidence from a controlled mesocosms study which showed a similar dose/response relationship. Thus strong evidence exists that harmful effects are possible in individuals, but what is not clear is whether these affects can lead to population declines. The authors of the report also link the presence of high PAH levels in the marine environment with a high incidence of tumours in fish. Again these may not be linked to population declines but certainly influence the value of fish as a consumer commodity, and may be symptomatic of a cascade of health implications. The ecological implication of much of the evidence presented by the authors, however, is not known.

In the marine environment, there can be significant levels of PAH locally as a result of many sources, including creosote treated pilings. PAHs can be biomagnified by some aquatic invertebrates, but not in organisms higher in the food chain that undergo rapid metabolism. To fish, however, they can show considerable toxicity in the presence of UV light as a consequence of their photooxidation. In humans, the main concern of PAHs has been about their mutagenic and carcinogenic properties. However, the ecological concerns of PAHs remain uncertain.

It is an extremely low level of PAH that is required to produce a behavioural effect in aquatic organisms. Considering the contamination of water or sediments, contamination of sediments with relatively high levels of PAHs is probably of most importance with respect to any potential effects on fish behaviour. It is not known whether the large quantities of PAHs in water after immersion of pilings might affect important behavioural responses in fish, such as alteration of homing behaviour to natural rivers by salmon, but compounds with greater solubility and aromaticity possibly within the complex creosote mixture are also likely to be of great importance.

Therefore although PAHs are ubiquitous in the environment, demonstrating a causative linkage between their occurrence and ecosystem harm is very difficult.

Evaluate the synthesis and interpretation of fate and transport information and state whether or not the conclusions regarding potential effects to ESA and EFH regulated species and habitats are supported by the scientific evidence

Generally, the information is insufficiently presented to be able to demonstrate linkages to the protected species or habitats – partly because such linkages would be hard to demonstrate for any toxin and partly because of the limited use of international examples.

Creosote
Given my comments above on the inadequate nature of the modelling and the interpretation of the data, in particular the focus on PAHs alone, I doubt that the approach or the conclusions reached are sufficient to guarantee the protection from potential from deleterious effects to the ESA and EFH regulated species and habitats; given the high degree of uncertainty surrounding the model data. There is uncertainty of predicted sediment concentrations and the unknown implication of exposure to acute low concentrations of PAHs and the other compound used in creosote on natural populations. It is unlikely that the conclusions and recommendations from the report (where made) would safeguard the species of concern in every situation.

If the conclusions are not supported by the available evidence, please provide a detailed explanation and new conclusions.

The conclusions presented reflect the evidence provided.

The models as described (some incompletely) reflect a high degree of variability and uncertainty. I do not believe that as described the evidence is sufficiently compelling to warrant their use in ERA, and although the authors of the report hint at this in their section 2 conclusions it is not sufficiently explicit to the reader. I would rather use empirical measurements or real data collected from a site.

Creosote
If one summarizes the data and information available for the past 15 years concerning the impacts of PAHs, and complex mixtures containing PAHs then a consensus can be built using a weight of evidence approach that may be used for assessing the ecotoxicological potential of PAHs for fish. This approach is useful because of the improbability of establishing either a strict scientific or legal standard of causal evidence for regulatory bodies to use in assessing environmental effects associated with mixed contamination.

Combining field and laboratory data and using a weight of evidence approach, it is suggested that levels of PAHs commonly found near pilings in many marine and freshwater environments are causing or contributing to health effects in fish. Effects have recently been reported (See comprehensive overview in Douben (2003)) with very low concentrations of PAHs in water. This points to a potential for effects on fish and especially larvae.

Evaluate the review of the leaching and environmental concentration models presented in the report.

Creosote

Furthermore, the complex and jointly ubiquitous nature of PAHs, halogenated hydrocarbons and metal contaminants often found in creosote or creosote combinations or creosote versus other marine contaminants makes it difficult to identify biological responses caused by PAHs. Separation of PAH effects from the effects of whole creosote is also difficult. The PAN Pesticides database (www.pesticideinfo.org) has very little information actually listed for creosote including a complete absence of acute toxicity test data. I am concerned that the focus of the review was almost entirely devoted to demonstrating the effects of PAHs in isolation of the parent complex mixture that is creosote.

Did the review adequately characterize these models by addressing model assumptions, uncertainties, and their applicability to ESA listed salmonids and the habitats of NOAA's Trust Resources? If not, provide explanation(s) and how subsequent conclusions are affected.

Creosote

The conclusion derived at by the reviewers should be more pointed and clearly highlight the uncertainties associated with using the models presented. I do not believe they are appropriate to be used to protect Salmonids or their habitats.

The review concluded that most of the factors present in the models would lead to an increase in leaching in the field compared to that observed in the laboratory. Is this conclusion supported by the scientific evidence? Please explain in detail why the models do or do not result in an under prediction of leaching.

Creosote

The justification presented in the text is sufficiently robust to indicate the degree of variability associated with the extrapolation of laboratory based measurements used to calibrate the models with real field data where variability is greater and control lost. The models are insufficiently robust to be able to accurately reflect what is happening to the 300 or so compounds contained in creosote, not least the inadequacies associated with simply predicating PAH concentrations.

Are additional precautions required to add a margin of safety to the model predictions? Provide examples?

The current models are insufficiently robust to be used as anything other than a qualitative estimate.

All these points are covered in detail above – the models are demonstrated by the authors of the report to be insufficient for risk assessment purposes.

The risk evaluation chapters in both reports conclude with a list of factors to be considered in risk assessments concerning the use of treated wood. Are there any other factors missing from the lists?

The factors are comprehensive, what is missing as described above is a detailed risk assessment protocol, although the final chapter alludes to this.

Creosote
In the EU there are New Regulations to prohibit the use of Creosote in certain circumstances. Most European countries have met the obligation to implement the provisions (in part) of European Directive 94/60/EC (the 14th Amendment to the Marketing and Use 76/769/EEC). This Regulation prohibits the placing on the market of wood treated with creosote and prohibits, subject to an exception for old treated wood, the use of treated wood in certain circumstances. Given the hazards of creosote and treated wood the regulation seeks to minimise the overall risk to man and the environment. A similar review is taking place in the US led by the EPA. Worthy of considerable note and relevant in the context of this report is that the decision to ban the use of creosote was based not on sound scientific evidence but on the principle of uncertainty and the precautionary principal.

The Directive was negotiated in 1993/94 by DTI (Department for Trade and Industry) and HSE (Health and Safety Executive) and was as stated above not based on a detailed risk assessment. However, the risks posed by creosote are well documented. Creosote placed on the market can have widely different compositions and thus exhibit different properties. Potentially they may cause skin irritation and cause harm when swallowed. Furthermore, all creosote contains aromatic type substances, some of which are known carcinogens. All contain phenols, which may pose a threat to the water compartment of the environment. It was this information in itself with the associated degree of uncertainty regarding the nature of the products in terms of their environmental safety that led to the ban.

It is this lack of accounting within the current report that causes me some unease. Correct, it is very difficult to show categorically that PAHs are deleterious to the environment, equally due to lack of documented information. It is virtually impossible to demonstrate this for creosote itself. So, you are left with the requirement to make decisions surrounded by a huge degree of uncertainty and lacking evidence. It is in this environment where the risk based approach (RBA) (detailing and highlighting the site specific risk assessment is crucial) and it is this aspect of the work that is lacking. The models portrayed are insufficient, in my opinion, to accurately predict harm to ecosystems (partly because that was never their intention) but partly because the model parameters are not constants.

One approach would be to use a risk based management approach, based around identifying and reducing risks associated with contamination to a level protective of the environment. In the context of RBM, risk is the measure of the likelihood and magnitude of an adverse effect including injury disease, ecological loss or economic loss arising from the realisation of a hazard. Within this approach the contamination is only identified as representing a risk if all three elements of a contamination linkage are present;

- A source;
- A sensitive receptor, and;
- A pathway linking the source to the receptor.

If one of these pathways is absent there can be no significant risk to the receptor. This is the basis of the site specific risk assessments necessary to be undertaken and such an approach requires elaboration within this report structure.

The copper treated wood report contains a chapter concerning alternative materials and includes a brief examination of toxicity considerations regarding these products. Are there any other considerations that are not mentioned in this chapter?

See text and comment above.

The current regulations and best management practices (BMP) chapter in this report discusses BMPs put forth by the industry as well as several government agencies. Do you feel that the available scientific evidence warrants the use of these BMPs? Do you think that utilization of the BMPs, given consideration of the site specific factors listed at the end of the risk evaluation chapters will provide protection to individuals of ESA listed species and to the habitat components of EFH?

See specific comments above.

Do any of the BMPs or restrictions seem unwarranted or are there additional BMPs or restrictions which should be utilized? Please provide explanations to answers including any site specific factors that should be considered in making decisions regarding the use of treated wood products in aquatic environments.

See specific comments above and further details given below covering aspects of the use of creosote treated wood.

The consultants report does not review the BMPs that exist but alludes to their location and literature source. In the absence of such detailed information it is difficult to make further judgements. However, one would envisage a Best Working/ Management Practice that considers a site specific risk assessment and details the process that should ensure as a consequence of such a requirement being triggered.

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Appendix A: Statement of Work

Consulting Agreement Between the University of Miami and Dr. Timothy Townsend

February 20, 2006

Background

The purpose of the technical review documents requiring independent review is to present an analysis of the potential effects and mitigations for the use of treated wood products in aquatic environments. The documents focus on copper treated wood, primarily ammoniacal copper zinc arsenate (ACZA), as this is the most prominent material used on the west coast of the United States and in Alaska, and creosote treated products.

These products are being examined by NOAA's National Marine Fisheries Service (NOAA Fisheries) to determine the risks generated by their usage to the living marine resources which NOAA is responsible for managing, referred to as NOAA's Trust Resources. These include anadromous salmonids managed under the Endangered Species Act (ESA) and Essential Fish Habitat (EFH) as designated by the Magnuson-Stevens Fishery Management and Conservation Act. The use of treated wood in or near aquatic environments commonly requires a permit issued by the U.S. Army Corps of Engineers under section 404 of the Clean Water Act. Under the ESA, federal agencies are to consult with NOAA Fisheries to insure that any action authorized, funded or carried out by the federal agency does not jeopardize the continued existence of any threatened or endangered anadromous salmonids or result in the destruction or adverse modification of designated critical habitat. The issuance of this permit by the U.S. Army Corps of Engineers requires consultation under the ESA to determine whether its approval action would jeopardize Federally-listed species or adversely modify designated critical habitat, and requires an EFH assessment to determine whether its approval action would adversely affect EFH. Since the use of treated wood materials in situations that may expose aquatic ecosystems is widespread along the west coast of the United States and in Alaska, development of these guidelines should help to streamline the review of permitting processes as well as the permitting processes themselves. In some instances, these guidelines may be used to update existing policies regarding treated wood.

The purpose of the ESA is to provide a means whereby the ecosystems upon which endangered and threatened species depend may be conserved, to provide a program for the conservation of threatened and endangered species and to take steps that may be appropriate to achieve this conservation. Conservation is defined in the ESA to mean using, and the use of all methods and procedures necessary to bring any endangered or threatened species to the point at which the protections provided by the ESA are no longer necessary. It is the policy of Congress, as declared in the ESA, that all Federal departments and agencies shall seek to conserve endangered and threatened species and shall utilize their authorities in furtherance of the purposes of the ESA. ESA regulates an activity with an eye toward its impact to as little as a single listed individual. These guidelines are meant to clarify the extent to which these authorities need to be applied for the use of treated wood.

The Magnuson-Stevens Fishery Conservation and Management Act established procedures designed to identify, conserve, and enhance EFH for those species regulated under a Federal fisheries management plan. EFH regulates an activity with an eye toward its impact on habitat characteristics. EFH is defined as those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity. Waters include aquatic areas and their associated physical, chemical, and biological properties that are used by fish and may include aquatic areas historically used by fish where appropriate; substrate includes sediment, hard bottom, structures underlying the waters, and associated biological communities; necessary means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and "spawning, breeding, feeding, or growth to maturity" covers a species' full life cycle. Essential Fish Habitat for salmonids includes their saltwater and fresh water ranges.

Effects of treated wood that need to be examined under the ESA and EFH regulations include direct, indirect, and cumulative effects. An example of direct effects includes the acute and sublethal impacts of copper and polycyclic aromatic hydrocarbons to salmonids and EFH regulated species. An example of an indirect effect includes the adverse impacts to the prey base upon which ESA listed and EFH regulated species depend. An example of a cumulative effect includes the impacts of multiple structures and contaminants in an area with or without additional loading from urban sources, historic mining, smelters, ships' hulls or any other source. The synthesis of these effects to habitat and to individuals, coupled with local environmental conditions and specific species of concern, defines the risk of a project proposing the use of treated wood.

The objective of the technical review and use recommendations development was to establish a solid scientific basis from which guidance development and implementation could proceed, particularly concerning potential direct and indirect effects.

Objectives of the CIE Review

The information presented for review has been developed by a consulting firm under contract to NOAA Fisheries. The use of an independent firm was determined to be the best way to initiate and complete a thorough review of the best available science concerning effects of treated wood, effects of the most likely contaminants coming from treated wood, and policies and guidelines already developed and in use throughout the United States, Canada and/or other jurisdictions involving the use of treated wood products. A brief review of the economic aspects of treated wood and its leading competitors as well as engineering aspects of all these materials was also commissioned as part of the process.

The review panelist is required to review the following reports (*Treated Wood in Aquatic Environments: Technical Review and Use Recommendations* and *Creosote – Treated Wood in Aquatic Environments: Technical Review and Use Recommendations*), in particular, the aquatic toxicology, the fate and transport aspects of the suite of contaminants that may result from its use, and the modeling that is used in conducting risk assessments concerning treated wood. These sections make up the bulk of the submitted documents and have been an area of considerable debate for many years.

Specific terms of reference for the review include:

- Evaluate the synthesis and interpretation of the toxicology information, and state whether or not the conclusions regarding the potential effects to ESA and EFH regulated species and habitats are supported by the scientific evidence.
- Evaluate the synthesis and interpretation of fate and transport information and state whether or not the conclusions regarding potential effects to ESA and EFH regulated species and habitats are supported by the scientific evidence.
- If the conclusions are not supported by the available evidence, please provide a detailed explanation and new conclusions.
- Evaluate the review of the leaching and environmental concentration models presented in both of the reports.
  B) Did the review adequately characterize these models by addressing model assumptions, uncertainties, and their applicability to ESA listed salmonids and the habitats of NOAA’s Trust Resources? If not, provide explanation(s) and how subsequent conclusions are affected.
  C) The review concluded that most of the factors present in the models would lead to an increase in leaching in the field compared to that observed in the laboratory. Is this conclusion supported by the scientific evidence? Please explain in detail why the models do or do not result in an under prediction of leaching.
  D) Are these models sufficient to predict leaching concentrations for use in ecological risk assessments concerning ESA listed species and their habitat?
  E) Are additional precautions required to add a margin of safety to the model predictions? Provide examples?
- The risk evaluation chapters in both reports conclude with a list of factors to be considered in risk assessments concerning the use of treated wood. Are there any other factors missing from the lists?
- The copper treated wood report contains a chapter concerning alternative materials and includes a brief examination of toxicity considerations regarding these products. Are there any other considerations that are not mentioned in this chapter?
- The current regulations and best management practices (BMP) chapter in the copper treated wood report discusses BMPs put forth by the industry as well as several government agencies. Do you feel that the available scientific evidence warrants the use of these BMPs? Do you think that utilization of the BMPs, given consideration of the site specific factors listed at the end of the

risk evaluation chapters, will provide protection to individuals of ESA listed species and to the habitat components of EFH?

- Do any of the BMPs or restrictions seem unwarranted or are there additional BMPs or restrictions which should be utilized? Please provide explanations to answers including any site specific factors that should be considered in making decisions regarding the use of treated wood products in aquatic environments.

Specific Activities and Responsibilities

The review panelist's duties shall occupy a maximum of 5 workdays (i.e., a few days for document review and a few days to prepare a Review Report). The review panelist will review the treated wood technical review and use recommendations documents and develop a review report in the context of responsiveness to the terms of reference. See Annex 1 for further details on report contents.

No later than March 13, 2006, the review panelist shall submit the Review Report to the CIE for review[1]. The CIE reports shall be addressed to "University of Miami Independent System for Peer Review," and sent to Dr. David Die, via e-mail to ddie@rsmas.miami.edu and to Mr. Manoj Shivlani via e-mail to mshivlani@rsmas.miami.edu.

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[1] All reports will undergo an internal CIE review before they are considered final.

Appendix B: Background material

Stratus Consulting, 2005. Treated Wood in Aquatic Environments: Technical Review and Use Recommendations. 160 pp.

Stratus Consulting, 2005. Creosote-treated Wood in Aquatic Environments: Technical Review and Use Recommendations. 104 pp.

Volume II
Section II
Stratus Creosote Report and Comments

9. Peer Review comments by Judith S. Weis of Rutgers for University of Miami Independent System for Peer Review

University of Miami Independent System for Peer Review

Review of Treated Wood Documents by Stratus Corp.

Judith S. Weis
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Review of *Treated Wood in Aquatic Environments: Technical Review and Use Recommendations* from Stratus Corp. Prepared for Joe Dillon, NOAA Fisheries. 2005

Executive Summary

This report has a very brief inadequate section that covers environmental fate and effects of the metals released from treated wood. By omitting a number of important peer-reviewed papers and taking at face value a large number of unrefereed reports from the wood treatment industry that tend to minimize and gloss over the risks, this report overall probably underestimates the risks posed by treated wood in the aquatic environment. However, it does include important information about best management practices and alternative materials that could be used, and does take a generally precautionary approach to protecting salmonids.

Background

I have read this report, and my findings and evaluation follow.

Findings

The Stratus reviewer has included a lot of papers, but has also omitted a number of important references – why this has been done is unclear. The report seems to have left out many peer-reviewed journal publications and included a large amount of "gray literature" reports. For example, a number of papers from the Weis group are omitted, and the many excellent papers of the Solo-Gabriele and Townsend group (some journal articles, some reports) dealing with leaching, and others are not included. I have included many of these references at the end of this evaluation. The report has 45 pages of appendices, including acute toxicity values of Cu, Cr, and As to all sorts of aquatic animals. It must have been time consuming to compile all this information that is probably not germane to the topic, since treated wood is not likely to cause mortality. They would have seen greater benefit from focusing on a better, more thorough, literature review.

I do not understand what kind of a literature search would come up with all this gray literature and leave out so many peer-reviewed journal articles. The consulting agreement says "The use of an independent firm was determined to be the best way to initiate and complete a <u>thorough review</u> of the <u>best available science</u>" (emphasis mine). This review does not meet that standard. Peer reviewed papers are the "gold standard" of scientific publishing, and good research should be submitted to scientific journals. Furthermore, with the exception of the chapter on models, the Stratus reviewer seems to have taken all the papers at face value, and has not read them all critically. The review does not distinguish between the value of peer-reviewed publications and "gray literature" reports from consultants to the wood preserving industry.

The report does include 11 citations by K. Brooks, who works for the wood preservers, of which only one was in a refereed journal. There are also several "personal communications" from Brooks. There do not seem to have been any personal communications with the investigators whose peer-reviewed publications have been omitted. I have not read all of Brooks' reports in detail, but one that I have read in detail was Brooks (2000) in the document from the Forest Products Laboratory studying the impact of preservative-treated wood in a wetland boardwalk. He concluded that leachates from wooden walkways increase the metal levels in sediments nearby, but do not affect the benthic community. Since Weis & Weis (1994, 1998) found clear effects on estuarine benthic communities near CCA-treated bulkheads, this finding of no effect of a "worst case scenario" on the benthic community was of considerable interest. When one reads the methods section of this report, one finds that the samples taken for infaunal community analysis were not replicated. Replication is essential for any good scientific study. In Brooks' study, replicates were taken for the invertebrates that settled on artificial substrates, but not for the Petite Ponar grab samples for infauna (although replicates were taken during the baseline survey prior to construction of the boardwalk). Although he found differences in abundance and diversity of organisms near and far from the treated wood, differences were not statistically significant. For example, at the AZCA site, taxa richness and diversity indices all drop immediately downstream of the site, but are not significant. For the CCA site, 16 species were found 1 m from the wood, while 46 species (3 times as many) were found 3 m away, but the difference was not considered significant. Similarly, for the sampling of invertebrates associated with vegetation, there were no replicates taken. Organisms in the vegetation at 0.5 m from the ACZA site are heavily dominated by one opportunistic species, *Limnodrilus* (a sign of stress), while at 2.0 m there is much greater evenness, reflecting a healthier environment. These differences are not considered significant. Biological samples tend to vary, and properly done benthic infaunal community studies generally take a minimum of 3-5 replicate samples. The fewer samples one takes, the less work one has to do and the less the chances of finding statistically significant differences. If there are no replicates taken, "statistically significant" differences are not likely to be found. If someone had the goal of finding "no significant differences" a good way to do it would be to not take replicate samples! This type of science would probably never have gotten through the peer review system of scientific journals. It is also interesting that there appears to be bias even in the formulation of a hypothesis for this study of a "worst case" scenario. Despite the fact that there was new wood and a poorly flushed system, Brooks hypothesized that "there would be no statistically significant changes in the benthic and epibenthic invertebrate community associated with the construction of wetland boardwalks…" This would be expected to be the <u>null</u> hypothesis for an unbiased researcher. The author of the Stratus review does not seem to have read this report critically and seen its major flaws, but takes its conclusions at face value, saying "no significant changes in invertebrate communities were reported." It is possible that careful critical review of other papers from this author would reveal other flaws.

In contrast, peer-reviewed studies of benthic communities at a number of different estuaries on the Atlantic coast found major (statistically significant) reductions in diversity in communities adjacent to and out for a few meters from treated wood bulkheads of various ages in both well-flushed and poorly flushed environments (Weis and Weis 1998).

The review devotes three pages and includes a table from the Forest Products Laboratory 2000 (Lebow et al. 2000) report on the chemical accumulation under a wetland boardwalk. However, it does not mention a comparable peer-reviewed publication (Weis and Weis 2002) dealing with contamination of salt marsh sediments and biota from CCA boardwalks. In that study, sediments and marsh plants from directly underneath and out from walkways that were new (three years old) and older (15 years old) were analyzed for the three metals. Dispersal was greater in the low marsh than the high marsh (due to tidal effects) and accumulation of the metals was also greater in the low marsh. While levels right below the boardwalk were greater under the new walkway, contaminants had spread out over a greater area from the older walkway. On the Pacific Coast, marsh plants provide juvenile salmon places to forage and hide, and the detritus-based food web provides them with abundant prey. They could be considered essential fish habitat for the juveniles. Meyer et al. (1981) and Weitkamp and Campbell (1980) found that juvenile salmon showed preferences for marsh-associated copepods, chironomids, and amphipods in a number of Puget Sound estuaries. Therefore salt marshes and their potential contamination with metals from treated wood should have been of interest in this review. Since juvenile salmon associate with salt marshes and would be expected to associate more with the low marsh than the high marsh, it is surprising that this relevant paper is omitted from the report.

I am unable to evaluate the leaching models, but assume that since Brooks' model passed peer review for the journal "Estuaries" it is reasonable and sound. The Stratus reviewers analyze the strengths and weaknesses of the model. Models need to incorporate estuarine conditions as well as riverine conditions into them; flow rates and directions change and reverse during the tidal cycle in an estuary. I agree that it is likely that the environmental conditions in the field will probably in most cases produce greater leaching than observed in laboratory studies.

In discussing laboratory and field studies, the report repeatedly uses the word "potential" with regard to impacts or adverse effects, when many of these have been clearly demonstrated. On page 4-11 the report says that biological effects appear to become attenuated within several months of construction. This is repeated in first paragraph of the conclusions on page 7-1. While this is the case for leaching and water levels of the metals, this is not the case for bioaccumulation as seen in a number of papers (e.g. Weis and Weis, 1992; Weis et al 1993). The report doesn't appear to appreciate the fact that, although leaching decreases with time and the water concentrations of the metals will decrease with time, this does not apply to metal levels in the sediments or bioaccumulation in the benthic and epifaunal animals, and the potential effects on the benthos. Clear, statistically significant, effects were seen in decreased diversity and abundance of estuarine benthos in many sites near treated wood bulkheads that had been in place for many years (Weis & Weis 1994, 1998). In the discussion of the 1998 paper, he says "effects were negligible by >1 m from the structures." While this was true for some of the sites, other sites showed effects out to 3 or even 10 m. Effects were seen both at sites with low water movement and sites with much faster water movement.

The section on toxicity of the chemicals is quite cursory and brief, and omits many important papers on sublethal effects of low levels of the three metals to aquatic biota. Effects generally are seen at the low *u*g/l level. It does do a good job on the avoidance response of salmonids to Cu, however, this is the only sublethal effect that is considered in any detail. The section does not consider Cu toxicity to algae and gastropods, both of which are particularly sensitive taxa (Cu can be used as an algicide and molluscicide) and important members of aquatic communities. The report has omitted a number of papers demonstrating additional aspects of leaching and the toxicity of CCA wood leachates. In fresh water subject to simulated acid rain, Warner and Solomon (1990) found that the leaching rate was accelerated. The copper leached was far in excess of the lethal level for *Daphnia magna*. Buchanan and Solomon (1990) reported that the LC_{50} for this species is about 36 µg Cu l^{-1}, which is only about 2% of the concentration in the leachate. Leachates from treated wood from different tree species all failed LC_{50} tests using fish. The acute toxicity of the three metals together to *Daphnia* was greater than that for Cu alone indicating that the metals act jointly. There was evidence that Cu and Cr interact synergistically. Sublethal effects were seen in oysters living on CCA bulkheads, which had elevated levels of micronuclei, an indication of genotoxicity (Weis et al. 1995). Laboratory bioassays of leachate were performed on larval oysters (*Crassostrea gigas*) to investigate behavioral responses (Prael et al. 2001). Early veliger stage larvae were observed to avoid concentrated leachate, and three- and seven-day old larvae swam faster in leachate than in clean seawater and moved up and down more in the leachate. This altered behavior may retard settlement of the larvae to metamorphose into adults.

Bacteria that normally degrade pentachlorophenol (PCP) play an important role in degrading and waste removal of this other chemical used as a wood preservative. When exposed to CCA, their ability to degrade the PCP was inhibited. Inhibitory effects were seen at concentrations thousands of times less than those used commercially (Wall and Stratton 1994). Other ecosystem level effects on microbial activities have been seen in terrestrial environments. Microbes in CCA-contaminated soils in the field have been shown to be negatively affected (Bardgett et al, 1994). Microbial biomass, carbon, and nitrogen were lower in contaminated soils. Bacterial respiration, biomass P, and denitrification all declined with increasing CCA contamination. In another study, biological activities, including respiration, nitrification and sulphatase, were reduced in soils contaminated by CCA (Yeates et al. 1994). It is likely that similar effects would be seen in bacteria in aquatic environments.

There is only one small paragraph devoted to dietary exposure to chemicals from leachate (P. 3-11). This is the probable route of exposure for salmon, which are the main reason for this report. This section should be much longer. He concludes that there is little likelihood of dietary toxicity because of limited potential for substantial metal accumulation in invertebrates. There have been at least two journal articles showing trophic transfer of CCA wood-derived contaminants. Algae taken from CCA bulkheads were fed to mud snails (*Ilyanassa obsoleta*), which caused snails to retract into the shells, cease activity, and eventually die (Weis and Weis 1992). Oysters taken from CCA bulkheads were fed to carnivorous snails (*Thais haemastoma*) and caused them to reduce their feeding rate, and thus reduce their growth (Weis and Weis 1993). After two months of consuming these contaminated oysters, the snails acquired body burdens of Cu equal to that of snails collected from treated wood bulkheads. These studies indicate that there is indeed a "potential for dietary toxicity." Trophic transfer is related to the way in which the prey organism stores the metal. The marine isopods *Limnoria* spp. (gribbles) bore through wood, including CCA-treated wood. (This is ironic, since one of the reasons for the use of preservative-treated wood in the marine environment is to prevent damage by marine borers.) They can tolerate the high concentrations of metals by storing copper in granules. An increased number of copper-containing granules were found in isopods from CCA-treated wood compared to those taken from untreated wood. The ability to store copper in inert granular form may explain why these organisms can consume CCA wood without suffering toxicity (Tupper et al. 2000). Furthermore, metals stored in granules are not available to consumers (Wallace et al 2003). This is another aspect of trophic transfer that is not covered in the report.

In any risk assessment, there is a need to distinguish between bulkheads or walkways, which have a lot of surface area for leaching, and pilings, which have much less surface area. From an overview of the literature, it appears that leachates from pilings in reasonably well-flushed areas do not produce obvious negative effects in the immediate vicinity. It would be expected that when flow rate is higher, the leaching rate might be higher, but the metals would be swept away downstream rather than accumulate near the treated wood. It should be noted, however, that estuaries have areas in which there are high rates of sediment deposition ("turbidity maximum") and the leachates that are swept away from the immediate site of the treated wood are probably being deposited somewhere else downstream. Metals do not degrade, but will accumulate at these depositional sites. The question is whether the risk assessment will be only for the immediate vicinity of a treated wood structure, or if it will consider potential effects at the depositional sites further downstream. Another factor that needs to be incorporated is the initial concentration of metals in the wood – for marine and estuarine uses it is 2.5 lb/ft^2 but in freshwater the wood used may be lower than this.

The best management practices (BMPs) as listed and described will reduce the potential for toxicity somewhat, but since there will still be leaching from treated wood, and the leaching is greatest when the wood is new, I would recommend another, more effective, BMP. If the wood were to be soaked out on site at the treatment facility for a few months before being put into service, the greatest amount of leaching into the environment, and thus the greatest amount of risk, would be eliminated. The water into which the wood leached could later be recycled by pressure-treating it into new pieces of wood. This would eliminate the large amount of leaching from newly installed wood, which is responsible for the greatest amount of the problems.

The discussion of alternative materials is good and appears to be thorough.

Specific comments

P. 2-18 discusses factors that could affect the leaching rates. The presence of knotholes in the wood is not discussed and could affect leaching rate. Knotholes are common in Southern yellow pine, which is the wood used most frequently in the Atlantic coast.

Chapter 3 , 3.1 discusses water exposures and briefly considers the toxicity of each of the three metals, but does not discuss the possibility of interactions (additivity, synergism, antagonism) when all three are present in the water.

I was surprised that there was no discussion of the importance of speciation and bioavailability of any of the metals. These are very important issues relevant to the effects of leachates from metal-treated wood in the aquatic environment and should be included in a report like this.

P 3-10 has bulleted different approaches to sediment toxicity, but does not include the Effect Range-Low and Effects Range Median approach of Long and Morgan, that is discussed later. The acid-volatile-sulfide (AVS) (Long et al.1998) approach and other sulfide-related approaches (Rozan et al. 2000) might also be included among the approaches to sediment toxicity.

P 7-4, recommendation #4, last bullet suggests that minimum current velocities should be greater than 2 cm/sec for treated wood to be acceptable. If taken strictly, this could rule out its use in estuaries, where during parts of the tidal cycle current velocities are less than this, or zero.

Summary and Conclusions

Overall, by having a very cursory review of sublethal toxicity studies, omitting many relevant peer-reviewed publications, and not critically reviewing the "gray literature" cited in the report. The report generally seems to underestimate the risks associated with copper-based treated wood, and says that any effects would attenuate after several months. This is clearly not the case in terms of bioaccumulation and effects on the benthic community, or in terms of trophic transfer. However, it does take a precautionary approach to salmon, especially juvenile life stages.

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Review of "*Creosote-treated Wood in Aquatic Environments: Technical Review and Use Recommendations*." from Stratus Corp. Prepared for Joe Dillon, NOAA Fisheries. 2005

Executive Summary

This report includes a much more adequate and comprehensive review of the literature than the previous report on metal-treated wood. It documents extensive toxicity of creosote and its components to aquatic life at low concentrations, includes regulations from many areas banning its use, and demonstrates that creosote components can accumulate in sediments many meters away from the structure. Therefore, the conclusions and recommendations that tend to say that this is not something to be concerned about do not seem to be in keeping with the documented effects. The report does not have a section discussing the breakdown of the PAHs in water and sediments, which should be important considerations in evaluating the risks posed by creosote treated wood. They do take a precautionary approach to salmonids, however.

Background

I have read this report and my evaluation follows.

Findings

The report documents faster leaching from newly treated wood, and shows that leaching occurs faster when flow rate is faster. It also shows that temperature can affect the leaching rate, and that different PAHs have different leaching rates, with low molecular weight compounds dissolving more readily than the heavier PAHs.

It considers the Brooks (1997) model, and notes that it has not been published in the peer-reviewed literature. The report critically examines the various models of Brooks and Poston and points out their strengths and weaknesses. One criticism of the Brooks model they do not mention is the assumption that low molecular weight PAHs do not volatilize. One criticism of the Poston model is using acute levels (LC_{50}) for the toxic threshold. A point where 50% of the animals die is certainly an extremely high level to be considered a threshold!

The authors of the report spend considerable time discussing Goyette and Brooks (1998, 2001) study of a "worst case scenario" of leaching, and note that "no positive controls were reported and percent recovery was not reported." They also point out that higher than expected amounts of creosote were found in the offshore direction – suggesting greater transport than the model expected. They also point out that the model does not consider the number or density of pilings, which would appear to be important issues, and that the model ignores the effect of water flow on leaching rate. This indicates that the Stratus reviewers were reading this part of the report critically – a good thing.

The chapter on toxicity is much more thorough and comprehensive than the comparable chapter of the other report dealing with CCA and related chemical treatments. They review routes of exposure, cover many peer-reviewed papers dealing with both water and sediment exposures, and indicate that effects in fish can be seen at water concentrations down to 16 *u*g/L. They have a brief section on phototoxicity, which can increase the toxicity of PAH compounds. They cover carcinogenesis, which has been studied extensively by the NOAA Seattle group, as well as researchers studying the Atlantic Wood Superfund site in the Elizabeth River. They have a good section on developmental effects, both laboratory studies and the field observations of herring eggs deposited near treated wood (Vines et al.2000). Eggs deposited on a very old creosote piling (40 years old!) failed to develop. This is a very important finding, in that the leaching and toxicity would have been expected to be minimal from such an old piling. That work indicated that 0.003 mg/L significantly reduced hatching success, and increased abnormalities in herring eggs. Wassenberg and diGiulio (2004) found effects of low concentrations on developing *Fundulus heteroclitus*, a species that is quite tough and insensitive to environmental toxicants. They cover effects on immunotoxicity, reporting that sediment levels of 25 mg/kg produced effects on winter flounder, and that Karrow et al (1999) found effects in rainbow trout at 17 *u*l/L. There is a table on pg 3-15 indicating that effects generally become apparent around 3 *u*g/L in the water.

The report does not have a section discussing the breakdown of the PAHs in water and sediments. The rate of degradation under various environmental conditions, pathways, persistence and toxicity of the degradation products should be important considerations in evaluating the risks posed by creosote treated wood. There is an extensive body of literature on this topic. Rates of degradation would be expected to be rather slow (given the creosote-loaded Superfund sites at former wood treatment facilities), and faster in aerobic vs anaerobic environments, both of which would be relevant to the issues involved in this report.

In examining community-level effects, they note that microcosm studies have found community level effects on zooplankton at levels as low as about 3 ug/L (Sibley et al. 2001). In contrast, Goyette and Brooks (1998, 2001) found significant sediment accumulation as far as 7.5 meters away from creosote-treated pilings, but no effects on the benthic community ("No significant changes in benthic community structure were observed.") Another study by Brooks (2000) is reported as finding that "Despite the toxicity threshold exceedences, the biological data that was collected did not reveal adverse effects on biota from PAHs at either the newer bridge site or the older bridge site" (p. 4-10). These reports are not in the open literature and were provided to me. I note that sampling procedures used by Goyette and Brooks (1998) involved three replicates, although, interestingly enough, they state that they were originally going to do only one sample per site. Perhaps this is the influence of Goyette on Brooks and it is a much better design than that used by Brooks subsequently (2000) in the study of walkways treated with copper preservatives in which no replicate samples were taken for infauna. In the creosote report, they note that baseline (before putting in the pilings) benthic community was extremely variable from place to place around Sooke Bay. It is likely that this natural variability masked any potential effects of the creosote. Given such a variable baseline, it might have been better to take benthic samples at the very same sites before and after putting in the pilings. In their graphs of abundance and taxa richness at different distances from the wood, despite taking three replicates, they do not indicate the variance around the means. Since they found that after over one year, the sediments 0.5 m from the piling exceeded various standards for PAHs, that mussel larval development was impaired, and that amphipod survival was reduced by these sediments, it is likely that a before/after design would have indicated a reduced benthic community as well. It should also be noted that this site, in British Columbia, has rather cold temperatures, and leaching and effects would be more severe at warmer temperatures.

There is only one paper discussed dealing with trophic effects (Rice et al. 2000), in which contaminated worms were fed to English sole, producing growth impairment. I am confident that there must be other papers dealing with trophic transfer. This issue, as with metals, is quite important if salmonids are of particular interest.

Risk Evaluation

Having established that effects can be seen at quite low levels, and that significant amounts of PAHs leach from treated wood and persist in the sediments, I was surprised by their risk evaluation. The evaluation seems to discount much of this work, although as they say on page 4-3 these results indicate that "PAHs that leach from treated wood are present at concentrations that are predicted to be toxic to aquatic biota under realistic environmental scenarios."

The report describes the large studies at Charlestown Navy Pier and Naval Station San Diego where new pilings severely contaminated the water and produced sediments with PAH concentrations 250 times greater than at a control site (Costa and Wade, 1989). The risk evaluation section then relies on the Goyette and Brooks (1998). Their Addendum Report (Goyette and Brooks, 2001) indicated that even after four years, evidence of sediment toxicity could still be detected as far as 2 m away from the wood.

It was a big surprise, after all the documentation, to read their conclusions on 4-14 that sediment accumulation "appears to be relatively minor." They further write "the duration of any biological effects appears to be attenuated within several months of construction (the time period when leaching rates are likely to be the highest)." This is not true for the creosote in the sediments that can cause tumors in bottom-dwelling fish, nor for the unfortunate herring eggs deposited on a 40-year old piling. The only possible justification for such a conclusion would be if the creosote degraded rapidly in sediments, which does not appear to be the case. There ought to be a section in the report covering rates of degradation of creosote PAHs, degradation pathways, toxicity of degradation products, and the length of time that various degradation products persist.

In any risk assessment, there is a need to distinguish between bulkheads or walkways, which have a lot of surface area for leaching, and pilings, which have much less surface area. It is expected that when flow rate is higher, the leaching rate will be higher, but the

PAHs would be swept away downstream rather than accumulate near the treated wood. It should be noted, however, that estuaries have areas in which there are high rates of sediment deposition ("turbidity maximum") and the leachates that are swept away from the immediate site of the treated wood are probably being deposited somewhere else downstream. The question is whether the risk assessment will be only for the immediate vicinity of a treated wood structure, or if it will consider potential effects at the depositional sites further downstream. After their conclusion they then advocate a precautionary approach with regard to salmonids.

The best management practices (BMPs) as listed and described will reduce the potential for toxicity somewhat, but there will still be leaching from treated wood, and the leaching is greatest when the wood is new. The Goyette and Brooks (1998, 2001) studies used wood treated to BMP standards, and nevertheless found persistent accumulation and toxicity in the sediments near the wood. And this was just a piling! I would recommend another, more effective, BMP. If the wood were to be soaked out on site at the treatment facility for some time before being put into service, the greatest amount of leaching into the environment, and thus the greatest amount of risk, would be eliminated. The water into which the wood leached could then be recycled into new pieces of wood for treatment.

Summary and Conclusions

The report documents numerous studies demonstrating toxic effects of creosote at very low environmental concentrations and the leaching of creosote from treated wood and accumulation in sediments going out over 7 meters. However, the conclusions then imply that effects are relatively minor, of short duration and not of great concern. The conclusions do not seem to follow from all the research documented in the report. Since many states and municipalities have banned the use of creosote treated wood in aquatic environments, they must have concluded that effects are of great concern. Nevertheless, the Stratus reviewers do recommend a precautionary approach to dealing with salmonids' exposure to creosote leached from treated wood.

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Appendix 1

Materials Provided:

Stratus Consulting, 2005. Treated Wood in Aquatic Environments: Technical Review and Use Recommendations. 160 pp.

Stratus Consulting, 2005. Creosote-treated Wood in Aquatic Environments: Technical Review and Use Recommendations. 104 pp.

Appendix 2 – Statement of Work

Consulting Agreement Between the University of Miami and Reviewer

February 20, 2006

Background

The purpose of the technical review documents requiring independent review is to present an analysis of the potential effects and mitigations for the use of treated wood products in aquatic environments. The documents focus on copper treated wood, primarily ammoniacal copper zinc arsenate (ACZA), as this is the most prominent material used on the west coast of the United States and in Alaska, and creosote treated products.

These products are being examined by NOAA's National Marine Fisheries Service (NOAA Fisheries) to determine the risks generated by their usage to the living marine resources which NOAA is responsible for managing, referred to as NOAA's Trust Resources. These include anadromous salmonids managed under the Endangered Species Act (ESA) and Essential Fish Habitat (EFH) as designated by the Magnuson-Stevens Fishery Management and Conservation Act. The use of treated wood in or near aquatic environments commonly requires a permit issued by the U.S. Army Corps of Engineers under section 404 of the Clean Water Act. Under the ESA, federal agencies are to consult with NOAA Fisheries to insure that any action authorized, funded or carried out by the federal agency does not jeopardize the continued existence of any threatened or endangered anadromous salmonids or result in the destruction or adverse modification of designated critical habitat. The issuance of this permit by the U.S. Army Corps of Engineers requires consultation under the ESA to determine whether its approval action would jeopardize Federally-listed species or adversely modify designated critical habitat, and requires an EFH assessment to determine whether its approval action would adversely affect EFH. Since the use of treated wood materials in situations that may expose aquatic ecosystems is widespread along the west coast of the United States and in Alaska, development of these guidelines should help to streamline the review of permitting processes as well as the permitting processes themselves. In some instances, these guidelines may be used to update existing policies regarding treated wood.

The purpose of the ESA is to provide a means whereby the ecosystems upon which endangered and threatened species depend may be conserved, to provide a program for the conservation of threatened and endangered species and to take steps that may be appropriate to achieve this conservation. Conservation is defined in the ESA to mean using, and the use of all methods and procedures necessary to bring any endangered or threatened species to the point at which the protections provided by the ESA are no longer necessary. It is the policy of Congress, as declared in the ESA, that all Federal departments and agencies shall seek to conserve endangered and threatened species and shall utilize their authorities in furtherance of the purposes of the ESA. ESA regulates an activity with an eye toward its impact to as little as a single listed individual. These guidelines are meant to clarify the extent to which these authorities need to be applied for the use of treated wood.

The Magnuson-Stevens Fishery Conservation and Management Act established procedures designed to identify, conserve, and enhance EFH for those species regulated under a Federal fisheries management plan. EFH regulates an activity with an eye toward its impact on habitat characteristics. EFH is defined as those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity. Waters include aquatic areas and their associated physical, chemical, and biological properties that are used by fish and may include aquatic areas historically used by fish where appropriate; substrate includes sediment, hard bottom, structures underlying the waters, and associated biological communities; necessary means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and "spawning, breeding, feeding, or growth to maturity" covers a species' full life cycle. Essential Fish Habitat for salmonids includes their saltwater and fresh water ranges.

Effects of treated wood that need to be examined under the ESA and EFH regulations include direct, indirect, and cumulative effects. An example of direct effects includes the acute and sublethal impacts of copper and polycyclic aromatic hydrocarbons to salmonids and EFH regulated species. An example of an indirect effect includes the adverse impacts to the prey base upon which ESA listed and EFH regulated species depend. An example of a cumulative effect includes the impacts of multiple structures and contaminants in an area with or without additional loading from urban sources, historic mining, smelters, ships' hulls or any other source. The synthesis of these effects to habitat and to individuals, coupled with local environmental conditions and specific species of concern, defines the risk of a project proposing the use of treated wood.

The objective of the technical review and use recommendations development was to establish a solid scientific basis from which guidance development and implementation could proceed, particularly concerning potential direct and indirect effects.

Objectives of the CIE Review

The information presented for review has been developed by a consulting firm under contract to NOAA Fisheries. The use of an independent firm was determined to be the best way to initiate and complete a thorough review of the best available science concerning effects of treated wood, effects of the most likely contaminants coming from treated wood, and policies and guidelines already developed and in use throughout the United States, Canada and/or other jurisdictions involving the use of treated wood products. A brief review of the economic aspects of treated wood and its leading competitors as well as engineering aspects of all these materials was also commissioned as part of the process.

The review panelist is required to review the following reports (*Treated Wood in Aquatic Environments: Technical Review and Use Recommendations* and *Creosote – Treated Wood in Aquatic Environments: Technical Review and Use Recommendations*), in particular, the aquatic toxicology, the fate and transport aspects of the suite of contaminants that may result from its use, and the modeling that is used in conducting risk assessments concerning treated wood. These sections make up the bulk of the submitted documents and have been an area of considerable debate for many years.

Specific terms of reference for the review include:

- Evaluate the synthesis and interpretation of the toxicology information, and state whether or not the conclusions regarding the potential effects to ESA and EFH regulated species and habitats are supported by the scientific evidence.
- Evaluate the synthesis and interpretation of fate and transport information and state whether or not the conclusions regarding potential effects to ESA and EFH regulated species and habitats are supported by the scientific evidence.
- If the conclusions are not supported by the available evidence, please provide a detailed explanation and new conclusions.
- Evaluate the review of the leaching and environmental concentration models presented in both of the reports.
  A) Did the review adequately characterize these models by addressing model assumptions, uncertainties, and their applicability to ESA listed salmonids and the habitats of NOAA's Trust Resources? If not, provide explanation(s) and how subsequent conclusions are affected.
  B) The review concluded that most of the factors present in the models would lead to an increase in leaching in the field compared to that observed in the laboratory. Is this conclusion supported by the scientific evidence? Please explain in detail why the models do or do not result in an under prediction of leaching.
  C) Are these models sufficient to predict leaching concentrations for use in ecological risk assessments concerning ESA listed species and their habitat?
  D) Are additional precautions required to add a margin of safety to the model predictions? Provide examples?
- The risk evaluation chapters in both reports conclude with a list of factors to be considered in risk assessments concerning the use of treated wood. Are there any other factors missing from the lists?
- The copper treated wood report contains a chapter concerning alternative materials and includes a brief examination of toxicity considerations regarding these products. Are there any other considerations that are not mentioned in this chapter?
- The current regulations and best management practices (BMP) chapter in the copper treated wood report discusses BMPs put forth by the industry as well as several government agencies. Do you feel that the available scientific evidence warrants the use of these BMPs? Do you think that utilization of the BMPs, given consideration of the site specific factors listed at the end of the

risk evaluation chapters, will provide protection to individuals of ESA listed species and to the habitat components of EFH?

- Do any of the BMPs or restrictions seem unwarranted or are there additional BMPs or restrictions which should be utilized? Please provide explanations to answers including any site specific factors that should be considered in making decisions regarding the use of treated wood products in aquatic environments.

Specific Activities and Responsibilities

The review panelist's duties shall occupy a maximum of 5 workdays (i.e., a few days for document review and a few days to prepare a Review Report). The review panelist will review the treated wood technical review and use recommendations documents and develop a review report in the context of responsiveness to the terms of reference. See Annex 1 for further details on report contents.

No later than March 13, 2006, the review panelist shall submit the Review Report to the CIE for review[1]. The CIE reports shall be addressed to "University of Miami Independent System for Peer Review," and sent to Dr. David Die, via e-mail to ddie@rsmas.miami.edu and to Mr. Manoj Shivlani via e-mail to mshivlani@rsmas.miami.edu.

[1] All reports will undergo an internal CIE review before they are considered final.

ANNEX 1: Contents of Panelist Report

1. The report shall be prefaced with an executive summary of findings and/or recommendations.

2. The main body of the report shall consist of a background, description of review activities, summary of findings, conclusions/recommendations, and references.

3. The report shall also include as separate appendices the bibliography of all materials provided and any papers cited in the Panelist's Report, along with a copy of the statement of work.

Volume II

Section II

Stratus Creosote Report and Comments

10. Stratus Creosote Report

STRATUS CONSULTING

Creosote-Treated Wood in Aquatic Environments: Technical Review and Use Recommendations

Prepared for:

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In the fall of 2004, the National Marine Fisheries Service (NMFS) contracted with Stratus Consulting to conduct an independent, third party review of treated wood utilization in aquatic environments. This review is meant to support developing or updating NMFS guidelines for the use of treated wood along the Pacific Coast of the United States. The contract was awarded for copper-treated wood products and later amended to include a review of creosote-treated products as well. Substantive work on the project was completed in the fall of 2005. These reports are the findings of Stratus Consulting regarding the use of treated wood. They have been subject to peer review and public comment. NMFS may utilize these reports and other available information, as appropriate, to develop or update guidelines on the use of treated wood in aquatic environments. Accordingly, these documents are not NMFS guidelines themselves.

Creosote-Treated Wood in Aquatic Environments: Technical Review and Use Recommendations

Prepared for:

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SC10702

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Acronyms and Abbreviations

AAC	alkyl ammonium compound
AET	Apparent Effects Threshold
AHR	aryl hydrocarbon receptor
amu	atomic mass unit
AWPA	American Wood-Preservers' Association
BaP	benzo[*a*]pyrene
BCFs	bioconcentration factors
BMPs	best management practices
BPDE	benzopyrene diol epoxide
CCC	California Coastal Commission
CPF	chlorpyrifos
CRMP	Coastal Resources Management Program
CTL	chlorothalonil
Cu8	oxine copper
CuN, CuNapth	copper naphthanate
CYP	cytochrome P450
DCOI	4,5-dichloro-2-n-octyl-4-isothiozolin-3-one
DDT	dichloro-diphenyl-trichloroethane
DMBA	7,12-dimethylbenzanthrace
EECs	estimated environmental concentrations
EFH	Essential Fish Habitat
ER-L	Effects Range-Low
ER-M	Effects Range-Median
EROD	ethoxyresorufin O-deeethylase
ESA	Endangered Species Act
ESUs	Evolutionarily Significant Units
FCA	foci of cellular alteration
FID	flame ionization detector
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act

GC	gas chromatography
GENEEC	Generic Expected Environmental Concentrations
HAPC	habitat areas of particular concern
HPAH	heavy PAH
IPBC	3-iodo-2-propynyl butyl carbamate
ISQG	Interim Sediment Quality Guideline
ISW	interstitial water
LOEC	lowest observable effects concentration
LPAH	light PAH
MSA	Magnuson-Stevens Act
MW	molecular weight
NAVSTA	Naval Station San Diego
NMFS	National Marine Fisheries Service
NEC	no effects concentrations
NOAA	National Oceanic and Atmospheric Administration
NOEC	no observable effects concentration
NOEL	no observable effects level
NPS	National Park Service
OC	organic carbon
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
pcf	pounds per cubic foot
PCP, Penta	pentachlorophenol
PEC	pigment-emulsified creosote
PEL	Probable Effect Level
Penta	pentachlorophenol
ppb	parts per billion
ppm	parts per million
ppt	parts per thousand
PPZ	propiconazole
PVC	polyvinyl chloride
QSAR	quantitative structure-activity relationship

RPD	redox potential discontinuity
RQs	risk quotients
SPMDs	semipermeable membrane sampling devices
SPME	solid-phase microextraction
SQGs	sediment quality guidelines
SQuiRTs	Screening Quick Reference Tables
T&E	threatened and endangered
TCDD	2,3,7,8-tetrachlorodibenzo-*p*-dioxin
TEB	tebuconazole
TEL	Toxicity Effect Level
TOC	total organic carbon
TPAH	total PAH
TU	toxic unit
U.S. EPA	U.S. Environmental Protection Agency
USFS	USDA Forest Service
USFWS	U.S. Fish and Wildlife Service
UV	ultraviolet
WHO	World Health Organization
WSF	water-soluble fraction
WWPI	Western Wood Preservers Institute

1. Introduction

1.1 Background and Report Organization

Wood is a common construction material used for bridges, docks, piers, and other submerged and overwater structures. Wood is subject to fungal decay and to attack by wood-boring organisms, especially in saltwater and estuarine environments. To reduce the incidence of decay and attack, chemicals are impregnated into wood used for submerged and near-water construction. Wood-treating chemicals, which include a wide array of organic and inorganic chemicals, can leach from the wood into the immediate aquatic environment, potentially harming aquatic biota.

The National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration (NOAA) is developing guidance on the use of treated wood in aquatic environments inhabited by NMFS trust resources. NMFS trust resources include commercially important marine species and their habitats, as well as threatened and endangered (T&E) marine species and their habitats. The NMFS provides review and consultation on marine, estuarine, and freshwater construction projects that potentially could impact trust resources. Federal and state agencies and industry have requested guidelines from the NMFS on the use of construction materials, including treated lumber, in aquatic environments in the Pacific coastal region.

The purpose of this report is to assist the NMFS with the development of these guidelines. Data and information are reviewed to evaluate potential hazards to aquatic organisms from treated wood in aquatic environments. The data and information review focused specifically on the Pacific Coast states of California, Oregon, Washington, and Alaska. This report is a companion to “Treated Wood in Aquatic Environments: Technical Review and Use Recommendations“ (Stratus Consulting and Paladin Water Quality Consulting, 2005). That report describes water-soluble wood treatments; this report describes creosote treatments. The two reports share a similar introduction and overall structure; however, the other report includes separate chapters about alternative materials and current regulations and best management practices (BMPs) that are covered more briefly in the introduction of this report.

In the following sections, we describe NMFS trust resources, types of oil-borne wood preservatives, the chemical composition of creosote, and creosote policies, regulations, and BMPs.

The remainder of this report is organized as follows. In Chapter 2, we discuss data and information regarding leaching of creosote from treated wood into aquatic environments, and the potential for exposure of aquatic organisms to leached creosote. In Chapter 3, we discuss the toxicity of the leached creosote compounds to aquatic biota. In Chapter 4, we discuss potential risks to NMFS trust resources, including recommendations to minimize the environmental risks of toxic chemicals in aquatic environments. Literature cited follows Chapter 4.

1.2 Trust Resources

Under the Magnuson-Stevens Act (MSA), sections 303(a)(7) and 305(b)(2), the NMFS is responsible for managing commercially harvested aquatic species (including several salmonid species) by, among other things, implementing fishery management plans and designating protective Essential Fish Habitat (EFH) areas. The fishery management plans for commercially important species are managed by regional fisheries management councils. The Pacific Fisheries Management Council manages commercially important species for the States of California, Oregon, and Washington. The Northern Pacific Fisheries Management Council manages commercially important species for the State of Alaska.

The fishery management plans must designate both the habitat essential to the commercial species of concern and the threats to their habitats from fishing and non-fishing activities. EFH areas include, as defined by Congress, ". . . those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." EFH guidelines at 50 CFR 600.10 also specifically define substrate as including, ". . . associated biological communities." This is interpreted to mean all organisms (and particularly prey organisms) belonging to the same food web as any of the trust species. Salmonid EFH areas designated in accordance with the MSA include all streams, lakes, and other water bodies currently or historically accessible to salmon in Alaska, Washington, Oregon, and California, and include most Pacific Coast rivers, streams, and estuaries. In addition to EFH areas, which are geographically broad, NMFS may designate habitat areas of particular concern (HAPC) for the protection of the commercially important species it manages.

Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus kisutch*), and pink salmon (*Oncorhynchus gorbuscha*) are the three main commercially significant salmon species managed under the MSA by the North Pacific and Pacific Fishery Management Councils. EFH for these species in marine and estuarine areas of the Pacific Coast region extends seaward from the shoreline out to the 200-mile limit of the U.S. Exclusive Economic Zone. Shoreward, salmonid EFH comprises all bodies of water extending inland that were historically accessible to salmon, with the exception of certain barriers and dams that fish cannot pass (PFMC, 2004). Chinook salmon habitat spans from the U.S.-Mexico border to Kotzebue Sound in northwestern Alaska. Coho salmon spawn in tributaries from the San Lorenzo River in Monterey Bay, California, to Point Hope, Alaska, and throughout the Aleutian Islands (PFMC, 2003).

Under the Endangered Species Act (ESA), NMFS' trust resources include T&E aquatic species. In addition to the MSA-mandated habitat protections, sections 3(5)(A) and 7 of the ESA require NMFS to conserve the ecosystems on which T&E species depend, to provide a program for the conservation of T&E species, and to ensure that they (and all federal agencies) do not fund, authorize, or carry out any actions that will harm the habitat or jeopardize the continued existence of listed species. To this end, NMFS is authorized to designate "critical habitat" for those species. Under ESA section 7(a)(2), NMFS is responsible for developing guidelines and policies to protect federally listed T&E aquatic organisms and their habitats from pollutants.

There are 1,290 species, subspecies, Distinct Population Segments, and Evolutionarily Significant Units (ESUs) listed under the ESA. Of the aquatic species, the NMFS Office of Protected Resources manages mostly marine and anadromous species. The U.S. Fish and Wildlife Service (USFWS) manages the remainder of the listed species, which are primarily terrestrial and freshwater species. The NMFS Office of Protected Resources manages 61 ESA-listed aquatic species, 43 aquatic species of concern, and approximately 175 marine mammal stocks listed under the Marine Mammal Protection Act. Of the 51 salmonid ESUs, 30 are either listed as T&E, or are candidates for listing (Table 1.1).

Table 1.1. Status of West Coast salmonid species and ESUs

Species	ESU	Listing status[a]	T/E status[b]
Pink salmon	Even year ESU[c]	NW	
	Odd year ESU[c]	NW	
Coho salmon	Central CA ESU	L	E
	Southern OR/northern CA coasts ESU	L	T
	OR coast ESU	L	T
	Puget Sound/Strait of Georgia ESU	C	
	Lower Columbia River ESU	C	
	Olympic Peninsula ESU	NW	
	Southwest Washington	NW	
Chinook salmon	Sacramento River winter-run ESU	L	E
	Snake River fall-run ESU	L	T
	Snake River spring/summer-run ESU	L	T
	Puget Sound ESU	L	T
	Lower Columbia River ESU	L	T

Table 1.1. Status of West Coast salmonid species and ESUs (cont.)

Species	ESU	Listing status[a]	T/E status[b]
Chinook salmon (cont.)	Upper Willamette River ESU	L	T
	Upper Columbia River spring-run ESU	L	E
	Central Valley spring-run ESU	L	T
	CA coastal ESU	L	T
	Central Valley fall and late fall-run ESU	C	
	Upper Klamath-Trinity rivers ESU	NW	
	OR coast ESU	NW	
	WA coast ESU	NW	
	Mid-Columbia River spring-run ESU	NW	
	Upper Columbia River summer/fall-run ESU	NW	
	Southern OR/northern CA coasts ESU	NW	
	Deschutes River summer/fall-run ESU	NW	
Chum salmon	Hood Canal summer-run ESU	L	T
	Columbia River ESU	L	T
	Puget Sound/Strait of Georgia ESU	NW	
	Pacific Coast ESU	NW	
Sockeye salmon	Snake River ESU	L	E
	Ozette Lake ESU	L	T
	Baker River ESU	NW	
	Okanogan River ESU	NW	
	Lake Wenatchee ESU	NW	
	Quinault Lake ESU	NW	
	Lake Pleasant ESU	NW	
Steelhead	Southern CA ESU	L	E
	South-Central CA coast ESU	L	T
	Central CA coast ESU	L	T
	Upper Columbia River ESU	L	E
	Snake River Basin ESU	L	T
	Lower Columbia River ESU	L	T
	CA Central Valley ESU	L	T
	Upper Willamette ESU	L	T

Table 1.1. Status of West Coast salmonid species and ESUs (cont.)

Species	ESU	Listing status[a]	T/E status[b]
Steelhead (cont.)	Middle Columbia River ESU	L	T
	Northern CA ESU	L	T
	OR coast ESU	C	
	Southwest WA ESU	NW	
	Olympic Peninsula ESU	NW	
	Puget Sound ESU	NW	
	Klamath Mountains Province ESU	NW	

a. L = listed, C = candidate, NW = not warranted.
b. E = endangered, T = threatened.
c. Managed by NMFS every other year (jointly with Canada).

Source: NOAA, 2005.

1.3 Types of Oil-borne Wood Preservatives

Treated wood pilings, timbers, and other wooden lumber have been used in marine construction in the United States for more than a hundred years (Lebow and Tippie, 2001). Although some woods are more naturally resistant to deterioration, wood construction materials exposed to water must be preserved with chemicals to prevent deterioration and eventual destruction by marine borers such as crustaceans (gribbles, *Limnaria* spp.), mollusks (boring clams, *Teredo* or *Bankia* spp.), and other wood-degrading organisms, including fungi. To protect wood from these organisms, preservative formulations must be toxic to the wood-degrading organisms.

Oil-borne wood treatments include creosote, creosote mixed with coal tar or petroleum, and other preservatives such as pentachlorophenol (PCP) and copper naphthanate (CuN) (Table 1.2) (Hutton and Samis, 2000; AWPA, 2003). Creosote is the most commonly used wood preservative worldwide, and comprises nearly 15% of the total volume of wood treatment preservatives used in the United States (Crawford et al., 2000). PCP is not resistant to marine borers, and therefore is only recommended for pilings in freshwater or in saltwater splash zones. CuN currently is not recommended for use in either freshwater or saltwater. The remainder of the P8 preservatives listed in Table 1.2 are used so infrequently that they are not listed in the BMPs for oil-borne preservatives (Hutton and Samis, 2000; Lebow and Tippie, 2001; WWPI, 2002b). Therefore, in this report we confine our analysis of oil-borne preservatives to creosote.

Table 1.2. Coal-derived and oil-borne wood preservatives in the United States

Type of preservative	AWPA standard	Components
Creosote	P1/P13	Coal tar distillate
Creosote solution	P2	Mixture of creosote and coal tar
Creosote-petroleum solution	P3	Mixture of creosote and petroleum, comprising at least 50% creosote
Other oil-borne preservatives	P8	Pentachlorophenol (PCP or Penta) Copper naphthenate (CuN or CuNapth) Oxine copper (copper-8-quinolinolate or Cu8) Alkyl ammonium compound (AAC) 4,5-dichloro-2-n-octyl-4-isothiozolin-3-one (DCOI) 3-iodo-2-propynyl butyl carbamate (IPBC) Chlorothalonil (CTL) Tebuconazole (TEB) Propiconazole (PPZ) Chlorpyrifos (CPF)

Sources: AWPA, 2003; Dickey, 2003.

The American Wood-Preservers' Association (AWPA) currently approves only the P1/P13 creosote standard (AWPA, 2003). The term creosote in this report refers specifically to the AWPA-recognized P1/P13 creosote standard. Australia has a standard for pigment-emulsified creosote (PEC), which it claims does not leach from treated wood (Crawford et al., 2000). Because this compound is not available in the United States, we have excluded it from our analysis.

1.4 Creosote Composition

Creosote is a distillate of coal tar, and its chemical composition varies depending on the source of the coal tar and the distillation conditions and fraction removed. The World Health Organization (WHO, 2004) concluded that there might be 1,000 compounds present in a typical coal tar creosote mixture, though most of them are present in minute quantities. Creosote compounds can be distributed among several chemical classes, including polycyclic aromatic hydrocarbons (PAHs), alkyl-PAHs, tar acids/phenolics, tar bases/N-heterocyclics (quinolines and carbazoles), S-heterocyclics (thiophenes), O-heterocyclics/furans (dibenzofuran), and aromatic amines (such as aniline). A detailed discussion of the physical properties and chemical structures of these compounds is beyond the scope of this document. See WHO (2004) and Eisler (2000) for more details.

Several studies have included summaries of creosote compositions, including Ingram et al. (1982), Cooper (1991), U.S. EPA (2003b), and WHO (2004). WHO (2004) includes creosote compositional analyses from eight separate studies, including creosotes from the United States, Britain, Germany, and the former Soviet Union.

Table 1.3 contains summary statistics for the more prominent chemical compounds in creosote from each of the above sources. On average, the compounds shown in Table 1.3 comprise roughly two-thirds of creosote. The remaining one-third includes hundreds of other compounds, each comprising less than 1% of the total mixture.

Table 1.3. Summary statistics for major compounds in creosote (by percent)

Class	Compound	n	Max	Min	Mean
PAHs	Phenanthrene	9	21.0	6.7	13.3
	Naphthalene	10	15.5	1.3	9.1
	Acenaphthene	10	14.7	3.1	8.4
	Fluorene	10	10.0	3.1	6.3
	2-methylnaphthalene	9	12.0	1.2	5.6
	Fluoranthene	9	10.0	2.3	5.3
	1-methylnaphthalene	8	14.5	0.9	4.4
	Pyrene	10	8.5	1.1	4.3
	Anthracene	8	8.2	0.8	3.3
	Chrysene	9	6.1	0.1	1.9
Phenolics	Phenol	3	0.6	0.2	0.3
	Cresols	3	2.3	0.3	1.2
O-heterocyclics/furans	Dibenzofuran	9	7.5	1.1	4.7
N-heterocyclics	Quinoline	6	2.0	0.6	1.0
	Carbazole	6	3.9	0.2	1.6
S-heterocyclics	Benzothiophene	4	0.5	0.3	0.4

Sources: Ingram et al., 1982; Cooper, 1991; U.S. EPA, 2003b; WHO, 2004.

The data in Table 1.3 show a wide range in composition for many compounds, depending on the source of the creosote. Xiao et al. (2002) and the U.S. Environmental Protection Agency (U.S. EPA, 2003b) cite separate studies that list creosote composition as typically 85% PAHs, 10% phenolic compounds, and 5% heterocyclics. However, of the 10 creosote compositions that are included in Table 1.3, the greatest total of phenolic compounds (sum of phenol, 2,4-dimethylphenol, and cresols) is 3.5% (WHO, 2004).

PAHs are by far the most common compounds in creosote (Table 1.3). In addition to the PAHs listed in Table 1.3, high molecular weight PAHs such as benzo[*a*]pyrene (BaP), benz[a]anthracene, and benzo[b]fluoranthene are some of the more common compounds in creosote not listed in Table 1.3 (U.S. EPA, 2003b; WHO, 2004).

Based on creosote industry data, U.S. EPA (2003b) lists the top 17 aromatic hydrocarbons typically in creosote. These include the 10 PAHs in Table 1.3 [which comprise 80% of creosote in the U.S. EPA (2003b) example], plus biphenyl, 2,3-dimethyl naphthalene, 2,6-dimethyl naphthalene, 2-methyl anthracene, anthraquinone, 2,3-benzo(b)fluorene, and BaP. The U.S. EPA notes that 16 of the 17 compounds are on the U.S. EPA's List of Priority Pollutants, pursuant to the Clean Water Act.

The U.S. EPA has classified seven PAHs as Group B2 probable human carcinogens: BaP, benz[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, dibenz[a,h]anthracene, and indeno[1,2,3-cd]pyrene. Most of these have been identified in creosote, including BaP, the most studied PAH in terms of carcinogenicity (WHO, 2004). In addition, of U.S. EPA's 31 priority chemicals, eight are PAHs: acenaphthene, acenaphthylene, anthracene, benzo[g,h,i]perylene, fluorene, naphthalene, phenanthrene, and pyrene (U.S. EPA, 2005).

Many studies of PAHs and creosote compounds in aquatic and marine environments distinguish between light PAHs (LPAHs) and heavy PAHs (HPAHs). Generally, PAHs with two or three aromatic rings are denoted LPAH, while PAHs containing greater than or equal to four rings are termed HPAH. All U.S. EPA Group B2 probable human carcinogens are HPAH, while all but two (benzo[g,h,i)perylene and pyrene) of the eight U.S. EPA priority chemical PAHs are LPAH. This distinction becomes important in later discussions of creosote-related environmental fates and toxicities. When considering the environmental impacts and toxicity of leached creosote in this report, we often refer to the contaminants in leachate as "PAHs" for simplicity, though we in fact mean "PAHs, phenolics, heterocyclics, and other contaminants."

1.5 Creosote Regulations and Policies

Both the European Union and the United Kingdom have banned all nonprofessional use of creosote (HSE, 2005). The U.S. EPA published a risk assessment, described below, that will be used by the Agency to decide whether creosote will be re-registered as a pesticide. Meanwhile, in the absence of federal guidelines, many states and local agencies have implemented their own regulations. A thorough review of creosote regulations and policies is beyond the scope of this document. However, Table 1.4 provides some examples of creosote regulations and policies that have been enacted in the past few years and demonstrates the consistency of approaches toward creosote use in aquatic environments.

Table 1.4. Examples of creosote regulations and policies as of summer 2005

Management entity	Regulation/action	Source
Washington State Ferries	Washington State Ferries concluded that creosote-treated timbers were significantly degrading water quality in Puget Sound, and they commenced a large-scale project to replace all creosote timbers in the ferry system. This project has been ongoing since 2000. By 2012, Washington State Ferries will have replaced over 15 million board-feet of creosote timbers in Puget Sound.	1
Port of Port Angeles, Washington	In 2004, Port Angeles instituted prohibitions on the installation of creosote-treated timbers in waters under their jurisdiction.	2
Oregon Dept. of Environmental Quality, State Marine Board	BMPs for recreational boating facilities state that creosote-treated wood should be avoided, and existing creosote-treated wood pilings should be removed.	3
California Coastal Commission (CCC)	The CCC originally recommended that creosote-treated pilings be wrapped in plastic to prevent leaching of creosote into water. After discovering that the plastic wrap tears readily, they recommended that plastic pilings should be used.	4
U.S. Army Corps of Engineers, Los Angeles District	Standard permit conditions restricting the use of creosote-treated wood, and requiring maintained isolation of creosote via plastic wrappings.	5
Delaware Dept. of Natural Resources and Environmental Control	Delaware banned creosote-treated timbers for boat docks in the early 1990s.	6
New York State legislature	In 2004, the legislature passed S04975 to phase out the manufacture, sale, and use of creosote in the state. Gov. Pataki vetoed the bill.	7, 8
Rhode Island Coastal Resources Management Program (CRMP)	CRMP “Red Book“ of regulations specifies that no residential docks, piers, or floats may be constructed of creosote-treated timbers, and creosote may not be used as a wood preservative on wetland boardwalks.	9

1. WSDOT, 2005.
2. PPF, 2004.
3. Oregon DEQ, 2002.
4. CCC, 2003.
5. Personal communication, D.J. Castanon, U.S. Army Corps of Engineers, Los Angeles District, November 30, 2004.
6. Delaware Department of Natural Resources and Environmental Control, 1992.
7. Pesticide.Net, 2004.
8. Online Lawyer Source, 2004.
9. RI CRMC, 2005.

In 2003, the U.S. EPA performed a data review and risk assessment on creosote as part of the creosote re-registration process (U.S. EPA, 2003a). The studies they reviewed did not meet the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) guidelines, did not describe specific creosote compositions, and many of the studies examined the fate of specific PAHs rather than creosote as a whole. Based on these limited data, the U.S. EPA calculated risk quotients (RQs) for acute and chronic effects on fish using their Generic Expected Environmental Concentrations (GENEEC) computer model to create estimated environmental concentrations (EECs) of creosote compounds. The U.S. EPA's (2003a) conclusions follow:

> The Agency has concluded that risk to birds and terrestrial mammals is probably minimal, due to lack of exposure and the ability of these organisms to avoid creosote. Risk to terrestrial plants would also be considered minimal due to lack of exposure. However, risk to freshwater and marine/estuarine aquatic organisms is harder to quantitate using these data. Certainly there will be some exposure due to leaching from the treated wood into the aquatic environment; however, determining the amount of exposure and the amount of toxicity due to this exposure is difficult using the data at hand. The RQ values calculated with the available data do not demonstrate a concern for acute effects on aquatic organisms or chronic effects on freshwater fish. However, the EECs were calculated for the component PAHs, while the aquatic toxicity data were generated using whole creosote. The available data found in the open literature were not adequate to supply the information needed to assess chronic effects to freshwater invertebrates or to marine/estuarine aquatic organisms. It is not possible, therefore, to determine the chronic risk creosote may present to freshwater invertebrates and marine/estuarine aquatic organisms, including endangered species. However, the data indicate that creosote does not exceed the level of concern for acute toxicity to fish and aquatic invertebrates or for chronic toxicity to freshwater fish.

According to the U.S. EPA re-registration schedule, the U.S. EPA is expected to make a decision on the re-registration of creosote soon. As detailed in Chapters 2-4 of this report, the conditions under which toxic constituents of creosote can reach marine resources are common enough that U.S. EPA's conclusions may benefit from greater emphasis on the known transport and toxicity of toxic constituents, rather than on the uncertainties. U.S. EPA's description of some of the uncertainties is valid, but might better fit in a standard characterization of uncertainties in a more definitive finding regarding the risks that creosote constituents pose to elements of the marine environment.

1.6 Creosote BMPs

The AWPA and the Western Wood Preservers Institute (WWPI) maintain BMPs for creosote-treated wood (WWPI and Canadian Institute of Treated Wood, 1996; WWPI, 2002b; AWPA, 2003). Most other sources of creosote treatment BMPs (e.g., Hutton and Samis, 2000; Lebow and Tippie, 2001; WDNR, 2002) reference the AWPA and/or the WWPI. The BMPs are quite detailed, with different BMPs for different tree species and different creosote mixtures. These BMPs are readily available from AWPA and WWPI and therefore will not be described here. For the purposes of this report, we attempt to call attention to laboratory and field leaching studies where BMPs are not followed. Most researches specify when they are not following BMPs in their leaching tests, particularly as they pertain to creosote retention in the timber. However, verifying that every leaching study that we reviewed followed BMPs was not possible.

2. Models of PAH Leaching from Treated Wood and Environmental Exposure

In this chapter we review and evaluate models that have been developed to predict the leaching of creosote constituents, primarily PAHs, from creosote-treated wood and the resultant concentrations in the environment. The rate and amount of PAHs that leach from treated wood is a key component in the evaluation of the potential effects of creosote-treated wood on aquatic biota, and much study has been conducted in this area. Nearly all studies of leaching from creosote-treated wood have been conducted in the laboratory under controlled conditions. The leaching models that have been developed predict PAH leaching under such controlled conditions. Estimating the environmental concentrations that result from the leaching is a second component in evaluating potential effects on aquatic biota. Few field and laboratory studies address this component, but two transport models have been developed to predict concentrations of PAHs in surface water and sediments around creosote-treated piling, based on modeled leaching rates.

Our review focuses primarily on PAHs, but where their leaching characteristics have been studied, N-heterocycles are also discussed. In Section 2.1, we discuss factors that affect PAH leaching rates from creosote-treated wood. In Section 2.2, we review leaching models that have been developed and applied; in Section 2.3, we discuss predictions of environmental concentrations of PAHs resulting from the use of creosote-treated wood; and in Section 2.4, we present conclusions.

2.1 Factors that Affect PAH Leaching from Treated Wood

The rate at which PAHs leach from treated wood is a complex function of many factors, including the nature of the wood, the treatment solution and method, and various environmental variables. In this section, information on factors that affect PAH leaching rates from treated wood is presented and summarized as a prelude to the description of the PAH leaching models contained in Section 2.2. In Section 2.1.1, specific laboratory and field studies on PAH leaching rates and the variables that can affect them are presented. In Section 2.1.2, review articles and other more general information on factors that affect PAH leaching from treated wood are summarized.

2.1.1 Laboratory observations of PAH leaching from creosote-treated wood immersed in water

Ingram et al. (1982)

Study description

Ingram et al. (1982) measured leaching of creosote from dual-treated southern pine pilings immersed in freshwater and seawater. The authors quantified the effects of water temperature, piling age, and exposure time on leaching rates.

The test pilings were treated to a preservative retention of 354 to 378 kg/m^3, and then aged for six months in open air. Leaching from the recently treated pilings was compared to leaching from dual-treated pilings that had been in seawater for approximately 12 years off Key West, Florida. Preservative retention in the aged sections ranged from 442 to 596 kg/m^3. Before testing, the freshly cut ends of all piling sections were coated with epoxy resin.

Water concentrations of 16 PAHs and dibenzofuran were measured. The tests were conducted in large (300-gallon steel tanks) and small (4-liter glass beakers) vessels. In both tests, the water in test vessels was stirred continuously. The focus of the small vessel studies was to compare leaching from recently treated wood in freshwater (distilled water), aged wood in freshwater, and aged wood in seawater. Water temperatures were held at 20ºC, 30ºC, or 40ºC. Test duration was 30 days. For the large vessel studies, pilings were placed in 200 to 250 gallons of seawater for 12-21 days. Water temperature was controlled to between 18ºC and 21ºC. Two-liter samples were removed daily, and analyzed by gas chromatography.

Temperature effects on leaching

Leaching rates in freshwater and saltwater increased with increasing water temperature (Table 2.1), with slopes of 1.5 and 1.7, respectively (Figure 2.1). The rates presented in Table 2.1 are an average of leaching over the first three days following immersion. Vertical bars in Figure 2.1 show the range of the leaching rates measured. At each temperature tested, total PAH leaching (the sum of all compounds measured) was higher in freshwater than in saltwater. Ranges of water concentrations are reported in the paper for each of the 16 PAHs plus dibenzofuran, and leaching was generally more rapid for the more water soluble compounds.

Table 2.1. Temperature and salinity effects on PAH leaching rates

Temperature (ºC)	Salinity (ppt)	Minimum (µg/cm^2 per d)	Maximum (µg/cm^2 per d)
20	0	26.6	35.9
30	0	39.4	56.9
40	0	52.5	70.2
20	30	7.94	7.94
30	30	14.7	27.7
40	30	36.6	47.9

Source: Ingram et al., 1982.

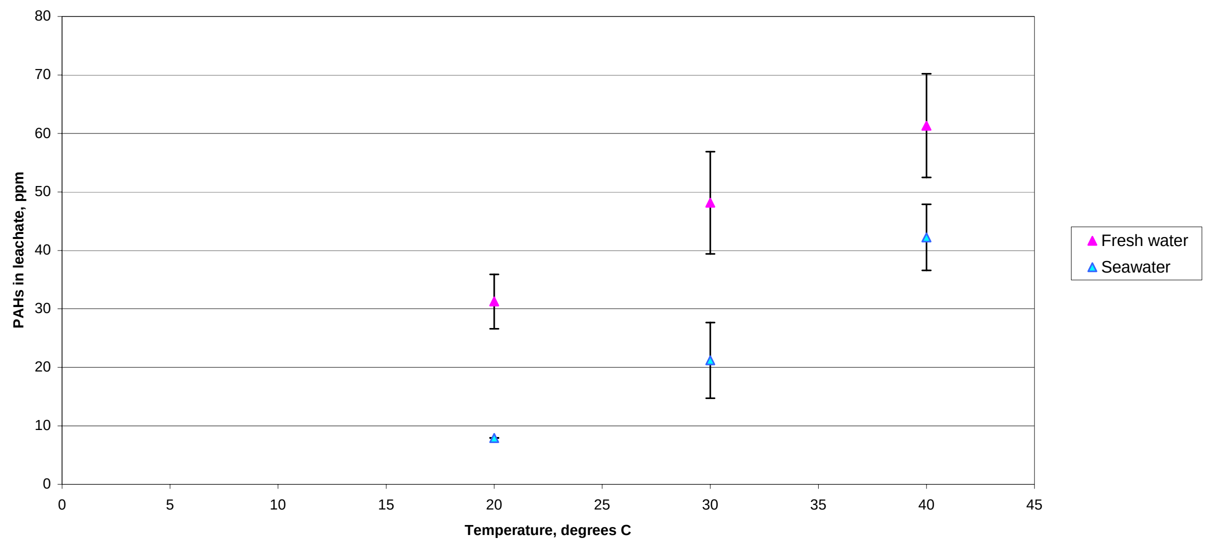

Figure 2.1. Effects of temperature and salinity on leaching.

Source: Ingram et al., 1982.

Aging effects on leaching

Leaching of PAHs into seawater over 30 days was greater from recently treated pilings than from aged pilings. Final concentrations of PAHs in seawater were approximately 750 µg/L for the aged wood and 1,000 µg/L for the recently treated wood (as estimated from graphs presented in Ingram et al., 1982). The 12 years of field installation in seawater appeared to have reduced leaching rates by only about 25%. This reduction is smaller than most model predictions suggest (see Section 2.3). Since the sample ends were sealed, leaching from the freshly cut portions should not have been a factor in the leaching rates. However, the aged and recently treated samples probably differed in other respects, including creosote formulation, initial retention, treatment method, post-treatment processing and storage, wood density, and possibly, wood species. The results may also be influenced by the test method: the water was stirred but not replaced, so increasing concentrations in the water over time might have limited leaching and diminished differences between the sample types.

PAH concentrations over time

Ingram et al. (1982) observed a decline in the concentration of PAHs in the large test tank over the 288-hour run of their “long-term” leaching experiment. In this study, concentrations leached from recently treated wood peaked at 432 parts per billion (ppb) after 72 hours, and declined to 156 ppb after 288 hours. PAH concentrations in the tank containing aged wood declined even more. The aged samples might have contained microbes that degrade PAHs. Therefore, the reported PAH leaching rates might underestimate either the total amount of leaching or the leaching rate. Furthermore, the tanks and beakers were not sealed, and the loss of volatile PAHs such as naphthalenes cannot be ruled out.

Kang et al. (2003)

Study description

Kang et al. (2003) determined leaching rates of individual PAHs at two flow rates: 1.2 cm/sec, and 3.3 cm/sec. Samples of Douglas fir lumber were treated with P1/P13 creosote to a retention of 12 pounds per cubic foot (pcf), in compliance with the WWPI’s BMPs. Freshly cut ends were sealed with epoxy. The samples were completely immersed in carbon-filtered tap water held at approximately 12°C. Water samples for PAH analysis were collected periodically throughout the 14-day test.

Effect of flow rate on leaching

Initial loss rates at 3.3 cm/sec were at least double, and, often, substantially more than double, the loss rates for the same compounds at 1.2 cm/sec.

Variations between individual PAHs

Leaching rates at the two flow rates over the 14-day test were reported for naphthalene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, and pyrene. As observed in several other studies, phenanthrene appeared to leach at a higher rate than predicted by its water solubility, but the remaining compounds tended to leach in a more predictable manner based on water solubilities.

Non-detected compounds

HPAH compounds were not detected in the leachate at any time during the test. Either these compounds did not leach from the wood, they were not detected because of some deficiency of the analytical method, or they were lost through volatilization, biodegradation, sorption to organic matter, or other route. HPAH compounds are routinely detected in similar tests, so it is unlikely that they did not leach from the samples in this test. Because of their low vapor pressures, it is also unlikely that they were lost though volatilization.

Naphthalene was lost at a high rate initially, but concentrations declined to below detection after four days. No PAHs were detected after seven days. The decline and lack of detection may reflect biodegradation, as suggested in Ingram et al. (1982), or methodological problems, as suggested above.

Becker et al. (2001)

Study description

Becker et al. (2001) compared leaching of creosote compounds in three water preparations. Samples comprised 5-mm diameter borings of *Pina nigra*, cut to 10-mm lengths. Samples (10 g each) were immersed in 100 mL of deionized filtered water, deionized water buffered to pH 4.7, or a solution containing humic substances. The water was stirred continuously during the 120-hour test. Water changes were performed at 24 and 48 hours.

Effect of water chemistry on leaching

The leaching rates of most of the creosote compounds measured were highest in deionized water. Leaching rates of N-heterocyclic compounds were greater than leaching rates of PAHs. The loss rates of N-heterocycles declined rapidly with time, but still exceeded the loss rates of the PAHs by approximately an order of magnitude at the end of the study. N-heterocycles are susceptible to protonation, unlike homocyclic PAHs. Even partial protonation tends to increase the water solubility of a compound, making it more available for leaching (Schwarzenbach, 1993; as cited in Becker et al., 2001), particularly in low pH water.

Although this study showed high leaching of N-heterocycles (in apparent contrast to other study results), most of the other researchers did not analyze for these compounds. In addition, because this study used small wood samples with a higher surface area to volume ratio, which increases the amount of leaching per volume, the results are not directly comparable to studies performed with larger samples of wood.

Xiao et al. (2000)

Study description

Xiao et al. (2000) treated Douglas fir samples with P1/P13 creosote in accordance with WWPI's BMPs. Freshly cut ends were sealed with epoxy, and the samples were wrapped in plastic to reduce volatilization losses between treatment and leaching in deionized water. An antimicrobial compound was added to the test water to prevent loss of creosote constituents through biodegradation. The tests were run at 35ºC. The water was replaced after each 72-hour test run. Wood samples were subjected to three consecutive test runs, and water concentrations were averaged among the runs at each time point. Water samples were collected regularly for analysis of four PAHs plus dibenzofuran (acenaphthene, fluorene, phenanthrene, and fluoranthene) using solid-phase microextraction (SPME) fibers analyzed by gas chromatography with a flame ionization detector (GC/FID).

PAH leaching rates over time

All components except phenanthrene leached at linearly declining (though different, based on their relative water solubilities) rates over the first eight hours. Phenanthrene leached at a higher rate than predicted by its solubility. With this exception, its leaching behavior was similar to that of the other PAHs.

Chemical concentrations appeared to approach a steady state at about 24 hours. The time between sample collection and analysis increased during the course of the study, and recovery rates were reduced by 8 to 14% per day of delay in analysis. Therefore, the apparent steady state might have been a function of increasingly poor compound recovery in samples collected at later intervals. Also, averaging water concentrations across three consecutive runs might have reduced the reported average concentrations since concentrations decreased with each subsequent round of leaching.

Xiao et al. (2002)

Study description

In a subsequent experiment, Xiao et al. (2002) treated Douglas fir samples with P1/P13 creosote to a retention of 12 pcf in accordance with WWPI's BMPs. Freshly cut ends were sealed with epoxy, and the samples were wrapped in plastic to reduce volatilization losses between treatment and leaching in deionized water. An antimicrobial compound was added to the water to prevent loss of creosote constituents through biodegradation. Test conditions included three temperatures (5ºC, 20ºC, and 35ºC) and three water flow rates (0 cm/sec, 4 cm/sec, and 8 cm/sec). Tanks were sealed and airspaces minimized to reduce volatilization of PAHs. The water was replaced after each 72-hour test run. Water samples were collected regularly for analysis of PAHs.

Variations between individual PAHs

During the test, there was variable detection of naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene, including non-detects. Those chemicals were excluded from further analysis. Concentrations of the same four remaining PAHs, plus dibenzofuran, in water were determined as in the previous study, by sampling with SPME (fibers), followed by GC/FID analysis. This method avoided delays in sample analysis. A high initial leaching rate was followed by an apparent decrease in leaching rate. Leaching of the remaining individual components was comparable to leaching reported by Ingram et al. (1982).

Effect of temperature and flow rate on leaching

Leaching rates of the sum of the PAHs measured increased with temperature and flow rate (Figure 2.2). The effect of temperature depended on flow rate; temperature had a smaller effect in still water, but an increasing effect with increasing flow rate. Leaching was greatest in warm, turbulent water.

Bestari et al. (1998a)

Study description

Bestari et al. (1998a) designed an outdoor freshwater mesocosm study to mimic field leaching conditions as closely as practical. Treated Douglas fir pilings (retention rate not specified) were suspended in 12,000 L mesocosms containing sediment, rooted and floating macrophytes, fish, phytoplankton, zooplankton, and benthic invertebrates. The pilings did not contact the sediment. Water column and sediment PAH concentrations were analyzed for 15 priority-pollutant PAHs over 16 weeks.

Leaching rates of individual PAHs

The authors estimated a leaching rate of 50 $\mu g/cm^2$ per day, leached primarily from the outer 1 mm of the piling surface. They found no differences in the relative amounts of individual PAH compounds remaining in the piling. Bestari et al. interpreted this to mean that all PAH components either leached at an equal rate, or that some type of degradation process was removing the remaining compounds in proportion to the compounds that leached.

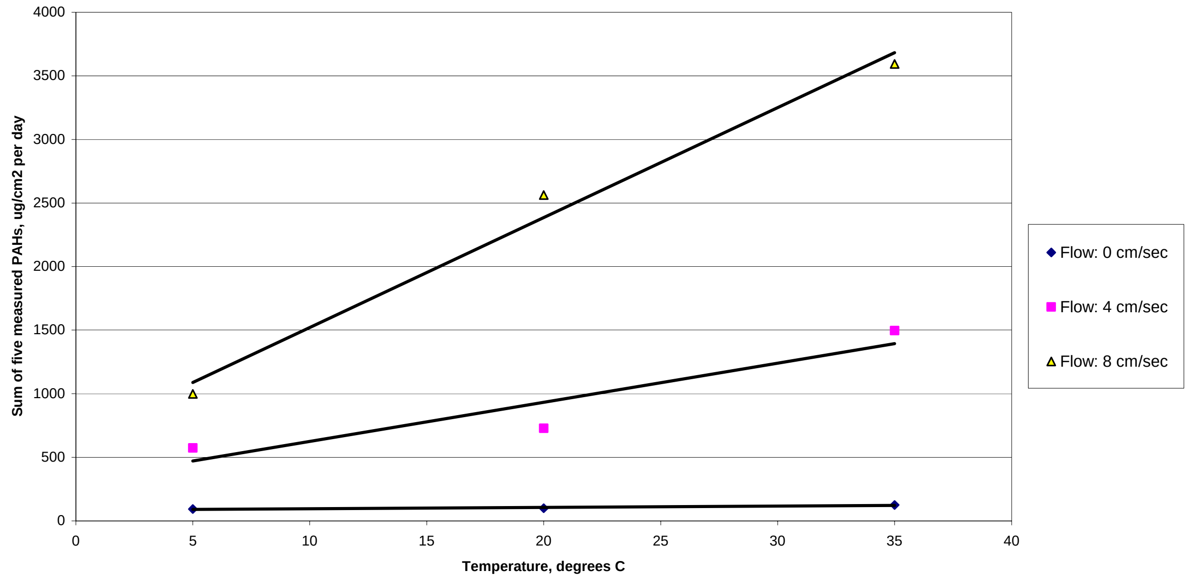

Figure 2.2. Effect of flow rate and temperature on total PAH leaching.

Source: Xiao et al., 2002.

Rao and Kuppusamy (1992)

Rao and Kuppusamy (1992) conducted field leaching tests of tropical wood species treated with a creosote formulation and method that differ from those currently recommended for use in the United States. Two relevant findings of this study are that leaching from samples treated to the same retention varied strongly both by species and within species tested.

2.1.2 Field observations of PAH leaching from creosote-treated wood subjected to natural or simulated rainfall

Whiticar et al. (1994)

Study description

Whiticar et al. (1994) subjected untreated and creosote-treated poles and timbers to natural and simulated rainfall. The treated wood was treated to retentions of 166 kg/m^3 or 198 kg/m^3. The leachate was collected and analyzed for 18 PAHs, phenols, and total organic carbon (TOC). The document reports the sum of the measured PAH concentrations, and concentrations of phenanthrene, naphthalene, benzo[a]pyrene, phenols, and TOC.

Concentrations of individual PAHs

The results of this study cannot be used to quantify leaching rates because of the design, but the relative concentrations of the individual PAHs leached from the treated wood are of interest (Table 2.2). More phenanthrene was present in the leachate than any other PAH, even though more naphthalene was present in the creosote, and the water solubility of phenanthrene is lower than that of naphthalene. This suggests that either there was less naphthalene than phenanthrene in the whole creosote before treatment, as reported by Lorenz and Gjovik (1972; as cited in Ingram et al., 1982), or that the naphthalene in the sample was lost by volatilization before analysis. Naphthalene has a relatively high vapor pressure compared to the other 17 PAHs measured.

Table 2.2. Relative concentrations in leachate

Substance	Minimum (mg/L)	Maximum (mg/L)	Solubility (mg/L)
Sum of 18 PAHs	0.6	3.2	N/A
Naphthalene	0.03	0.3	34.4
Phenanthrene	0.2	1.1	1.0
Benzo[a]pyrene	0.00066	0.026	Highly insoluble
Phenols	0.7	6.0	Highly soluble

Source: Whiticar et al., 1994.

The TOC released from untreated (control) timbers was as high or higher than the TOC released from treated timbers. TOC ranged from 11 to 261 mg/L from untreated timbers and from 11 to 194 mg/L from creosote-treated timbers. Much of the TOC released from the untreated timbers was thought to be resin acids.

2.1.3 General review papers of PAH leaching

Two papers review creosote leaching research. Cooper (1991) summarized losses of creosote from treated wood in laboratory and environmental exposures, and Sinnott (2000) described the timing of loss of creosote components based on reviews of a number of studies. Other references, including some of the specific studies cited above, draw general conclusions concerning factors that affect PAH leaching from treated wood. In this section, we list and briefly summarize the factors generally recognized as being the most important in determining PAH leach rates from treated wood.

(i) Wood species, density, and surface area

Leaching varies markedly between woods of different species, probably for many complex reasons that are not well understood (Cooper, 1991; Rao and Kuppusamy, 1992). In southern pine and Douglas fir, leaching decreases as wood density increases (Leach, 1960; Miller, 1972; both as cited in Cooper, 1991). There have been no systematic analyses of leaching rates by species or wood density.

Leaching also predictably increases as the surface area to volume ratio of the wood increases (Leach, 1960; Colley and Burch, 1961; Stasse and Rogers, 1965; Gjovik, 1977; Miller, 1977; all as cited in Cooper, 1991), so the shape and configuration of structures built from treated wood can be a factor in predicting or limiting overall leaching rates.

(ii) Preservative formulation and loading rate

Different preservatives are known to leach at different rates (Cooper, 1991), but the magnitude of the variability is not well quantified. In the United States, currently only the P1/P13 formulation of creosote is approved by AWPA for use in aquatic systems, and BMPs specify a preferred loading rate.[1] In recent studies, use of this single formulation and loading rate has allowed for investigation of leaching related to non-formulation variables. In the past, however, a number of creosote formulations and application methods and rates were used, complicating the comparison of leaching studies from different eras. Therefore, few quantifiable conclusions can be drawn about how different preservative formulations and application methods have influenced leaching rates over time.

In addition, as the preservative loading rate increases, the leaching rate may increase (Cooper, 1991). The effect of loading rate is small and inconsistent relative to environmental factors such as temperature and water flow rate.

(iii) Individual PAH compounds

The water solubilities of creosote components influence their relative leaching rates in predictable ways (Ingram et al., 1982; Cooper, 1991; Whiticar et al., 1994). Lower boiling point, low molecular weight compounds [compounds with an atomic mass less than 200 atomic mass units (amu)], and 1 to 3 benzene rings, comprise approximately 61% of the PAH compounds in creosote. These compounds dissolve more readily in the water column than the heavier PAHs. The higher molecular weight PAHs, which are compounds with an atomic mass greater than 200 amu, and 3 or more rings, are lost from wood more slowly. These heavier PAHs are more likely

1. Dual treatment of pilings with chromated copper arsenate and P1/P13 creosote is also approved by AWPA, but the leaching characteristics of dual-treated wood versus wood treated with only P1/P13 creosote have not been studied.

to accumulate in sediments than remain dissolved in the water column. Brooks (1994) presents a compilation of percent composition for 13 PAHs in creosote-treated wood.

(iv) Environmental factors

The factors that affect leaching rates most significantly are temperature, water chemistry, water flow, and disturbance or abrasion. Figure 2.1 illustrates higher leaching rates in freshwater than saltwater, and the effect of temperature on leaching rate (Ingram et al., 1982). Figure 2.2 shows that the combined effects of temperature and flow are greater than the effects of either alone (Xiao et al., 2002). Becker et al. (2001) found that leaching of PAHs and N-containing heterocyclic compounds was greatest in deionized water; less in a slightly acidic, buffered solution; and least in a solution containing humic substances.

Disturbance and abrasion, which expose more surface area and sections of wood farther from the surface, can maintain higher leaching rates over time. For example, Bestari et al. (1998a) estimated that most of the leaching they observed in their outdoor freshwater mesocosm derived from the outer 1 mm of the piling surface. Removal of the outer 1 mm of the piling surface would expose less weathered wood, and could increase leaching long after the initial immersion. Indeed, most of the investigators in the studies reviewed in this section applied epoxy to cut ends of samples to minimize the effect of disturbance and abrasion as confounding factors.

(v) Time since treatment

In general, in the absence of disturbance and abrasion, leaching decreases with time since treatment whether the wood is kept in storage or placed in the water. Numerous investigators report substantial losses by volatilization of certain creosote components during dry storage (Stasse and Rogers, 1965; Stasse, 1966; Arsenault, 1973; Ingram et al., 1984; all as cited in Cooper, 1991). Whiticar et al. (1994) document both volatilization losses and rainwater leaching losses of creosote components during outdoor storage. Similarly, numerous investigators have documented a decline in leaching rates over time following installation in water (Leach, 1960; Colley and Burch, 1961; Stasse and Rogers, 1965; Gjovik, 1977; Miller, 1977; all as cited in Cooper, 1991). Furthermore, the WWPI BMPs and other post-treatment processing can reduce the rate of leaching (WWPI and Canadian Institute of Treated Wood, 1996; WWPI, 2002a).

2.2 Models of PAH Leaching Rates

Three investigators have used mechanistic understanding of leaching rates and relevant factors to develop models of PAH leaching rates. Dr. K. Brooks, Dr. T. Poston, and Dr. Y. Xiao each lead the development of models to describe the leaching of PAHs from treated wood. In the sections below, we describe and evaluate these models. Because of the influence of multiple factors on

PAH leaching rates and the relative paucity of empirical data on PAH leaching that can be used directly in an environmental risk assessment, the available PAH leaching rate models should be viewed as incompletely calibrated to realistic environmental settings, but still useful approximations of known first-order mechanistic processes that affect leaching and transport of PAHs, including in environmental settings.

2.2.1 Model descriptions

Brooks CREOSS model

Dr. K. Brooks developed a model to predict water column and sediment concentrations of PAHs near creosote-treated wood installations. He has written two descriptive papers (Brooks, 1994, 1997) and produced several versions of a spreadsheet model, the most recent of which is called "CREOSS" (copy in Appendix to this report; Brooks, 2004a). Versions of the model have been reviewed by industry and government representatives. These reviews have included comparisons between model predictions and environmental PAH concentrations. The model has not been published in the peer-reviewed literature.

Below, we describe the equations CREOSS uses to calculate a water concentration of PAHs and a leaching rate of PAHs. The model is not set up to calculate a leaching rate, but by rearranging some of the equations, a leaching rate can be derived.

Migration factor

The first step in deriving a leaching rate is the calculation of a unitless "migration factor" (Equation 1). Calculation of the migration factor requires the user to input water temperature and salinity. The migration factor increases with water temperature and decreases with salinity. Default input values are 30 parts per thousands (ppt) salinity and 15ºC.

$$\text{Migration factor} = \left[24.4 + \left(0.78 \times \text{WaterTemp}\right) - \left(0.58 \times \text{Salinity}\right)\right] \qquad \text{Eq. 1}$$

Water concentration

The migration factor is used to calculate a water concentration (Equation 2). The equation also requires inputs of piling radius, an "age factor," a "retention factor," and a water flow rate term ("model velocity").

$$\text{Water concentration} = \frac{\left[\left(1{,}000{,}000 \times \text{MigrationFactor}\right) \times \left(3.14 \times 2 \times \text{PilingRadius}\right) \times \text{AgeFactor} \times \text{RetentionFactor} \times \text{WaterPartitioningCoefficient}\right]}{\left(2 \times 86{,}400 \times \text{PilingRadius} \times \text{ModelVelocity}\right)} \qquad \text{Eq. 2}$$

The term "water partitioning coefficient" describes the partitioning of PAHs between the dissolved and particulate compartments in the water column, and for the purpose of this equation, a default of 1.0 (indicating that all of the PAHs are assumed to be in the dissolved state) is used.

The piling age factor is calculated as an exponential decay function (Equation 3),

$$\text{Piling age factor} = \exp\left(\frac{-\text{piling age in years}}{10}\right) \qquad \text{Eq. 3}$$

The default value for piling age in the CREOSS model, 0 years, yields the highest possible piling age factor. Over the short term (less than one year), the decline in value of the piling age factor is nearly linear. After 10 years, the piling age factor decays to 0.37, or a leaching rate that is 37% of the rate at installation (Figure 2.3). After 20 years, it decays to 0.14.

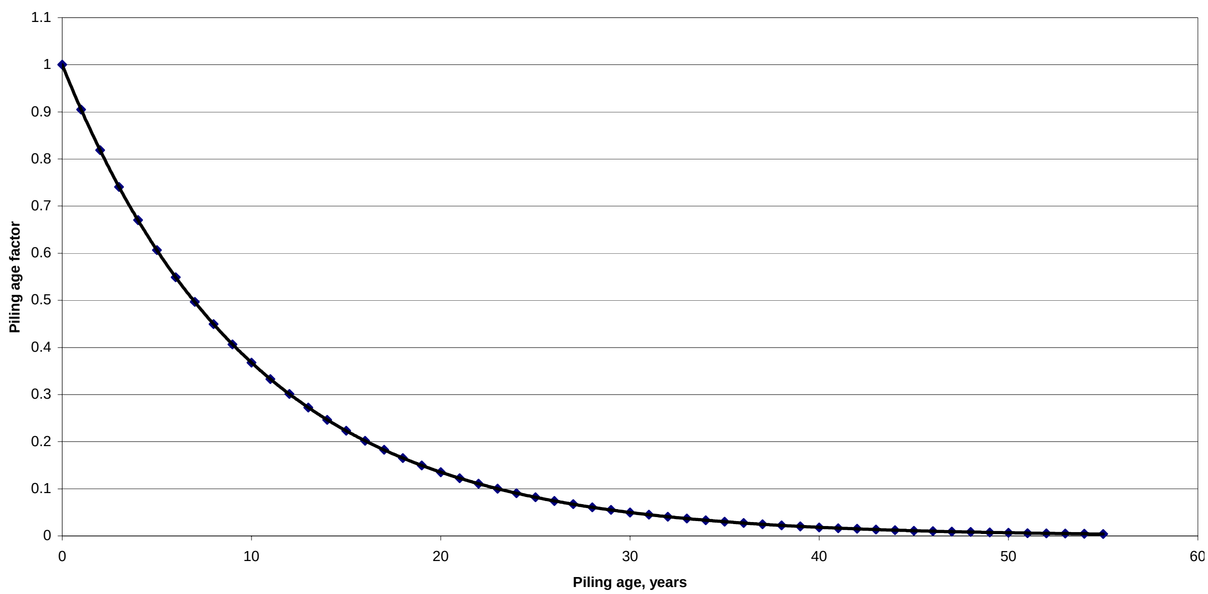

Figure 2.3. Piling age factor value over time, CREOSS model.

Source: Brooks, 2004a.

The retention factor is calculated as (Equation 4):

$$\text{Retention factor} = \exp\left\{0.5\left[\left(\frac{\text{piling retention in pcf}}{22.4}\right) - 1\right]\right\} \qquad \text{Eq. 4}$$

Although the retention factor is calculated as an exponential function, the formula yields a linear output over the range of realistic input values for piling retention, and the potential range of values is small. Using the default value for piling retention in CREOSS, 27 pcf, the retention factor is 1.108.

Leaching rate

The predicted leaching rates (µg/cm^2 per day) in fresh and seawater, calculated using the default values, are (Equation 5):

$$\text{Leaching rate} =$$
$$\left[24.4 + (0.78 \times \text{WaterTemp}) - (0.58 \times \text{Salinity})\right] \times \exp\left(\frac{-\text{Piling age}}{10}\right) \times \exp\left\{0.5\left[\left(\frac{\text{Piling retention in pcf}}{22.4}\right) - 1\right]\right\} \qquad \text{Eq. 5}$$

40.0 µg/cm^2 per day in freshwater, and 20.7 µg/cm^2 per day in seawater (at 30 ppt salinity).

Poston et al. (1996) model

The Poston et al. (1996) water concentration model depends on assumptions about the leaching rate of PAHs from wood. The model uses a freshwater leaching rate of 40 µg/cm^2 per day of total creosote, from Brooks (1994), that is assumed to be constant over the first four days following piling installation. The model assumes that the components of creosote migrate from the treated wood in proportion to their concentration in the wood. The proportions are taken from a Brooks (1994) compilation of percent composition for 13 PAHs in creosote-treated wood. This assumption is not supported by laboratory leaching experiments.

Xiao et al. (2002) model

This report presents insufficient details to permit an analysis of the leaching model presented.

2.2.2 Applicability and limitations of leaching rate models

Brooks (2004a) CREOSS model

The CREOSS model is complex, and documentation is essential to understand the model design. Currently, model documentation (Brooks, 1997) is older than the most recent model version, and certain contradictions are apparent. For example, the model documentation (Brooks, 1997) states that different leaching rates are used for LPAH and HPAH. The spreadsheet, however, uses the same migration rates for all components of creosote. The model documentation itself states that this assumption is not supported by laboratory studies. In addition, the documentation of the model is insufficient to address issues such as unit consistency and the treatment of time, and it is difficult to determine which portions of the current model are mechanistic, which are empirical, what data the empirical portions are based on, and how calibration was accomplished.

In CREOSS, leaching rate is unaffected by water velocity. Water velocity only modifies a final water concentration. This conflicts with empirical data from Xiao et al. (2002), who found large increases in leaching rates as water velocity increased (Figure 2.2).

Empirical results from Ingram et al. (1982) and modeled results from CREOSS under the conditions tested in Ingram et al. (1982) are shown in Figure 2.4. Over the range of water temperatures tested by Ingram et al., leaching rates increased with temperature. The lowest temperature in the Ingram et al. test was 20°C, and if the slope of the temperature-leaching relationship above 20°C holds below 20°C, then CREOSS might over-predict leaching rates in both fresh and seawater at temperatures below 20°C.

Figure 2.4 also includes three data points from Miller (1977) and one from Graham (1991; as cited in Brooks, 1997). The Miller data points are for three pilings that were immersed in seawater for two years at a mean temperature of 10.4°C. The loss rate from one of the pilings, 89.9 $\mu g/cm^2$, is nine times greater than the maximum loss rate measured by Ingram et al. (1982) at the lowest temperature they tested in seawater (20°C). The loss rate from the other two similarly exposed pilings was zero (the two data points overlie one another in Figure 2.4). Brooks (1997) averaged the three Miller (1977) loss rates. Graham's single reported average leaching rate, 27.93 $\mu g/cm^2$ per day at 19ºC in seawater (Figure 2.4), is nearly triple that reported by Ingram et al. (1982). Discrepancies between migration rates reported by Ingram et al. (1982), Miller (1977), and Graham (1991) may be at least partially explained by the fact that Ingram et al. used WWPI BMPs, which specify treatment practices intended to minimize post-treatment loss of preservative. Regardless, it is unclear whether data from these studies were used to develop or calibrate the CREOSS model, or if the studies were cited for comparison.

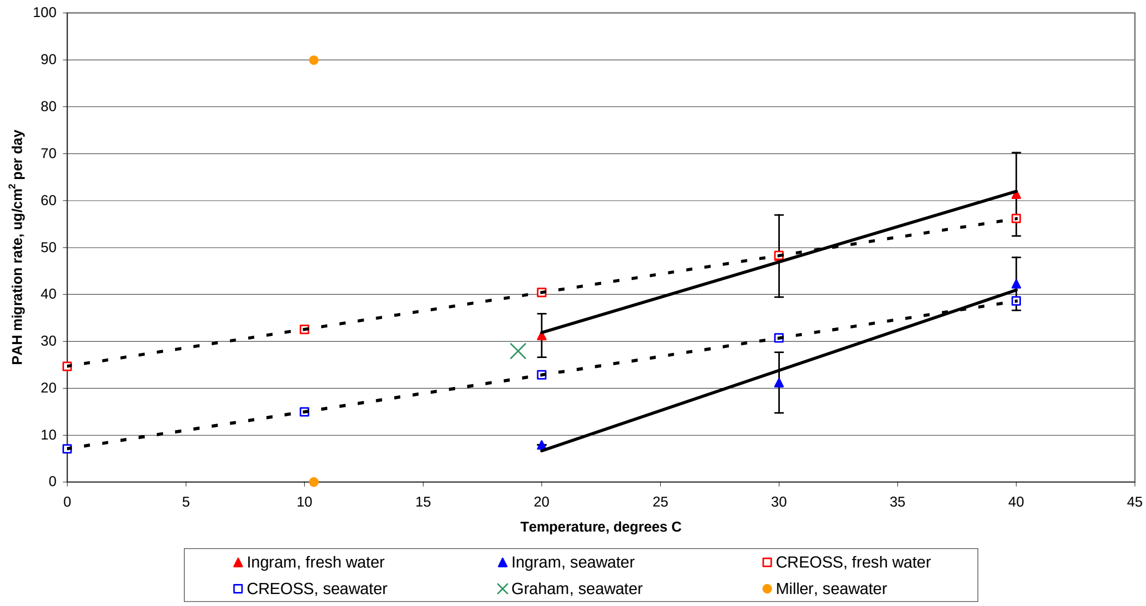

Figure 2.4. Temperature and salinity effects on leaching.

Sources: Ingram et al., 1982; CREOSS model output, Brooks, 2004a.

In CREOSS, all components of creosote leach equally as migration rates change due to changes in temperature, salinity, or other factors. Therefore, if the model over-predicts the overall migration rate, as suggested by comparison to empirical data in Figure 2.4 for temperatures below 20°C, the migration rate and amount of the less water soluble fractions leached is likely to be more over-predicted than the migration rate and amount leached of the remaining, more water-soluble fractions of creosote.

Poston et al. (1996)

The Poston et al. (1996) model uses Dr. Brooks' leaching assumptions. The applicability and limitations of those assumptions, as described above, also apply to the Poston et al. model.

2.2.3 Conclusions

Although the existing models do not account for all of the relevant data and do not contain complete documentation in some cases, they appear to adequately represent many first-order mechanisms of PAHs transport from creosote-treated wood into aquatic environments. The models account for differential transport related to salinity, temperature, water flow rate, time since application, and chemical constituents. In Section 2.3, we evaluate how well environmental concentrations are predicted by the models.

2.3 Predicting Environmental Concentrations of PAH Resulting from the Use of Treated Wood

PAH leaching rates can be used to predict concentrations in the environment. Predicted environmental concentrations can then be compared to toxic effects thresholds (Chapters 3 and 4). PAHs in the aquatic environment are present in both dissolved form and adsorbed to particulate materials. The fate and transport of PAHs in the environment depends on concentrations in both the water column and sediments. Lower boiling point, low molecular weight compounds dissolve more readily in the water column than the heavier PAHs. The higher molecular weight PAH compounds in creosote tend to accumulate in sediment rather than remain dissolved in the water column.

Transport models estimate concentrations of PAH compounds in the surrounding water column and sediments. Below, we describe a transport model that predicts water column and sediment concentrations in tidal and non-tidal flows, and a transport model that estimates mean water column concentrations based on the ratio of the mass of contaminant leached to the volume of receiving water. The underlying objective of the models, to predict the PAH concentrations that occur under realistic environmental conditions, is the same, although their approaches differ.

2.3.1 Description of the available models

Brooks (1997)

Model description

Brooks (1997) developed a spreadsheet transport model that predicts water column and sediment concentrations of creosote-borne PAHs that leach from treated wood. The model estimates average concentrations in the water column in a cylindrical volume of water surrounding a piling, and PAH deposition in sediments with distance from the piling.

Fifteen input parameters (Table 2.3) that can be measured or estimated by the user are required to run the model. A set of recommended default input parameters for freshwater, marine, and estuarine environments is provided for cases where field data are unavailable and cannot be estimated (Brooks, 1997).

Table 2.3. Required input parameters

Parameter	Units
Piling retention of creosote	pcf
Average piling radius	Cm
Piling age	Years
Average annual water temperature	°C
Salinity	ppt
Sediment particle settling velocity	0.05 cm/s for silt; 0.0005 cm/s for clay
Sediment density	g/cm^3
Steady state current speed	cm/sec, measured at slack tide
Average maximum tidal speed	cm/sec
Redox potential discontinuity (RPD)	cm
Sediment TOC	%
Sediment total PAH standard	parts per million (ppm) TOC
Maximum allowable sediment PAH	ppm TOC
PAH water partition coefficient	unitless
PAH sediment partition coefficient	unitless

The model calculates a series of intermediate outputs including migration, age factor, retention factor, degradation coefficient, model velocity, and geometry factor as follows:

$$\text{Migration rate } (\mu g/cm^2 \text{ per d}) = 24.4 + 0.78\,T - 0.58\,S \qquad \text{Eq. 6}$$

$$\text{Age factor} = \exp\left(\frac{-A}{10}\right) \qquad \text{Eq. 7}$$

$$\text{Retention factor} = \exp\left[\frac{\left(\frac{\text{Ret}}{22.4} - 1\right)}{2}\right] \qquad \text{Eq. 8}$$

$$\text{Degradation coefficient} = \frac{\exp\left[\left(\frac{4 - \text{RPD}}{3}\right)^3\right]}{0.047\,T} \qquad \text{Eq. 9}$$

$$\text{Model velocity (cm/s)} = V_{ss} + 0.64\, V_{max} \qquad \text{Eq. 10}$$

$$\text{Geometry factor} = 1 + \frac{V_{model}}{10} \qquad \text{Eq. 11}$$

where:

T	=	temperature (°C)
S	=	salinity (ppt)
A	=	age of piling (years)
Ret	=	initial creosote retention of piling (pcf)
RPD	=	redox potential discontinuity (cm)
V_{ss}	=	steady state velocity (cm/s)
V_{max}	=	maximum tidal velocity (cm/s)
V_{model}	=	model velocity.

These intermediate outputs are then used to calculate concentrations of leached PAH in the water column and sediments. Equation 12 is used in the model to estimate water column concentrations of PAHs leached from creosote-treated pilings:

$$PAH_{water}\ (\text{pptr}) = \frac{83333.3 \times WPC \times M_r \times A_f \times Ret_f \times R_p \times G_f}{\left[\left(1800 \times V_{model} + R_p\right)^2 - R_p^{\ 2}\right]} \qquad \text{Eq. 12}$$

where:

WPC	=	water partition coefficient (defines the proportion of PAH assumed to be dissolved in the water column)
M_r	=	migration rate
A_f	=	age factor
Ret_f	=	retention factor
R_p	=	piling radius
G_f	=	geometry factor.

The tidal current equation (an input to model velocity) is based on an equation for harmonic motion, assuming a frequency of 12 hours. Transport appears to be based on advection only (molecular and turbulent diffusion are not considered), but it is not clear how advective transport is modeled.

The predicted water column concentration appears to be an average concentration, for some unspecified length of time, calculated over a volume that is dependent on the model velocity (V_{model}). However, we were unable to confirm this from the available documentation, and replication of the model was beyond the scope of this report. Therefore, we recommend further documentation and peer review of the model before reaching any definitive conclusions from these modeling results.

In addition, dimensional analysis of the equation shows inconsistent units.

The equation used in the model to estimate sediment PAH concentrations is:

PAH sediment accumulation (µg/cm^2 per day) =
Deposition H Degradation H SPC H G_f Eq. 13

where:

$$\text{Deposition } (\mu g/cm^2 \text{ per day}) = \frac{M \times A_f \times Ret_f \times R_p}{\left[\left(\frac{V_{model}}{V_{vert}}\right) \times (r + R_p)\right]}$$

SPC = sediment partition coefficient (defines the proportion of PAH assumed to be adsorbed to sediment)

V_{vert} = particle settling velocity (cm/s)

r = distance from the piling perimeter where the concentration is predicted (cm).

The equation for sediment deposition appears to be mechanistically based. Average deposition is calculated by dividing the loss per unit area of the piling that partitions to the sediment by the incremental area over which that sediment is deposited. Sediment concentrations (in units of µg/g dry weight or ppm) are obtained by dividing the sediment accumulation by the sediment density. The recommended input for the particle settling velocity value (necessary to calculate the incremental area over which deposition occurs) is also mechanistically based; it is derived using Stokes' law for the settling velocities of small particles. The sediment deposition equation does not consider post-deposition disturbance such as bioturbation, sediment mixing from current, propeller wash, or other disturbances.

Model assumptions include:

- Marine-grade creosote contains 80.14% total PAH (TPAH; Environment Canada, 1993), of which 19.57% is HPAH and 60.57% is LPAH.

- HPAH and LPAH migrate from the piling in proportion to their content in whole creosote.

- Once released into the environment, all HPAHs are adsorbed to the silt-clay fraction and settle to the bottom sediment.

- Once released into the environment, 4.83% of the LPAHs are adsorbed to the silt-clay fraction and settle to the bottom sediment and 95.17% of the LPAHs are dissolved in the water column where they degrade with determinable half-lives. Brooks (1997) indicates that these values were determined by assuming minimal mineralization of HPAH in the water column and combining the relative proportions of LPAH and HPAH in whole creosote with the relative proportions reported for contaminated sediments. Explanation for the numbers used is not provided.

- No volatilization of LPAH occurs.

- Ambient water pH does not affect the migration of PAH from creosote-treated wood.

- Tidal flows are harmonic with a frequency of 12 hours.

- The receiving water volume is large in comparison with the total amount of PAH lost from the structure.

Model predictions

As an example, for a 13-in diameter piling submerged in 20 feet of seawater that leaches 1.24 grams of PAH per day, the model predicts a water column concentration of 0.003 ppb TPAH. The volume of water containing this concentration and the length of time that this concentration persists are not specified, but it appears that the concentration is an average that might not be representative of instantaneous concentrations at a particular location. The predicted sediment PAH concentration is 5.89 ppm within 25 cm of the piling and 2.00 ppm 1 m from the piling. These results are based on inputs of a maximum tidal current of 2.5 cm/s and an RPD of 3 cm.

Estimated sediment concentrations appear to be influenced by current velocity and oxygen availability in the sediments. As expected, environments with poor circulation (low velocity) and low sediment oxygen availability (low RPD) are predicted to pose the greatest risk for elevated sediment concentrations of PAHs.

Volatilization and turbulence (which would increase dilution), and abrasion of pilings (which would increase PAH loading in sediment as abraded wood particles become water logged and sink) are not considered in the model. In addition, since the model assumes that the receiving water volume is large in comparison with the total amount of PAH lost from the structure, it is less applicable to small systems and systems lacking circulation.

Poston et al. (1996)

Model description

Poston et al. (1996) developed a “box” plume model to estimate PAH concentrations around creosote-treated wood pilings. The model estimates spatially averaged water column concentrations of PAH compounds for one-day units in a hypothetical rectangular plume. The model does not predict sediment PAH concentrations.

The source of PAHs in the model is a vertical “footprint” (in square meters) perpendicular to the current representing an assumed number of pilings (50, 100, or 350) compressed into a plane of a given area. Several footprint areas can be modeled to simulate different configurations of the pilings (200, 400, 800, and 1,524 m^2). Smaller footprint areas model higher density configurations. The volume of the box plume is determined by the surface area of the vertical plane of the source and the distance that water flows in one day (determined by the current velocity).

Initial runs were conducted at a maximum velocity of 40.6 cm/s. Four additional current velocities were also simulated: 0.3, 0.5, 1.0, and 10 cm/s. A conceptual model of the plume dimensions is shown in Figure 2.5.

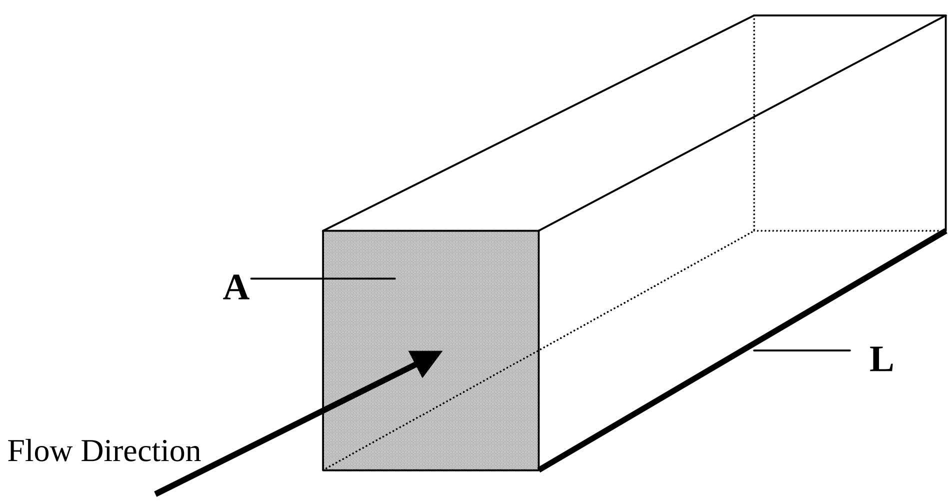

Figure 2.5. Conceptual schematic of the Poston et al. (1996) box plume. The vertical plane A represents the pilings (different piling configurations result in different values of A) and the length L is the distance that water flows away from the pilings in one day.

The volume of the plume is calculated as follows:

$$V = A \times L \qquad \text{Eq. 14}$$

where:

A = vertical footprint (representative of the pilings)
L = current velocity × 86,400 seconds/day × 1 day.

The concentration in the plume is calculated by dividing the amount of contaminant leached from all pilings in a 24-hour period by the plume volume. This yields an average concentration throughout the "box" plume. The amount of PAH leached per day is calculated as follows:

$$\text{Mass of leachate (ug)} = \text{number pilings} \times \text{surface area of piling} \times \text{leaching rate per day} \qquad \text{Eq. 15}$$

The key assumptions incorporated into the model are as follows:

- There is no lateral mixing.
- Exposure concentrations modeled for the first day do not change for at least four days.
- Leaching is constant for a period of four days at a rate of 40 µg/cm^2/day for total PAHs (Brooks, 1994). Leaching rates for individual compounds were obtained by multiplying the percent composition in creosote of the compound (as reported in Brooks, 1994) by the total PAH leaching rate.
- Each piling has a diameter of 30 cm and 10 m of submerged length with a surface area of 94,284 cm^2.
- All pilings are assumed to be installed in one day.

Model predictions

Model results are expressed in terms of exceedence of a toxic threshold. For each of the PAH compounds evaluated in the model, the model compares the predicted plume concentration to a published toxic threshold for that compound to get a toxic unit (TU). Toxic units greater than 0.1 are summed to calculate a total TU. The toxic thresholds used in the model for each PAH are

LC_{50}s, or concentrations at which 50% of test organisms are killed (Table 2.4).[2] An overall TU > 1.0 indicates an overall toxic threshold for all of the PAHs combined.

Table 2.4. LC_{50}s used to calculate toxic unit values for each PAH in the Poston model

PAH compound	LC_{50} (µg/L)
Naphthalene	3,852
Acenaphthylene	474
Acenaphthene	480
Fluorene	337
2,6-dimethylnaphthalene	172
Anthracene	140
Phenanthrene	140
Fluoranthene	18
Chrysene	4.02
Benz(a)anthracene	2.7
Benzo(a)pyrene	1.09
Dibenzo(a,h)anthracene	0.57
Benzo(k)fluoranthene	0.23
Benzo(g,h,i)perylene	0.1
Indeno(1,2,3-c,d)pyrene	0.03

Source: NMFS, 1996.

Modeled PAH concentrations increase with the number and density of pilings, and decrease with flow rate. For example:

- For the 350-piling scenario, concentrations of all PAHs modeled exceeded the 0.1 TU threshold at flows of ≤ 0.8 cm/s, regardless of footprint size. At a flow rate of 7.0 cm/s, PAH concentrations exceeded the threshold for footprints of 400 m^2 and smaller.

- For the 100-piling scenario, predicted concentrations of PAHs exceeded the 0.1 TU at all modeled flow rates for footprint areas of 800 m^2 and less.

2. Note that compounds listed in Table 2.4 do not match exactly the major creosote constituents listed in Table 1.3, which introduces some additional uncertainty regarding the applicability of the model to creosote-treated woods.

- For the 50-piling scenario, flows of 1 cm/s or less and footprint areas of 400 m^2 and less resulted in predicted concentrations greater than the threshold.

This model is a simplified transport model that depicts average concentrations in a hypothetical box plume. Sedimentation, volatilization, lateral mixing, and turbulent mixing (which would decrease concentrations in the water column) are not considered in the model. Poston et al. (1996) acknowledge that the model probably over-predicts concentrations for water column PAHs and that model results are "approximate estimates at best."

2.3.2 Comparison to field data

(i) Brooks (1997)

Brooks (1997) compared his predicted sediment concentration results to measured sediment concentrations at two sites in British Columbia. Belcarra Bay has poor circulation, a maximum tidal current of 3.9 cm/s, an average salinity of 15.7 ppt, and an average RPD of 1 cm. The newest piling was 1.5 years old. The model over-predicted sediment concentrations 1 m from the piling but under-predicted concentrations at 3 and 5 m from the piling. Approximate predicted and measured concentrations, estimated from Figure 3 in Brooks (1997), are shown in Table 2.5.

Table 2.5. Approximate predicted and actual concentrations at Belcarra Bay, British Columbia

Distance from piling (m)	Predicted PAH concentration (ppm)	Measured PAH concentration (ppm)
1	9	4
3	5.5	10
5	3	8.5
10	0	Negligible
20	0	Negligible
40	0	Negligible

Source: Figure 3, Brooks, 1997.

Westham Island Bridge had greater circulation, an average maximum tidal current of 18.1 cm/s, an average salinity of less than 2 ppt, and an average RPD of 1.25 cm. The newest piling was 8 years old. The model somewhat over-predicted sediment concentrations at 0.5 and 2.0 m from the piling. Predicted and measured concentrations were similar at 5 m from the piling (Table 2.6).

Table 2.6. Approximate predicted and actual concentrations at Westham Island Bridge, British Columbia

Distance from piling (m)	Predicted PAH concentration (ppm)	Measured PAH concentration (ppm)
0.5	0.56	0.17
2	0.17	0.03
5	0.08	0.07

Source: Figure 4, Brooks, 1997.

(ii) Goyette and Brooks (1998, 2001)

Goyette and Brooks (1998, 2001) compared modeled versus measured concentrations of PAHs in surface water and sediment for sets of six treated pilings, both weathered and unweathered, and a set of untreated pilings in a poorly flushed basin of Vancouver Island, British Columbia. They also included a no-piling control. The pilings were all Douglas fir, and the new (unweathered) pilings were treated to a retention of 27 pcf using WWPI BMP standards. The weathered pilings had an unspecified retention and were not treated to BMPs. The pilings, with an average diameter of 30-cm each, were installed in 6-piling dolphins (a dolphin is a boat-mooring structure composed of multiple closely spaced pilings) having a minimum base diameter of 2.5 m. The current direction and speed were assessed over a two-day period, and determinations of “upstream” and “downstream” sampling directions and locations were made on the basis of this assessment.

In this study, the modeled total PAHs included all PAHs leached from creosote, but the measured total PAHs included only 17 measured PAHs (potentially underestimating the total). The site was said to have been selected as a “worst-case” scenario, with low current speed, but one of the site-selection criteria involved the presence of oxic sediments (having an RPD greater than 3 cm below the sediment surface). Sediments above the RPD are oxic, which increases the rate of PAH breakdown, and sediment samples for PAH analysis were routinely collected from the top (0-2 cm) layer during the study.

Goyette and Brooks (1998, 2001) used a 1994 version of Dr. Brooks’ model to predict an increase of 336 ng/L total PAH in the water column within 15 cm of individual pilings This predicted concentration was approximately 11 times greater than the maximum of 30.8 ng/L total PAH measured with semi-permeable membrane sampling devices (SPMDs). Water column results were dependent on the ability of the SPMDs to accurately reflect water column concentrations. Although method blanks are documented, no positive controls were reported, and percent recovery was not noted.

PAHs were regularly measured in the upstream and downstream directions from each dolphin, beginning at 0.5 m. Although the distribution of PAHs was observed to be patchy (there was high spatial, and between-replicate, variability, and small oily particles were observed in the sediment samples), the model generally also predicted sediment concentrations that were higher than those observed in the upstream and downstream directions. However, a single sampling event sampled sediments within the dolphins and in a direction described as “offshore” of the dolphins. This sampling event revealed far higher sediment concentrations both inside the dolphins and outside the dolphins in the offshore direction than those observed close to, but outside of, the dolphins in the upstream and downstream directions, and also far higher than model predictions (Table 2.7).

Table 2.7. Observed and predicted sediment PAH concentrations in the Sooke Basin study, day 384/385 (per Goyette and Brooks, 1998, 2001)

Dolphin type	Direction relative to dolphin	Distance from dolphin (m)	Predicted PAH concentration (all), ppm	Observed PAH concentration (17 PAHs), ppm
BMP unweathered	Downstream	0.5	~24	16.1
	Downstream	1.0	~19	5.7
	Inside dolphin	0.0	N/A	30.8
	Offshore	0.5	N/A	68.3
	Offshore	2.0	N/A	2.9
Weathered	Downstream	0.5	~24	10.8
	Downstream	2.0	~6	6.3
	Offshore	0.5	N/A	33.8
	Offshore	2.0	N/A	15.3
	Inside dolphin	0	N/A	47.4

Also, the peak of sediment concentrations occurred somewhat sooner than predicted, giving the appearance of model under-prediction earlier in the experiment followed by over-prediction later in the experiment.

The results of these comparisons of modeled to measured PAH concentration data are insufficient to make any specific quantitative conclusions about the accuracy of the model in predicting actual sediment concentrations. The variability in the results is understandable because of the many site-specific conditions and simplifying assumptions required to run the model. For instance, Brooks (1997) presents the age of the newest piling, but it is unknown whether just some, or all, of the pilings were installed or replaced at that time. Also, both the number and density of pilings, factors that the Poston et al. (1996) model considers to be important, are not included in the Brooks (1997) transport model.

2.3.3 Applicability of the models

The aquatic systems that the Brooks (1997) and Poston et al. (1996) models simulate are highly complex systems that are difficult to describe quantitatively. Numerous simplifying assumptions were necessary to construct the models. For example, tidal currents are very complex and are influenced by many highly variable factors. Turbulence, the main process by which mixing occurs in these systems, is a chaotic three-dimensional process that is notoriously difficult to model. Furthermore, the leaching rates used in the model as inputs are themselves model results with their own set of uncertainties.

Despite these uncertainties and assumptions, the leaching and transport models have value in qualitatively describing many first-order factors related to PAH leaching from treated wood and movement in the environment. For example, Brooks (1997) recognizes the importance of oxygen availability in the system, and sediments with a thin layer of oxygenated sediments (a small RPD) result in higher predicted concentrations of PAH compounds than well oxygenated sediments. Both the Brooks (1997) and Poston et al. (1996) models incorporate flow rate as a critical variable affecting concentrations in the environment, and the Poston et al. (1996) model also incorporates piling density (and thus surface area), which laboratory studies have confirmed to be important.

2.4 Conclusions

The modeling of PAH leaching rates from treated wood and the resulting environmental concentrations are important for evaluating the environmental risks from treated wood structures. Our review and evaluation of the available information and models on PAH leaching and environmental concentrations, support the following:

The rate of leaching of PAH is greater:

- In freshwater than in seawater
- At high temperatures than at low temperatures
- At high flow rates than at low flow rates
- From less dense wood than from denser wood
- From freshly treated wood than from wood that has either been stored after treatment or been exposed to water
- From end grain than from face grain

- At a higher wood surface area to volume ratio
- From wood that has not been treated to the WWPI BMPs than from wood that has been treated to the BMPs.

Also, leaching is faster for the more water-soluble compounds. Variations in the leaching rates of PAHs from same-species wood samples can be surprisingly large (Miller, 1977, as cited in Brooks, 1997; Rao and Kuppusamy, 1992). In addition to PAHs, compounds such as N-heterocycles can leach from treated wood, and this issue has not been thoroughly investigated in the literature. Most leaching studies to date, with the exception of Becker et al. (2001), have focused on PAH leaching.

The Brooks leaching model, in its most current incarnation (the CREOSS spreadsheet model) incorporates only temperature, salinity, piling age, and creosote retention factors in the calculation of leaching rates. The predicted leaching rates generally behave as expected based on the results of laboratory studies for all components considered, but agreement with laboratory observations, where comparisons can be made, could be improved, particularly at temperatures below 20°C (Figure 2.4). The model ignores the effect of water flow rate on leaching rates, relies on studies of older installations probably missing peak leaching rates, and assumes an equal migration rate of all components of creosote, which is not supported by laboratory observations. However, the model appears to be adequate for predicting many first-order factors that explain laboratory and field observations.

The transport models for predicting environmental concentrations of PAHs in surface water and sediment are based on assumptions regarding modeled leaching rates and environmental parameters such as water flow, surface area of treated wood, and sediment settling and movement (Poston et al., 1996; Brooks, 1997). The inputs needed to run these models are highly site-specific. The models can provide site-specific predictions where site-specific conditions are known, and they are useful for evaluating the relative importance of different environmental variables on environmental concentrations of PAHs. The models may not fully describe transient concentrations of PAHs, particularly shortly after installation of treated wood in water, or during severe disturbances (especially abrasion).

The transport models indicate that environmental concentrations decrease with increasing flow rates, due to increasing dilution. However, several leaching studies suggest that the rate of leaching also increases with increasing flow rates. This raises the issue of the relative contributions of leaching rate and dilution to water column concentrations of PAHs, since both are affected by changes in flow rate. As flow rate increases, both leaching and dilution increase, but their effects on water column concentration oppose one another. Available data are insufficient to answer questions regarding the net outcome of this relationship under various realistic scenarios; that is, at any point, as flow rate increases, will the increase in leaching outweigh the increase in dilution? The results in Xiao et al. (2002) appear to show leaching doubling or more than doubling under some circumstances, when flow rate simply doubles, but this issue has not been thoroughly investigated.

The current models only incorporate flow velocity into the dilution portion of the model, and do not consider the effect that increased velocity may have on leaching rates. It is possible that, because of this omission, the models under-predict actual concentrations. However, these models do not consider lateral mixing or turbulence, both of which increase dilution and mitigate the effect of increased leaching due to increased flow rates.

3. Toxicity of Creosote to Estuarine Organisms

This chapter discusses the environmental toxicity of creosote, including constituents of creosote that are known to be toxic (Section 3.1), the routes by which toxic constituents expose organisms (Section 3.2), the toxicity of various constituents to organisms under environmentally relevant conditions (Section 3.3), and the concentrations at which biological effects begin to occur (Section 3.4).

3.1 Toxic Components of Creosote

As described in Section 1.4, the chemical composition of creosote is very complex. This compositional complexity can obscure the toxicity of the mixture and of particular constituents in environmental settings. PAHs are the dominant class of compounds in creosote, comprising 85-90% of creosote's mass. PAHs are the most comprehensively studied group of chemicals found in creosote, due largely to the potency of some as carcinogens, and to their widespread, and apparently increasing, occurrence in the environment (e.g., Van Metre et al., 2000).

Although a number of PAHs have been well studied regarding their potency as carcinogens, less is known about the non-carcinogenic toxicities of PAHs and other components of creosote to aquatic and marine organisms. This appears to be true particularly for creosote components such as alkylated PAHs and heterocycles. However, while there is little information concerning interactive effects of creosote components, there is a reasonable body of work addressing the effects of creosote per se, both in laboratory exposures and from field studies.

Many studies of PAHs and creosote compounds in aquatic and marine environments distinguish between LPAHs and HPAHs. Generally, LPAHs are PAHs with two-or three-fused benzene rings; HPAHs are PAHs containing four or more rings. In some cases, such as fluorene and fluoranthene, a 5-carbon aromatic cyclic ring replaces benzene. The focus of the rest of this chapter is the current state of knowledge about routes of exposure and the toxicity of creosote components and the mixture itself, highlighting the sensitive endpoints that drive risk assessments.

3.2 Routes of Exposure

Meador et al. (1995) provided a thorough review of the literature on factors governing the bioaccumulation of PAHs in marine organisms (invertebrates and fish). Their conclusions are supported by subsequent studies, and while they focused on parent PAHs (i.e., non-alkyl-substituted compounds), their analysis probably holds for other major components in creosote such as phenolics, alkylated PAHs, and heterocycles.

Meador et al. (1995) concluded that the major routes of exposure for marine animals were uptake of waterborne chemicals and through the diet. Waterborne chemicals include those in the interstitial water (ISW) of sediments. ISW is probably the compartment governing the bioavailability of many organic chemicals in marine systems. Direct uptake of sediment-bound chemicals (e.g., through the integument of worms and fish) appears to be negligible. This conclusion is supported by studies that demonstrate that the water-soluble fractions of contaminated sediments generally drive the toxicity of chemicals in bulk sediments (e.g., Roberts et al., 1989; Swartz et al., 1989; Padma et al., 1998). Thus, in hazard assessments of PAH-contaminated sediments, K_{oc}, which describes equilibrium partitioning between the organic carbon of sediment and the surrounding ISW, becomes a key driver for exposure assessment. K_{ow}s are often used to estimate K_{oc}s for individual compounds (see Swartz et al., 1995).

The diet can also be an important source of PAHs and related creosote chemicals (Meador et al., 1995), and particularly so for deposit-feeding invertebrates and for fish that feed on invertebrates. Malins et al. (1985) reported elevated concentrations of PAHs and related chemicals in the stomach contents of marine fish inhabiting a creosote-polluted site in Puget Sound, Washington. However, absorption efficiencies of dietary PAHs may be limited; Niimi and Dookhran (1989) reported uptake efficiencies of 2% to 32% for various PAHs.[1]

The relative roles of uptake from the water column (including ISW) and the diet vary greatly, depending on factors such as the organism's life history, physico-chemical characteristics of specific compounds (such as solubility and K_{ow}), and environmental variables (such as sediment organic carbon content). In general, water column uptake is more important for chemicals with higher solubility (or lower K_{ow}), and also is more important for filter-feeding organisms. However, as Meador et al. (1995) stress, the route of uptake is, in the long run, relatively unimportant. Over time, equilibrium among media (sediments, water, and biota) will occur and the same tissue burdens (or other measures of exposure, as described below) will occur regardless of route of exposure.

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1. However, many hydrophobic organic compounds have higher uptake efficiencies than this. Niimi and Dookhran (1989) packed one gelatin capsule per day into ground trout diet, which may not be comparable to ingesting invertebrate prey.

The assessment of exposure to, and accumulation of, creosote hydrocarbons is complicated by metabolism. Halogenated hydrophobic chemicals, such as polychlorinated biphenyls (PCBs), chlorinated dioxins and furans, and chlorinated hydrocarbon pesticides, such as dichloro-diphenyl-trichloroethane (DDT), that are also of concern in marine and estuarine systems, are highly resistant to metabolism by most organisms. In contrast, creosote hydrocarbons are not halogenated and consequently are readily prone to metabolism by many organisms. Among estuarine and marine animals, metabolic capacity is generally very high in fish (and other vertebrates), intermediate in crustaceans, and very limited in bivalves (Meador et al., 1995). For this reason, tissue concentrations of creosote hydrocarbons provide a reasonably accurate measure of exposure in bivalves, but an inaccurate measure in vertebrates. Crustaceans are probably intermediate in this respect.

Vertebrate metabolism is discussed in more detail in Section 3.3. Briefly, the metabolism of hydrocarbons gives rise to relatively hydrophilic metabolites, most of which are excreted via the bile in vertebrates, and to reactive metabolites that can bind to cellular macromolecules such as DNA. Thus, measures such as concentrations of bile metabolites and DNA adducts are often used as measures of hydrocarbon (mainly PAH) exposure in vertebrates.

3.3 Toxicities

Information concerning the toxicity of creosote and constituent chemicals is not equally complete for all constituents. Much information is available concerning PAHs, particularly HPAHs, in part because of the potent carcinogens in this group. There is also some information concerning the toxicities of heterocycles and creosote. Phenolics appear to be the least studied of the key components of creosote.

Most toxicity experiments published in the peer-reviewed literature have been conducted by exposing aquatic biota either to creosote-spiked water or to sediments or sediment elutriates containing creosote, which may be either spiked with whole creosote or field-collected product.

These exposures are not directly equivalent to exposures conducted using leachates (either in water or sediment) from treated wood, for several reasons. Although all creosote exposure experiments contain PAHs and other compounds, the individual constituents and their concentrations can be heavily influenced by weathering and by the leaching process itself. Also, many creosote-spiking experiments use solvents such as acetone to increase the aqueous bioavailability of the mixture’s more hydrophobic components. And, finally, sediments for use in creosote bioassays are often field-collected from sites where creosote was released from wood treatment facilities. At such sites, other toxicants such as pentachlorophenol and metals are frequently present in potentially toxic amounts, making it difficult to determine what portion of observed toxicity is attributable to the creosote in the sediments.

Plants appear to be less sensitive to creosote chemicals than animals in aquatic and marine systems (WHO, 2004). Our discussion focuses on animals, particularly invertebrates and fish. In studies with invertebrates, endpoints that have been examined most frequently include acute toxicity (mortality), phototoxicity (a distinct form of acute toxicity), and effects on populations and community structure. Studies with fishes have included investigations of acute toxicity and phototoxicity, and more basic investigations of reproduction and growth, effects on the immune system, early life stage development, and chemical carcinogenesis. The effects of creosote and creosote chemicals on key endpoints are discussed below.

3.3.1 Toxicity from acute (short-term) exposure

Under standard laboratory conditions, the acute toxicities of water-borne PAHs and alkylated PAHs to marine organisms vary widely among chemicals and test organisms (see reviews by Neff, 1985; and Eisler, 2000). For marine and freshwater invertebrates and fishes, 24- and 96-hour LC_{50}s generally range from approximately 0.1 to 4 mg/L (ppm); crustaceans tend to be relatively more sensitive and fish less sensitive in these tests. Eisler (2000) noted that these concentrations are generally orders of magnitude greater than those encountered in surface waters, including at polluted sites. Few studies of this nature examining heterocycles have been reported.

Other studies have investigated the acute toxicity of creosote itself, either in sediments or water-extracted fractions. Padma et al. (1998) exposed the mysid shrimp *Mysidopsis bahia* to either a creosote-contaminated sediment (Elizabeth River, Virginia) or to the water-soluble fraction (WSF) of this sediment. Chemical analyses were performed on both sample types. As measured by total identified aromatic compounds, they determined 24-hour LC_{50}s to be approximately 180 µg/L (ppb) and 700 µg/L for the water-extractable fraction and sediment, respectively, indicating an approximate four-fold greater toxicity of the WSF. A major difference between the two samples was higher concentrations of low molecular weight PAHs (< three rings) in the WSF compared with the sediment. N-heterocycles were also reported to be higher in the WSF, but no data were provided.

Swartz et al. (1989) measured the acute toxicity of various dilutions of creosote-contaminated sediments and ISW extracted from the sediments, collected from Eagle Harbor, Washington, to the marine amphipod *Rhepoxynius abronius*. They measured 13 PAHs in these samples; heterocycles apparently were not measured. Based on these studies, the four-day LC_{50} for total PAHs was 666 mg/kg (wet weight). The ISW LC_{50} was found to be 0.89% of the undiluted ISW. Based on data for undiluted ISW provided in Table 4 of Schwartz et al. (1989), this equates to an ISW LC_{50} of 100 µg/L. Dominant PAHs observed in both sample types included acenaphthene, fluorene, phenanthrene, fluoranthene, and pyrene.

Sved and Roberts (1995) constructed a flow-through dilutor system to continually expose the estuarine teleost, spot (*Leiostomus xanthurus*), to selected dilutions of suspended sediment mixed with commercial marine creosote. They measured over 100 compounds, including heterocycles, but provided data for only six PAHs that comprised 64% of total resolvable PAH: naphthalene (21%), acenaphthene (8%), fluorene (6%), phenanthrene (14%), fluoranthene (9%), and pyrene (6%). Based on these exposures, the 96-hour LC_{50} was determined to be 1,740 µg/L, and the no observable effects level (NOEL) was 250 µg/L. In a previous study that involved exposures of spot in this system for 14 days (Sved et al., 1992), mortality, fin erosion, and epidermal lesions were observed at total PAH concentrations as low as 76 µg/L. Induction of hepatic ethoxyresorufin O-deeethylase (EROD) activities were observed at all concentrations tested, down to 16 µg/L. In this study, concentrations of individual chemicals were not reported.

Sved et al. (1997) also used the flow-through dilutor system to compare the toxicity of commercial creosote that had been fractioned into HPAH and LPAH, with the exception that phenanthrene and fluoranthene were important components of both. In 10-day exposures of spot, mortality, fin erosion, epidermal lesions, and EROD inductions were observed in fish exposed to HPAH. Of these responses, only limited epidermal lesions were observed in fish exposed to LPAH. Dominant PAHs in the LPAH fraction were acenapthalene (14%), fluorene (12%), phenanthrene (28%), and fluoranthene (9%). Dominant PAHs in the HPAH fraction were phenanthrene (22%), fluoranthene (26%), and pyrene (15%). The authors concluded that the HPAH fraction better mirrors weathered creosote in the field and produces responses similar to field and laboratory responses to exposures to creosote-contaminated sediments.

The identity of key chemicals responsible for the acute toxicity of creosote (as well as some other endpoints described below) remains unresolved. In his review, Neff (1985) concluded that only PAHs in the molecular weight (MW) range of naphthalene (MW = 128) to fluoranthene and pyrene (MW = 202) demonstrated significant acute toxicity to aquatic organisms, and within this range, bioaccumulation increases with increasing molecular weight. A number of subsequent studies, including some described above, support this conclusion. However, Padma et al. (1999) concluded that more water-soluble LPAH, perhaps including heterocycles, dominated toxicity in their study. Kuehl et al. (1990) used a fractionation scheme to determine key chemicals in a creosote mixture that were acutely toxic to the water flea *Ceriodaphnia dubia.* They concluded that PCP and low molecular weight heterocycles in the mixture were probably the chemicals responsible. However, in a study of creosote-contaminated sediments in Finland, Hyotylainen and Oikari (1999) noted that, over time, the sediments became enriched in very high molecular weight PAHs, such as benzo[a]pyrene (MW = 252). They concluded that the high molecular weight PAHs appeared to be primarily responsible for the toxicity of the sediments to *Daphnia magna* and the photoluminescent bacterium *Vibrio fischeri*. In a study attempting to elucidate the fractions of weathered middle-distillate oils (a petroleum product that contains many of the chemical components in creosote) toxic to *Mysidopsis bahia*, Barron et al. (1999) concluded that aromatic compounds (including "classic" PAHs and substituted PAHs) were not primarily responsible for toxicity. However, the relevance of that study to creosote is unclear.

Clearly, assessing the toxicity of complex mixtures such as creosote is very challenging. However, at least for PAHs common in creosote, considerable effort has focused on predicting the cumulative toxicity of PAHs in sediments, which is the key reservoir for creosote-derived chemicals in aquatic and marine systems. One of the proposed approaches that appears to be very useful, and that includes measurements and predictions of acute toxicity of PAHs, is the ΣPAH model of Swartz et al. (1995). This model incorporates 10-day acute toxicity tests (for acenaphthene, phenanthrene, and fluoranthene) with several sensitive marine and estuarine amphipods (including *Rhepoxynius abronius*), quantitative structure-activity relationship (QSAR) predictions of the toxicities of 10 additional PAHs (naphthalene, acenaphthylene, fluorene, anthracene, pyrene, benz[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, and benzo[a]pyrene), field chemistry data (sediment concentrations of these 13 PAHs and organic carbon content), and equilibrium partitioning to predict ISW concentrations of each PAH.

Swartz et al. (1995) predicted the 10-day LC_{50}s for these PAHs to range from 0.17 µg/L for benzo[k]fluoranthene to 3,500 µg/L for naphthalene. Their analyses and predictions support the notion that acute toxicity increases with increasing molecular weight (between 2- and 4-ring structures). This might be important in creosote-contaminated systems where higher molecular weight compounds appear to persist and eventually dominate the sediment profile relative to lower molecular weight compounds.

3.3.2 Phototoxicity

Concentrations of PAHs in surface waters rarely approach the concentrations associated with acute toxicity of these compounds under standard laboratory testing protocols (Eisler, 2000). A potentially important exception to this is the enhancement of the acute toxicity of some PAHs to various aquatic invertebrate and fish species examined under ultraviolet (UV) radiation. UV radiation is largely absent in normal indoor lighting. QSAR models have been developed that are reasonably accurate in predicting the phototoxic potencies of aromatic compounds (Ankley et al., 1997). Among the PAHs found to be highly phototoxic are anthracene, fluoranthene, pyrene, benzo[a]pyrene, benz[a]anthracene, and benzo[k]fluoranthene (Newsted and Giesy, 1987). The degree of enhancement of PAH toxicity is dramatic, with measures of acute toxicity generally increasing by one to two orders of magnitude. In animals, phototoxicity is thought to require bioaccumulation of the phototoxic chemical (Weinstein and Oris, 1999). It has also been shown that UV radiation can transform some PAHs (such as anthracene, phenanthrene, and benzo[a]pyrene) into products such as quinones that are more toxic than parent PAHs (Huang et al., 1993). Very recently, it has been reported that some photo-products of anthracene, such as

2-hydroxyanthroquinone, are estrogenic and occur at much greater concentrations than the parent compound in natural waters (Kurihara et al., 2005).

While many studies of phototoxicity have examined water-column-inhabiting organisms, the phenomenon has also been shown to occur in sediment-inhabiting invertebrates. For example, UV-enhanced phototoxicity has been demonstrated in oligochaetes (*Lumbriculus variegatus*) and amphipods (*Rhepoxynius abronius*) exposed via PAH-amended sediments (Ankley et al., 1994; Swartz et al., 1997), as well as in *Lumbriculus variegatus* and the amphipod *Hyalella azteca* exposed to field collected PAH-contaminated sediments (Ankley et al., 1994). UV exposure was also shown to markedly increase the acute toxicity of creosote-contaminated sediments from the Elizabeth River, Virginia, in larvae of the estuarine killifish, *Fundulus heteroclitus* (Meyer and Di Giulio, 2003).

The ecological relevance of UV-mediated PAH toxicity in the environment remains controversial, with some contending that factors operating in the environment ameliorate PAH phototoxicity (McDonald and Chapman, 2002). For example, humic acids that are often abundant in natural waters but generally minimal in most laboratory studies can reduce PAH bioaccumulation and attenuate UV light penetration, and thereby greatly reduce phototoxicity (Weinstein and Oris, 1999).

3.3.3 Carcinogenesis

From the standpoint of human health, the greatest concern for creosote constituents, particularly PAHs and aromatic amines, is the potency of many as mutagens and carcinogens. There is also a very substantial literature concerning chemical carcinogenesis, including PAHs, in fish. The mechanisms by which PAHs produce cancers are very similar in mammals and fish, and fish models have been used extensively in cancer research. Cancer, and the steps leading to it, comprise a key endpoint relevant to chronic exposures of vertebrates to PAHs, and might be important in assessing environmental risks of creosote in aquatic systems.

Many of the epizootics of cancer (predominantly liver neoplasms) described in fish populations in North America have been in areas contaminated by PAHs and associated aromatics such as N heterocycles (Landahl et al., 1990; Johnson et al., 1993; Baumann and Harshbarger, 1995; Myers et al., 2003). Among these are cases where creosote was strongly indicated as the source of the chemicals underlying the observed liver cancers, including cancers in English sole (*Pleuronectes vetulus*) in Puget Sound, Washington (Malins et al., 1985) and in *Fundulus* spp. in the Elizabeth River, Virginia (Vogelbein et al., 1990). In a more recent (2001) survey of Elizabeth River *Fundulus* spp. from the former Atlantic Wood creosote site (which closed in about 1990), Vogelbein and Unger (2003) observed hepatic neoplasm rates of 8% and altered hepatocellular foci (a precancerous lesion) rates of 65%. These rates were diminished somewhat from earlier surveys. They provided quantitative data for sediment concentrations of 10 LPAHs and 8 HPAHs. Total mean PAH concentration was approximately 490,000 ng/g (ppb), dry weight, of which approximately 440,000 ng/g were HPAHs, including fluoranthene (approximately 125,000 ng/g), pyrene (approximately 71,000 ng/g), and the carcinogens benzo[a]pyrene (approximately 56,000 ng/g), benz[a]anthracene (approximately 41,000 ng/g), chrysene (approximately 60,000 ng/g), and dibenz[a,h]anthracene (approximately 12,000 ng/g). These data support the relative persistence of creosote-derived HPAHs, including carcinogenic PAHs, over time.

Laboratory studies have confirmed a causal link between PAHs and liver cancer and associated lesions in fish, including dibenzo[a,l]pyrene in rainbow trout (*Onchorhynchus mykiss*) (Williams et al., 2003), and benzo[a]pyrene and 7,12-dimethylbenzanthrace (DMBA) in Japanese medaka (*Oryzias latipes*) and guppy (*Poecilia latipes*) (Hawkins et al., 1990). There appears to be variability in sensitivity to chemical carcinogenesis among fish species. However, most species involved in epizootics are benthic species, such as English sole and winter flounder (*Pleuronectes americanus*) in marine systems, and brown bullhead (*Ameriurus nebulosus*) in freshwater systems. These species are frequently in contact with sediments; their life history behavior is thought to increase their exposure to carcinogens and thereby play a role in their sensitivity.

The mechanisms by which PAHs cause tumors appear to be similar in mammals and fish. They are briefly summarized here due to their relationship to the assessment of exposure and effects of creosote hydrocarbons in estuarine and marine systems. To initiate cancer, PAHs must first be metabolized into reactive products that can bind to or otherwise damage DNA. DNA damage occurs when the base sequence is altered and the alteration is passed along during subsequent cell divisions, i.e., a mutation has occurred (see review by Pitot and Dragan, 2001). For a resulting mutation to initiate cellular events leading to cancer, it must occur at a critical site in a gene that codes for a protein that serves a role in cellular growth, regulation, differentiation, or signaling. For example, benzo[a]pyrene has been shown to produce mutations in the DNA-binding regions of the tumor suppressor gene, p53, which leads to loss of the DNA damage surveillance function of the p53 protein (Denissenko et al., 1996). The processes occurring between initiation (DNA damage) and cancer, including promotion and progression, are complex and beyond the scope of this report.

However, mechanisms underlying initiation merit consideration here. Benzo[a]pyrene is the most well studied PAH in terms of DNA damage and cancer initiation, but mechanisms underlying these phenomena generally apply to other genotoxic PAHs also. Benzo[a]pyrene is oxidized mainly in the liver of vertebrates by cytochrome P450 (CYP); in fish the dominant enzyme catalyzing PAH oxidations is CYP1A (Stegeman and Hahn, 1994). Various oxidations to phenolics and epoxide metabolites can occur on the benzo[a]pyrene molecule, and the majority of these oxidations lead to their excretion via the bile due to enhanced water solubility. However, specific metabolites can be highly reactive with cellular macromolecules, including DNA. In the case of benzo[a]pyrene, the 7,8-diol, 9,10-epoxide (benzopyrene diol epoxide, BPDE) is the best characterized genotoxic metabolite that covalently binds to DNA bases, such as guanine. Cells are equipped with DNA repair machinery that can excise and replace damaged bases. However, bulky adducts such as PAHs can elicit misrepair, with the wrong base inserted to replace the damaged one. If the cell containing the resulting altered base sequence remains viable and able to divide, mutation has occurred, with the potential for carcinogenesis, as described above.

These processes have been used in the biomonitoring of PAHs in environment and risk assessments (Myers et al., 1998). Expression of the CYP1A protein is regulated by the aryl hydrocarbon receptor (AHR). Ligands for the AHR can elicit very marked up regulations of CYP1A that can be readily measured, for example by the EROD enzyme activity assay mentioned earlier, which is highly specific for CYP1A activity. A number of PAHs, particularly HPAHs, are effective AHR agonists that elicit CYP1A inductions. Thus, EROD activity provides a very sensitive biomarker for vertebrate exposures to PAHs, and it has been effective in field studies. This is important for PAHs because they are so readily metabolized by vertebrates and hence not amenable to standard tissue residue analysis. One downside of CYP1A measures is that there are other potent AHR agonists that also induce the protein, including polyhalogenated aromatics such as dioxins and PCBs. An assay that gets around this issue is the measure of PAH metabolites in the bile, which, though somewhat more difficult and less sensitive than EROD, can be very useful. DNA adducts to DNA can also be measured; this is accomplished in field studies principally by the ^{32}P-post-labeling assay (Myers et al., 1998). This is a much more involved assay than the previous two, but very powerful in that it has a clear relationship to cancer. Finally, hepatic anomalies, including pre-neoplastic lesions (lesions suggestive of carcinogenesis) and frank neoplasms can be quantified by standard histopathologic methods. Myers et al. (1998) provide a detailed example from Puget Sound of the integrated use of these markers for biomonitoring, in which the NOAA NMFS laboratory in Seattle, Washington, has been involved for many years.

Thus, the mechanisms underlying PAH metabolism and genotoxicity provide for an array of useful biomonitoring tools, or biomarkers, including:

- CYP1A
- Bile metabolites
- DNA adducts
- Lesions
- Cancer.

Sensitivity and ease of measurement generally decline from the top to the bottom of this list, but biological importance, and perhaps regulatory clout, increases from top to bottom.

3.3.4 Development

The effects of PAHs and related hydrocarbons on early life stage development have emerged as important issues relatively recently. In contrast to cancer, where concerns originated in the context of human health and subsequently spread to concerns for aquatic and marine systems, developmental effects have been primarily the purview of environmental studies. Field and laboratory investigations aimed at elucidating the impacts of the *Exxon Valdez* oil spill in Prince William Sound identified significant effects of petroleum hydrocarbons on development in endemic species such as the Pacific herring (*Clupea pallasi*) (Hose et al., 1996; Marty et al., 1997; Middaugh et al., 1998; Carls et al., 1999). Effects observed in exposed embryos included decreased hatching success, DNA damage, reduced heart rates, and gross morphological abnormalities such as scoliosis, pericardial edema, and cranio-facial abnormalities.

The morphological abnormalities observed are very similar to those described for fish embryos exposed to polyhalogenated hydrocarbons, particularly 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD; Walker et al., 1991). This effect, ultimately associated with drastic declines in Great Lakes lake trout populations (Cook et al., 2003), is referred to as blue sac disease, due to the appearance imparted by pericardial edema. Recent studies using zebrafish (*Danio rerio*) as a model have investigated the pathologies and mechanisms underlying TCDD-mediated blue sac disease. TCDD is among the most potent ligands for the AHR and is a very potent inducer of CYP1A. Using gene silencing techniques with antisense morpholinos to block translation of specific genes, it has been shown that activation of the AHR is required for the effects on cardiovascular development that underlie blue sac disease, but the role of CYP1A is unresolved (Prasch et al., 2003; Carney et al., 2004). Given that some PAHs are also effective AHR ligands and CYP1A inducers, petroleum and creosote might have similar developmental effects.

Incardona et al. (2004) investigated the effects of selected PAHs, including an S-substituted heterocycle, on cardiovascular development in the zebrafish. They investigated 2- to 4-ring PAHs, abundant in crude oil, singly and in mixtures. PAHs studied were naphthalene, fluorene, anthracene, phenanthrene, dibenzothiophene, chrysene, and pyrene. Among those, the chemicals exhibiting the most severe effects on cardiovascular development were phenanthrene, dibenzothiophene, and pyrene. Phenanthrene and dibenzothiophene produced particular effects on cardiac conduction resulting in reductions in circulation, which appeared primary to subsequent effects on cardiovascular development. The effects of pyrene were distinct and included anemia, peripheral vascular defects, and neuronal cell death; these effects resemble effects associated with TCDD. Coincidentally, 4-ringed pyrene is an AHR agonist (though far weaker than TCDD), while 3-ringed phenanthrene and dibenzothiophene are not. Incardona et al. (2004) suggested that pyrene may be acting through mechanisms similar to those by which TCDD acts, while the 3-ringed PAHs are directly perturbing atrioventricular conduction. They provide a convincing argument that narcosis is not a likely mechanism for the cardiovascular effects produced by these compounds. Relatedly, Billiard et al. (1999) reported blue sac disease in rainbow trout and zebrafish embryos exposed to the alkylated 3-ringed PAH, retene (7-isopropyl-1-methylphenanthrene).

In a study directly addressing the effects of creosote on development, Vines et al. (2000) placed Pacific herring embryos in seawater containing creosote-treated wood, with seawater alone and seawater containing untreated wood as controls. Embryos collected from creosote-treated pilings in San Francisco Bay were also examined. This species spawns on a variety of substrates including pilings. In the laboratory studies, all embryos adhering directly to treated wood, and approximately 40-50% of those not adhering, failed to develop beyond the first few days of incubation. Surviving embryos displayed a 93% reduction in heart rate, and moderate to marked arrhythmia. Approximately 15-20% of the embryos exposed to creosote hatched, but all of these exhibited deformities including scoliosis, pericardial edema, and ascites. These effects were not observed in untreated wood or seawater controls. Also, similar effects were observed in embryos collected from the Bay, which displayed a 72% decrease in hatching success and similar deformities in surviving larvae.

Vines et al. (2000) measured total hydrocarbons diffusing from the treated wood by UV fluorescence, and individual components were measured in C-18 extractions of seawater by GC-MS. They concluded that 92.5% of this extract was composed of four 3-ringed PAHs – anthracene, phenanthrene, fluorene, and diphenlethyne – and lesser amounts of furans and non-aromatics. These results are somewhat surprising because the pilings used as the source for the treated wood had been placed in a marina about 40 years before the studies. Based on their results, the authors calculated the LC_{50} for hatching success to be 0.05 mg/L (total hydrocarbons in seawater). A sublethal exposure of 0.003 mg/L significantly reduced hatching success and increased abnormalities in surviving larvae (gross morphology and reduced heart rates); these effects were largely independent of three test salinities (8, 16, and 28 ppt – low, optimal, and high).

Wassenberg and Di Giulio (2004b) exposed *Fundulus* spp. embryos to dilutions of water extracts of sediments from the creosote-impacted portion of the Elizabeth River and observed significantly elevated EROD activities at all dilutions tested (ratios of extract to seawater ranged from 1:5,000 to 1:4). They observed deformities, including pericardial edema, deformed hearts, and shortened tails, at the 1:4 dilution. Addition of the PAH-type CYP1A inhibitor α-naphthoflavone, which had no effects on development by itself, effectively inhibited EROD activities at all dilutions studied and greatly enhanced the teratogenic potency of the extract, with significant effects seen down to the 1:1,000 dilution. Subsequent studies examining the interactive effects of a model PAH-type AHR agonist (β-naphthoflavone) and CYP inhibitor (α-naphthoflavone) demonstrated a potent synergy between these chemicals. Such synergy has also been demonstrated for creosote-associated PAHs (Wassenberg and Di Giulio, 2004a; Wassenberg et al., 2005). For example, fluoranthene, carbazole, and dibenzothiophene were shown to be effective CYP1A inhibitors that markedly enhanced the effects of the AHR agonist benzo[a]pyrene on cardiovascular development in *Fundulus* spp. Collectively, these studies bring into question current assumptions of additivity for PAH mixtures (Barron et al., 2004) and hence may have relevance for ecological risk assessments of these mixtures, including creosote.

The laboratory studies described above tested aqueous exposures; this is probably an important route of environmental exposure. For example, Petersen and Kristensen (1998) measured bioconcentration factors (BCFs) in the range of 3.25 (naphthalene) to 4.32 (benzo[a]pyrene) for several PAHs in the eggs of several freshwater and marine fishes following aqueous exposures. However, these compounds can be transferred from the mother to the egg, as well. For example, adult female *Fundulus* spp. exposed to benzo[a]pyrene transferred parent compound and metabolites to developing eggs, with the compounds transported in associated with vitellogen that entered the eggs during oogenesis (Monteverdi and Di Giulio, 2000a, 2000b).

3.3.5 Immunotoxicity

PAHs have been shown to impact function of the immune system in mammals (White et al., 1994). Studies with fish, some involving creosote exposures, show similar impacts. Payne and Fancey (1989) exposed winter flounder to sediments contaminated with a petroleum source of PAHs. They observed reduced numbers of melanomacrophage centers (primitive analogs of mammalian lymph nodes and important for the cellular immune system of fish) at exposure levels down to approximately 25 mg/kg, total sediment PAH. Faisal et al. (1991) found that anterior kidney and splenic leukocytes from *Fundulus* spp. captured from a creosote-contaminated site in the Elizabeth River had less cytotoxic activity against a tumor cell line than leukocytes from *Fundulus* spp. from a reference site. Karrow et al. (1999) studied the effects of liquid creosotes added to microcosms on immune responses of rainbow trout exposed for up to 28 days to a range of creosote concentrations (5-100 µl/L). Major effects were concentration-dependent reductions in leukocyte oxidative burst response and in the number of surface immunoglobin positive (sIg+) peripheral blood leukocytes. Major chemicals identified in the microcosms were fluoranthene, pyrene, fluorene, and anthracene, with fluoranthene and pyrene exhibiting the strongest associations with immune system effects. They calculated the lowest observable effects concentration (LOEC) for these effects to be 17 µl/L, corresponding to a total PAH concentration of 611.63 ng/L.

3.3.6 Community effects

Several microcosm and field studies have investigated the effects of creosote on phytoplankton and invertebrate communities. Sibley et al. (2001a, 2001b) examined the effects of marine-grade creosote on freshwater microcosms applied at concentrations ranging from 0.06 to 109 mg/L with a single application. These studies involved about 200 species of phytoplankton and

86 species of zooplankton. Creosote caused a concentration-dependent reduction in zooplankton abundance and number of taxa that were maximal at 5-7 days; most taxa recovered within the 83 days of observation following the application. Community composition varied with time and creosote composition, and interspecific competition appears to have played a factor in the population decline and reduced recovery of rotifera relative to cladocera and copepoda; however, rotifera were generally more tolerant to increased creosote exposure. Based on their results and measured concentrations of total PAH, the authors calculated the EC_{50} for total zooplankton abundance (day 7) to be 2.9 µg/L, and the no observable effects concentration (NOEC) for community effects ($NEC_{community}$) to be 3.7 µg/L. In contrast, creosote had no direct adverse effects on phytoplankton communities. Instead, increases in total abundance and number of taxa were observed, apparently in response to reduced grazing pressure by zooplankton. A similar study was subsequently performed, in which Douglas fir pilings impregnated with the same creosote used in the above studies served as the contaminant source (Sibley et al., 2004). The effects on zooplankton and phytoplankton communities in this study mirrored those observed with direct creosote applications; the NOEC for zooplankton community effects was calculated to be 11.1 µg/L total PAH.

In a controlled field study, Goyette and Brooks (1998, 2001) examined the effects of creosote-treated pilings placed in an uncontaminated marine system (Sooke Basin, Vancouver Island, British Columbia). They investigated the effects of these pilings on endpoints including 10-day amphipod (*Eohaustorius washingtonianus*) toxicity; bacterial toxicity (Microtox^{R}); echinoid fertilization; *in situ* assays in deployed blue mussels (*Mytilus edulis*) for growth, spawning, larval development, and PAH accumulation; and benthic community analysis. Some of these endpoints were tracked for up to 1,540 days post-deployment of the pilings. In the first of these reports covering baseline studies and the first 535 days of the piling deployment, Goyette and Brooks (1998) reported significant sediment PAH accumulation up to 7.5 m downstream of pilings (18 µg/g and 7.5 µg/g total PAH at 0.5 m and 7.5 m, respectively), significant toxicity in laboratory tests with sediments collected within 0.65 m of pilings, and significant effects on PAH accumulation and reduced growth rates in mussels deployed within 15 cm of the pilings. Based on Washington State guidelines, they concluded that the greatest risks were posed by phenanthrene, followed by fluorene, acenaphthene, fluoranthene, and chrysene. In the later report covering sampling dates 1,360 and 1,540 days post-deployment, Goyette and Brooks (2001) reported sharply reduced PAH concentrations in sediments and mussels, and toxicity of sediments to amphipods was attributed to elevated sulfide due to anoxic conditions created by the pilings and associated biological communities.

3.3.7 Other effects

Other deleterious effects in estuarine and marine organisms have been noted for creosote and creosote-related compounds, including effects on growth and specific organ systems (Eisler, 2000; WHO, 2004). For example, Borthwick and Patrick (1982) found a 96-hour EC_{50} for reduced shell deposition in eastern oysters (*Crassostrea virginica*) of 710 µg/L. Also, Rice et al. (2000) observed severe impacts on growth in English sole fed polychaete worms that had ingested PAH-contaminated sediment (other contaminants in the sediment were not reported). Most of the sediment PAHs came from creosote released from a wood treatment plant. PAH concentrations in the worms were 11.3 ppm dry weight. Field-contaminated sediment fed to the worms was first diluted with clean sediment, producing a final concentration (3.3 ppm dry weight) that was 0.1% of the original sediment concentrations. Rice et al. (2000) conducted two similar experiments with this sediment. Although both experiments resulted in severe growth impairment, only the first was significantly different from control, possibly due to low statistical power in the second experiment.

Although a full review of all of these other toxicological endpoints is beyond this scope of this report, the response measures described in the preceding sections of this chapter appear to be appropriate and reasonably protective of aquatic receptors in evaluating wood-treating projects.

3.4 Conclusions: Biological Effects Concentrations

Based on the forgoing review of toxicities, acute toxicity to sediment-inhabiting invertebrates, and chronic effects on reproduction, development, the immune system, and the liver (i.e., effects generally leading to liver cancer) in fish merit consideration as adverse effects thresholds (as concentrations in sediment or water). Section 3.4.1 discusses biological effects concentrations in surface water; Section 3.4.2 in sediment.

3.4.1 Biological effects concentrations – surface water

Of the quantitative data available, some are given in terms of sediment concentrations, and some are provided as water column or ISW concentrations. When chemical-specific concentrations are provided in one media, equilibrium partitioning based on K_{ow}s and/or K_{oc}s can be used to make predictions in other media. Unless otherwise noted, concentrations are presented below in terms of total chemical concentrations; these are generally the sums of compounds identified and measured in a given sample, usually TPAH. For water concentrations, some representative effects concentrations are shown in Table 3.1.

The biological effects thresholds for total PAHs in water (Table 3.1) fall within a relatively small range, considering the differences in organisms and endpoints. The lowest value is for immune system effects in rainbow trout (Karrow et al., 1999), but the relationship of this effect to fish health is unclear since the study did not address disease susceptibility. A slight increase in the ratios of liver weights to body weights were observed at 1.0 µg/L. Complete mortality was

Table 3.1. Effects thresholds for PAHs in surface water (concentrations in µg/L)

Organism	Exposure source	Toxicity endpoint	Concentration	Citation
Mysidopsis bahia	Elizabeth River, Virginia, sediment extracts	24-hr LC_{50}	180	Padma et al., 1999
Rhepoxynius abronius	Eagle Harbor, Washington, sediment extracts	96-hr LC_{50}	100	Swartz et al., 1989
Pacific herring	PAHs leaching from ~ 40 year old pilings	LC_{50} for hatching success	50	Vines et al., 2000
Zooplankton	PAHs leaching from pilings placed in microcosms	No effects concentrations (NEC) for communities	11.1	Sibley et al., 2004
Zooplankton	Commercial creosote added to microcosms	NEC for communities	3.7	Sibley et al., 2001b
Pacific herring	PAHs leaching from ~ 40 year old pilings	Significant reduction in hatching success and increased abnormalities in surviving larvae	3	Vines et al., 2000
Zooplankton	Commercial creosote added to microcosms	EC_{50} for abundance	2.9	Sibley et al., 2001b
Trout	Commercial creosote added to microcosms	LOEC for immune effects	0.6	Karrow et al., 1999

observed within three days of the initiation of the experiment at the highest concentration of creosote tested, which appears to have been approximately 6 µg/L at the outset of the study. Control mortality was 23% in the course of the 28-day experiment, and no LC_{50} calculations were presented.

3.4.2 Biological effects concentrations – sediment

The biological effects of PAHs in sediment have been widely studied. A complete review of sediment PAH studies and a compilation of calculated threshold concentrations is outside the scope of this report. However, several studies summarize sediment quality guidelines (SQGs) for PAHs. Swartz (1999) includes many thresholds from many studies, and he compares those to his proposed SQG based on the sum of the PAH concentrations (∑PAH). The Oak Ridge National Laboratory compiled sediment toxicity benchmark data in 1997 (Jones et al., 1997). The U.S. EPA has provided guidance for determining sediment toxicity thresholds, including guidance for the use of equilibrium partitioning (e.g., Di Toro and McGrath, 2000) to determine sediment quality guidelines (Hansen et al., 2003). Thresholds calculated according to this guidance do not carry regulatory authority at this time. Other U.S. EPA publications, such as Ingersoll et al. (2000) and Hellyer and Balog (1999), summarize sediment toxicity thresholds from many other studies, in an attempt to find some consensus.

Similarly, NOAA has compiled sediment toxicity thresholds for PAHs for consideration (not formally adopted), including an analysis of over 1,000 toxicity data points from the early 1990s (Long et al., 1998), and has published Screening Quick Reference Tables (SQuiRTs) that provide a quick reference to four freshwater sediment and five saltwater sediment threshold concentrations for many PAHs, as well as total PAHs (NOAA, 1999a). MacDonald et al. (2000) provide a thorough compendium of sediment quality benchmarks; Appendix III of their report contains well over 100 pages of sediment quality criteria and guidelines from the United States and Canada. Cormack (2001) provides a detailed review of sediment toxicity thresholds and their relation to sediment criteria in U.S. state and federal, and Canadian national and provincial, policies.

Table 3.2 lists an important subset of SQGs for PAHs that are well known and often cited, and/or promulgated and enforceable criteria. Each study in Table 3.2 contains threshold endpoints with acronyms for that threshold. An explanation of those thresholds follows.

- Effects Range-Low (ER-L) and Effects Range-Median (ER-M) are the lower 10th percentile and the 50th percentile, respectively, of a database of effects thresholds originally compiled by Long and Morgan (1991). NOAA guidance states that these are not derived as toxicity thresholds; rather, they were intended to be estimates of concentrations below which toxicity is least likely. They are meant to be used for ranking and prioritizing sites with contaminated sediments (NOAA, 1999b).

- Toxicity Effect Level (TEL) and Probable Effect Level (PEL) were derived for the promulgation of sediment quality criteria for the State of Florida (MacDonald, 1994). They divided their biological effects database into a database of effects concentrations and a database of no effects concentrations. They then calculated the TEL as the geometric mean of the 15th percentile of effects concentrations and the 50th percentile of no effects concentrations, and calculated the PEL as the geometric mean of the 50th percentile of the effects concentrations and the 85th percentile of the no effects concentrations (MacDonald, 1994). The Canadian Council of Ministers of the Environment (2003) copied MacDonald's Florida criteria for the Canadian Environmental Quality Guidelines, though they renamed the TEL the Interim Sediment Quality Guideline (ISQG).

Table 3.2. Sediment quality guidelines or criteria for marine/estuarine sediment. See text for explanation of acronyms and the thresholds they represent. MW = molecular weight (g/mol). Concentrations in ppb dry weight (see below).

		NOAA		FL and Env. Canada		WA	BC		Swartz, 1999	
Parameter	**MW**	**ER-L**	**ER-M**	**TEL**	**PEL**	**AET**[a]	**SedQC$_{scs}$**	**SedQC$_{tcs}$**	**∑PAH TEL**[a]	**∑PAH LC$_{50}$**[a]
Naphthalene	128.2	160	2,100	34.6	391	990	240	470	130	710
2-methylnaphthalene	142.2	70	670	20.2	201	380				
Acenaphthylene	152.2	44	640	5.87	128	660	80	150	30	150
Acenaphthene	154.2	16	500	6.71	88.9	160	55	110	40	230
Fluorene	166.2	19	540	21.2	144	230	89	170	170	900
Anthracene	178.2	85	1,100	46.9	245	2,200	150	290	210	1,140
Phenanthrene	178.2	240	1,500	86.7	544	1,000	340	650	290	1,550
Fluoranthene	202.3	600	5,100	113	1,494	1,600	930	1,800	690	3,710
Pyrene	202.3	665	2,600	153	1,398	10,000	870	1,700	900	4,810
Benzo(a)anthracene	228.3	261	1,600	74.8	693	1,100	430	830	210	1,110
Chrysene	228.3	384	2,800	108	846	1,100	520	1,000	310	1,690
Benzo(a)pyrene	252.3	430	1,600	88.8	763	990	470	920	330	1,790
Dibenz(a,h)anthracene	278.4	63	260	6.22	135	120	84	160		
Sum LPAH		552	3,160	312	1,442	3,700			870	4,680
Sum HPAH		1,700	9,600	655	6,676	9,600			3,060	16,460
Sum TPAH		4,022	44,792	1,684	16,770		10,000	20,000	3,930	21,140

a. Threshold concentrations originally in ppm organic carbon (OC). We assumed 1% OC to convert to ppb dry weight.

Sources: MacDonald, 1994; NOAA, 1999b; Swartz, 1999.
State of Washington: WAC 173-204-320.
Province of British Columbia: B.C. Reg 375/96 Schedule 9.
Canadian Council of Ministers of the Environment, 2003.

- Apparent Effects Thresholds (AETs) are thresholds above which statistically significant biological effects always occur (Swartz, 1999). These threshold concentrations are considerably higher than other thresholds, because they indicate concentrations where deleterious biological effects *will* occur, rather than concentrations where effects might occur, or concentrations below which effects are not likely to occur. The sediment criteria for Washington State are AETs (Gries and Waldow, 1996).

- British Columbia promulgated two separate criteria for PAHs in marine sediment, with a criterion for sediment in a "typical" environment ($SedQC_{tcs}$) and a more conservative criterion for sediment in a "sensitive" environment ($SedQC_{scs}$). These criteria are listed online in Schedule 9 of the Environmental Management Act Contaminant Sites Regulation (B.C. Reg 375/96) (http://www.qp.gov.bc.ca/statreg/reg/E/EnvMgmt/EnvMgmt375_96/375_96.htm; British Columbia Ministry of Labour and Citizen's Services, 2005). We have no guidance for the derivation of these criteria. The $SedQC_{tcs}$ concentrations are similar to the TEL from Florida, and the $SedQC_{scs}$ fall between the TEL and PEL (Table 3.2).

- While at the U.S. EPA, Swartz (1999) proposed sediment criteria based on the ∑PAH model of toxicity to marine and estuarine amphipods. Using data from other studies and translating other thresholds into his ∑PAH metric, Swartz derived a low effects threshold similar to the TEL that he called the "∑PAH toxicity threshold" (which we called the ∑PAH TEL in Table 3.2). He also derived a "∑PAH mixture LC_{50}" at which the concentrations of individual compounds, LPAH, HPAH, or TPAH are sufficient to cause 50% mortality in amphipods (Swartz, 1999).

Table 3.2 shows the wide disparity in sediment quality guidelines for PAHs. As discussed earlier, scientists at the NOAA NMFS Laboratory in Seattle, Washington, have examined the effects of pollutants, particularly PAHs, on benthic fish in Puget Sound for many years, allowing them to derive guidelines using their extensive data set. Here, we summarize some of their work. As described in Section 3.3.3, the liver is an important target for PAHs in some benthic fishes. The worst-case manifestation is cancer, but various biochemical and physiological effects precede the development of cancer, and many of these have been the focus of biomonitoring. Drawing on NOAA's data sets, Horness et al. (1998) developed "hockey stick" regressions to determine sediment thresholds for effects in benthic fish. The analysis focused on liver lesions in English sole in relation to TPAHs in sediments for approximately 30 sites in the Puget Sound comprising a wide gradient of PAH concentrations. Liver lesions evaluated were neoplasms, specific degenerative/necrotic lesions, such as megalocytic hepatosis and nuclear polymorphism, proliferative lesions, and foci of cellular alteration (FCA). Threshold concentrations are the sediment TPAH concentrations (based on dry weight of whole sediments) above which lesions are predicted to occur above background incidences. Threshold values ranged from 54 ng/g (ppb) for FCA to 2,800 ng/g for neoplasms. Values for other lesions ranged between 230 and 940 ppb.

The very low FCA value, however, was deemed insignificant because the confidence interval did not lie entirely within the data range, and it was suggested that FCAs may be a non-threshold response. Among the other thresholds, the most sensitive was 230 ppb, the threshold value for proliferative lesions.

Johnson et al. (2002) built on the hockey stick approach developed by Horness et al. (1998) to incorporate additional endpoints (DNA damage and endpoints associated with reproduction) and to explicitly calculate a sediment quality threshold for PAHs. Again, data for English sole provided the basis for their analysis, and they incorporated the results for liver lesions from the Horness et al. (1998) paper. Threshold values for three reproductive endpoints that were relatively sensitive (inhibition of spawning, infertile eggs, and abnormal larvae) were all calculated to be 630 ppb. The threshold value for DNA damage, measured as PAH-DNA adducts, was 288 ppb. Based on their overall analysis, Johnson et al. (2002) concluded that at sediment concentrations greater than 1,000 ppb, there is a substantial increase in the risk of liver disease and reproductive impairment, and suggested that 1,000 ppb be used as a SQG for TPAH in estuarine systems. This SQG is less than the TPAH criteria shown in Table 3.2, though it is close to the 1,684 ppb TPAH criterion for the Florida TEL and Environment Canada's ISQG. Based on the foregoing, a sediment effects concentration of 1 ppm total PAH appears to be a reasonable screening value for use in the evaluation of potential creosote applications. Chapter 4 discusses how this threshold and other toxicity information presented in this chapter can be used in tandem with leaching and mobility information from Chapter 2 to assess the risk to the environment of various creosote treatments and applications.

4. Risk Evaluation

Having established in previous chapters that significant amounts of PAHs (and other contaminants) can leach from creosote-treated wood under environmentally relevant conditions, resulting in toxicity to organisms exposed to nearby surface waters and sediments, this chapter discusses further the risk to aquatic biota, including NOAA trust resources, from the use of creosote-treated wood. Two alternative lines of evidence are available to evaluate potential impacts. Section 4.1 briefly presents the results of previous ecological risk assessments of treated wood products, and Section 4.2 uses the results of the leaching and environmental distribution models described in Chapter 2 in a separate risk evaluation. Section 4.3 discusses the results of empirical laboratory and field studies (including many of the studies discussed in Chapters 2 and 3) designed to evaluate potential biological and/or ecological effects. Section 4.4 discusses factors that should be considered for site-specific risk assessments.

4.1 Previous Risk Assessments

Sinnott (2000) developed a simulation model to evaluate ecological risks from creosote-treated wood. Using leaching rates from Ingram et al. (1982) and Hochman (1967), as cited by Kelso and Behr (1977), and degradation rates from the U.S. EPA (1979), the author estimated average daily concentrations of naphthalene, phenanthrene, and anthracene for the first month following immersion, and for the subsequent 11 months of immersion, in a 6-foot deep pond. Sinnott concluded that much of the leaching occurs shortly after immersion of treated wood in water, that the PAHs dissipate rapidly or are not present in high enough concentrations to cause harm, and that treated wood is not generally a toxicological problem in aquatic environments. The predicted sum of these compounds in the water column was below New York State water quality standards.

Brooks (1995) conducted an assessment of risks to T&E species in the Columbia River Basin from PAHs released from creosote-treated wood using a version of his leaching and environmental distribution model described in Chapter 2. The author compared predicted sediment PAH concentrations, given two pilings spaced 1 m apart, against then-current Washington State sediment quality criteria (total PAH of 1,330 in ppm TOC, or 25.3 ppm sediment dry weight, at 1.9% TOC), and made the following recommendations:

1. Creosote-treated wood products can be used without further risk assessment when:

    a. The RPD (a depth measure of the transition between oxic and anoxic sediment) is greater than or equal to 0.5 cm and current speeds are greater than 10.0 cm/sec.

   b. The RPD is greater than or equal to 1.0 cm and the sum of the RPD in cm and the current speed exceeds 7.0 cm/sec.

2. An individual project risk assessment should be required when:

   a. The RPD is less than 0.5 cm deep or when current speeds are less than or equal to 2.0 cm/sec.
   b. A project uses more than four pilings installed in a line parallel to the currents at inter-piling distances less than 1 m.
   c. The sum of the RPD and the current speed is less than or equal to 5.0 cm/sec.
   d. A new project is located within 10 m of an existing creosote-treated wood project.

3. Creosote projects should not be constructed in areas where current speeds are less than or equal to 1.0 cm/sec without further assessment.

4.2 Risk Assessments Using PAH Leaching Models

Chapter 2 described several PAH leaching and environmental distribution models that have been developed to predict the environmental concentrations of PAHs that result from the use of treated wood. Since the models contain many variables, specific scenarios must be assumed to generate model predictions. Table 4.1 lists model predictions for the specific scenarios described in Chapter 2 where the model authors were comparing the results of their models to measured PAH concentrations in specific field settings. Table 4.1 also includes the results for a specific model run for a hypothetical single-piling scenario.

As shown in Table 4.1, in most of the scenarios modeled, the predicted sediment PAH concentrations are well above the 1.0 mg/kg total PAH threshold discussed in Chapter 3. The single exception is the model predictions of Brooks (1997) for the pilings of the Westham Island Bridge in British Columbia that are at least eight years old and are in an area of high tidal velocity. For the other scenarios, concentrations greater than 1.0 mg/kg are predicted for areas within several meters of the pilings. In the model for Belcarra Bay, British Columbia, Brooks (1997) predicts that the sediment concentration of 9 mg/kg at 1 m within the piling decreases to approximately 0 within 10 m of the piling.

In addition to the results shown in Table 4.1, the model of Poston et al. (1996) also predicts that concentrations of PAHs in the water column may be toxic around newly installed pilings of relatively high density (as described in Chapter 2). However, the Poston et al. (1996) model is a simplistic model that most likely overestimates PAH concentrations in the water column. On the other hand, they use toxic thresholds for many individual PAH compounds that are most likely too high, based on the review provided in Chapter 3.

Table 4.1. Environmental PAH concentrations predicted by PAH leaching and distribution models

Source	Scenario description	Environmental medium	Distance from piling/structure (m)	Predicted PAH concentrations mg/kg (dw)
Brooks, 1997	Belcarra Bay, British Columbia; > 1.5 year-old pilings	Sediment	1 3 5 10 20 40	9 5.5 3 0 0 0
Brooks, 1997	Westham Island Bridge, British Columbia; > 8 year old pilings; low salinity water; high tidal current	Sediment	0.5 2 5	0.6 0.2 0.1
Chapter 2 (using model of Brooks, 1997)	Single, 13-inch piling in seawater, 2.5 cm/s tidal current	Sediment	0.25 1	5.9 2.0
Goyette and Brooks, 1998, 2001	6-piling dolphins in Sooke Basin, British Columbia; unweathered	Sediment	0.5 2.0	24 19
	6-piling dolphins in Sooke Basin, British Columbia; weathered	Sediment	0.5 2.0	24 6

In conclusion, these results indicate that the available models on PAH leaching and environmental distribution predict that PAHs that leach from treated wood are present at concentrations that are predicted to be toxic to aquatic biota under realistic environmental scenarios. The models predict that these affects will be relatively localized around pilings (within approximately 5 m, depending on the specific conditions).

The predictive models applied here and described in Chapter 2 appear to capture the available laboratory data on PAH leaching reasonably well under certain conditions. However, for a variety of reasons discussed in Chapter 2, there is uncertainty in applying the results of laboratory study-based leaching models to field conditions. Depending on the specific field application, the laboratory-based leaching models appear to be more likely to under-predict than over-predict leaching under field conditions, at least for the initial leaching period that occurs within the first hours and days after construction. Furthermore, there is much uncertainty in modeling actual environmental concentrations from the leaching study models, as also described in Chapter 2. Therefore, the results of the predictive risk assessment models should be interpreted carefully, as they may have substantial (and unquantified) uncertainty. Finally, by their nature, models use simplifying assumptions that may miss uncommon but important conditions that result in temporary or localized concentration spikes that could affect marine organisms.

4.3 Laboratory and Field Studies

Several laboratory and observational field studies have been performed to evaluate the potential impacts of creosote-treated wood products on aquatic biota. These studies allow for a direct assessment of the potential adverse effects and ecological risk associated with use of creosote-treated wood in aquatic habitats.

This section evaluates the potential impacts of creosote leaching first by looking at three highly relevant areas of research: (1) large-scale studies showing creosote leaching from sites where dozens or hundreds of pilings are clustered together, specifically the Charlestown Navy Pier in Boston, Massachusetts, and the Naval Station San Diego (NAVSTA) in San Diego Bay, California; (2) creosote leaching studies performed under the auspices of Dr. Kenneth Brooks, including a study of creosote leaching effects in the Fraser River Estuary in British Columbia and several subsequent studies; and (3) laboratory studies of creosote leaching in aquatic microcosms by University of Guelph researchers. We then provide reviews of several other field and laboratory studies that provide ancillary evidence of creosote leaching in the environment.

4.3.1 Large-scale studies: Charlestown Navy Pier and Naval Station San Diego

In 1987, the National Park Service (NPS) replaced about 90 creosote piles at Pier #2 of the Charlestown Navy Yard in Boston (Graham and Johnsen, 2002). The NPS rejected many of the piles because of insufficient retention. The re-treated piles were then over-impregnated to an average retention that was 25% higher than BMPs specified. The result was a noticeable slick of creosote from the new pilings after installation (Graham and Johnsen, 2002).

Costa and Wade (1989) collected samples and provided analyses of the Pier #2 creosote leachate, including chromatography analyses and sea urchin toxicity tests. The chromatography analyses showed that the surface sheen emanating from the pier was unquestionably creosote, as the peaks in the slick matched the peaks in creosote for all major PAHs except the lightest, most volatile ones. Dissolved PAH concentrations were high in the surface sheen and relatively high in water directly above the sediment, but dissolved PAHs were undetectable in samples from within the water column below the surface slick. Target PAH concentrations in the water near the sediment were 0.87 to 1.7 µg/L, about 8-14 times higher than the concentrations at a control site near a different pier. The PAH concentration of the surface slick was up to 5,350 µg/L – the authors stated that "it can be presumed that the surface slick is toxic to organisms residing in the surface layer" (Costa and Wade, 1989).

The concentrations of the target creosote PAHs in sediment near Pier #2 pilings were 250 times greater than the concentrations at a control site, with total target PAH concentrations as high as 6,390 µg/g dry weight. The samples were described as having a strong creosote odor (Costa and Wade, 1989). Surface sediment PAH concentrations decreased rapidly with distance from the pilings, reaching background concentrations between 6 and 21 feet from the creosote pilings.

Costa and Wade (1989) collected the leachate in the surface slick and attempted to fertilize sea urchin eggs in the presence of the leachate. Over 50% of the eggs failed to fertilize in all tests in which the test water contained at least 1% leachate. The authors calculated the LOEC at 0.38% leachate, or 20 µg/L PAH, and the NOEC at 0.19% leachate. Their results show that at 0.09% leachate (4.8 µg/L PAH), the most dilute test they performed, 21% of the eggs failed to fertilize, compared to 0.3-0.7% failure using control water. The difference was not statistically significant.

In summary, the approximately 90 new pilings at the Charlestown Navy Pier exuded a surface slick with PAH concentrations of 5,350 µg/L, several orders of magnitude greater than concentrations predicted to impact sea urchin reproductive success. Samples of the slick caused significant toxicity to sea urchins in a reproductive endpoint test at mixtures of 0.38% slick. PAH concentrations in water near the sediment interface were up to 1.7 µg/L, and were not detected in the water column between the sediment and water surface. The sediment near the pilings contained PAH concentrations 250 times greater than the concentrations at a nearby control site (Costa and Wade, 1989).

At NAVSTA in San Diego Harbor, the U.S. Navy made important operational changes in the 1990s in an effort to reduce PAH contamination in San Diego Bay. Specifically, the Navy stopped discharging bilge water directly to the bay, and they made a concerted effort to replace all creosote pilings at the base. In 1997, Katz (1998) examined the changes in dissolved PAH concentrations in the bay after approximately 50% of the creosote pilings had been replaced with plastic, concrete, or untreated pilings.

Katz (1998) compared historical surface water PAH concentrations from 1990 to 1994 with concentrations measured in the summer and fall of 1997. In all studies from both time periods, PAH concentrations were higher near the Navy piers than in other areas within San Diego Bay. In the early 1990s, the two sample sites adjacent to the piers contained average total PAH concentrations of 1.2 and 1.7 µg/L, including a sample at one site that exceeded 8 µg/L in a surface slick. The average total PAH concentration from 36 samples collected near NAVSTA piers from 1990 to 1994 was 1.1 µg/L, compared to an average of 0.16 µg/L for the 65 samples collected away from the piers. In 1997, after 50% of the pilings were replaced with non-creosote alternatives, the total PAH concentrations in the surface water near the pilings were an order of magnitude lower than the average concentrations between 1990 and 1994, with concentrations between 0.1 and 0.2 µg/L (Katz, 1998). Total average PAH concentrations decreased to 0.12 µg/L at NAVSTA and 0.06 µg/L at non-NAVSTA sites in 1997. Chromatograms of the water samples showed PAHs that matched the pattern for creosote from samples at the Navy pier (Katz, 1998). Unfortunately, this study did not include analyses of sediments or biota in the bay. However, the study does suggest that creosote pilings at NAVSTA were at least partly responsible for elevated PAH concentrations in the surface water of San Diego Bay, and that the program to replace those pilings led to measurable decreases in dissolved PAH concentrations in the Bay.

4.3.2 Fraser River estuary and related studies

In 1994, EVS Consultants (1994) conducted a creosote evaluation project for the Fraser River Estuary Management Program in British Columbia. They examined sediment PAH concentrations and conducted toxicity tests on amphipods and bacteria near creosote piling installations at Belcarra Bay and at Westham Island in the Fraser River estuary. The pilings at the Belcarra Bay wharf ranged from 2 to 20 years old, and the pilings closest to the Westham Island study site were 8 years old. At Belcarra Bay, sediment PAH concentrations within 10 m of the pilings were significantly higher than reference concentrations, and the survival of amphipods and bacteria exposed to the sediment in laboratory toxicity tests was significantly diminished. Total sediment PAHs were as high as 19.7 µg/g, about 10 times higher than reference concentrations. By contrast, at Westham Island, total sediment PAH did not exceed 0.5 µg/g and was not significantly different than background concentrations. Amphipod survival was similar in sediment collected from the Westham Island site and the control site. EVS Consultants (1994) attributed the different results at Westham Island compared to Belcarra Bay to a higher water flow rate at Westham Island that carried leached creosote away from the site. Furthermore, the newest pilings at the Westham Island site were over 8 years old, compared to the 2 year old pilings at the Belcarra Bay site.

The EVS study in the Fraser River estuary led to a Phase II study (Goyette and Brooks, 1998, 2001) in the Sooke River Basin on Vancouver Island, examining more closely the possible impacts of creosote leaching. Sooke Basin conditions were similar to Belcarra Bay in the Fraser River estuary but with less background PAH contamination. The Sooke Basin site was away from intense human activity, with weak tidal currents (1.89 cm/s) and no freshwater runoff input. The study consisted of three tests using 6-piling dolphins, one containing a dolphin with newly treated pilings, one with 8 year old weathered pilings, and one with untreated pilings. As at Belcarra Bay, sediment PAH concentrations near the creosote-impregnated test dolphins in Sooke Basin were elevated compared to background. Table 4.2 shows the sediment PAH concentrations near the weathered piling dolphins. Figure 4.1 shows sediment PAH concentrations near the newly treated dolphins, including the changes in PAH concentration with time (Figure 4.1a) and the changes in PAH concentration with distance from the pilings (Figure 4.1b). It should be noted that surficial samples in this study were collected as the top 2.0

Table 4.2. Summary of sediment PAH concentrations near dolphins containing six weathered creosote pilings in the Sooke Basin, British Columbia. (+) is downstream, (-) is upstream of the pilings. Concentrations immediately before installation are listed as 0 days since installation. PAH concentrations in µg/g.

Distance from pilings (m)	Days since installation	Mean % TOC	Mean LPAH	Mean HPAH	Mean TPAH
0	0	0.9	0.03	0.1	0.13
0.5	0	1	0.04	0.16	0.19
0	384	0.7	5	42.3	47.4
+0.5	14	1.3	34	71	105
+0.5	180	0.9	2.9	11.2	14.1
+0.5	180	1.3	6.2	11.6	17.8
+0.5	384	0.7	1.3	9.5	10.8
+0.5	384	0.6	4.6	29.2	33.8
+2.0	14	1.3	0.8	2.1	2.9
+2.0	180	1.3	0.9	3.9	4.8
+2.0	384	0.6	0.8	5.6	6.3
+2.0	384	0.9	3	12.2	15.3
-2.0	14	1.2	0.6	0.7	1.3
-2.0	180	1.1	0.4	1.1	1.5
-2.0	384	0.7	0.5	3.8	4.3
+5.0	384	0.6	0.3	2	2.3
+10.0	384	1.2	0.1	0.8	0.9

Source: Goyette and Brooks, 1998; Appendix VI(B).

to 2.5 cm, and therefore evaluation of the accumulation of creosote in the surficial sediments at a scale finer than the top 2.0 to 2.5 cm is not possible. Nevertheless, the results of the study document that increased creosote accumulation in sediment was observed downstream of the pilings.

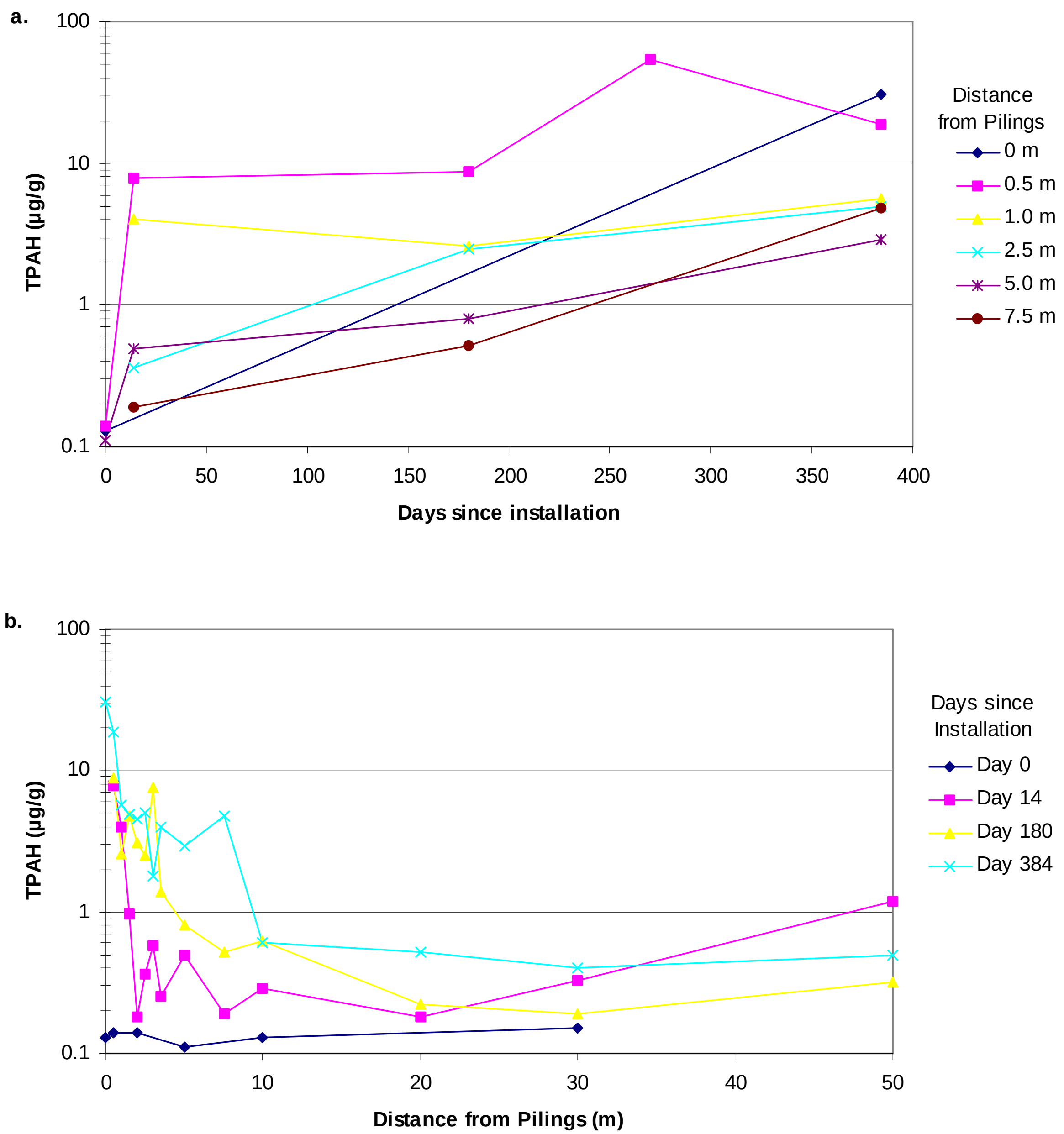

Figure 4.1. Sediment total PAH concentrations downstream (downcurrent) of newly treated pilings in the Sooke Basin study, as they varied with (a) time and (b) distance from the pilings. Note the logarithmic scale for TPAH.

Source: Goyette and Brooks, 1998.

The data in Table 4.2 and Figure 4.1 clearly show increases in sediment PAH concentrations within two weeks after installation, with elevated PAH concentrations remaining over a year after installation and extending up to 50 m from the pilings. The following summarizes the conclusions of Goyette and Brooks (1998) after one year of data from the Sooke Basin study:

- Two weeks after installation of the weathered piling dolphin, the sediment PAH concentration 0.5 m downstream of the pilings (where downstream is the dominant direction of current flow) was over 100 μg/g dry weight, nearly three orders of magnitude greater than the concentration before installation (Table 4.2). The authors suggest that physical abrasion of the treated wood surface during installation may have caused an initial release of creosote.

- Surface sediment PAH concentrations were statistically significantly higher than baseline concentrations to a distance of 7.5 m from the newly treated pilings. Smaller PAH increases occurred at a distance of 50 m (Figure 4.1b).

- The proportion of HPAH to LPAH in the sediment increased notably between Day 14 and Day 384 (Table 4.2), suggesting the preferential loss of the LPAH through solubilization.

- The surface sediment PAH concentrations were highly variable, with poor correlation amongst replicate samples in some cases.

- No significant changes in benthic community structure were observed.

- Toxicity tests on mussels (*Mytilus edulis*) showed slightly elevated PAH body burden and slightly less growth in the presence of sediments contaminated with PAHs leached from the pilings. There were no adverse effects to mussel survival or viability.

In 2001, Goyette and Brooks (2001) published an addendum to the Sooke Basin study, showing results four years after the installation of the dolphins. This study showed a significant decline in PAH concentrations between Year 1 (384 days) and Year 4. An active invertebrate community had become established, with the pilings serving as an artificial reef. Mussels living on pilings contained PAH concentrations less than background concentrations. The limiting factor on biota was reported to be low oxygen and high sulfur due to the accumulation of detritus near the pilings.

Dr. Brooks, who was part of the steering committee for the Fraser River Estuary study and was co-author of the Sooke Basin study, published several more reports examining creosote leaching into the environment. They include a study showing the leaching of PAHs from bridge timbers into an aquatic environment (Brooks, 2000) for the USDA Forest Service (USFS), a study of PAH leaching from creosote timbers in Puget Sound (Brooks, 2003) for the Creosote Council, an industry group, and a study examining PAH leaching from railroad timbers into wetlands (Brooks, 2004b) for the USFS. His results and conclusions for each of these studies are similar to the results and conclusions from Belcarra Bay (EVS Consultants, 1994), and the Sooke Basin study (Goyette and Brooks, 1998, 2001). Brief summaries of these studies are provided below.

Brooks examined sediment PAH concentrations in Pipe Creek, Indiana, immediately downstream of two bridges built with creosote timbers (Brooks, 2000). At the time of the study, one bridge was 2 years old and one was 17 years old. The results of the study showed the following:

- Sediment PAH concentrations at the older bridge increased from undetectable (< 0.11 µg/g) upstream of the bridge to a maximum of 2.3 µg/g 1.8 m downstream of the bridge. Beyond 1.8 m, PAH concentrations generally decreased with distance downstream of the bridge, though were still detectable (0.5 µg/g) at 10 m, the most downstream location.

- Sediment PAH concentrations at the newer bridge increased from undetectable (< 0.23 µg/g) upstream of the bridge to a maximum of 5.5 µg/g 1.8 m downstream of the bridge. PAHs were still detectable (0.5 µg/g) at 6 m downstream, and were undetectable at 22.8 m downstream.

- The highest PAH concentrations downstream of the newer bridge exceeded toxicity threshold effect levels, whereas none of the concentrations downstream of the older bridge did.

- Despite the toxicity threshold exceedences, the biological data that was collected did not reveal adverse effects on biota from PAHs at either the newer bridge site or the older bridge site (Brooks, 2000).

Brooks (2003) conducted a comprehensive study of sediment PAH concentrations and the effects on biota at several locations in Puget Sound, Washington State, in a manner similar to the Sooke Basin study. This study included wharfs with dozens of creosote-impregnated piers and sites with dolphins similar to Sooke Basin. The results, summarized below, are similar to the results of his previous studies.

- At a long wharf at Fort Worden, total PAH concentrations in sediment were 16 µg/g closest to the pier, 11 µg/g at 2.5 m distance, and 5.4 µg/g at 7.5 m distance. Background concentrations were 0.5 µg/g or less. Within 2 m of the densest cluster of pilings, sediment PAH concentrations were as high as 34 µg/g, compared to 0.07 µg/g at background sites, though some of the PAHs at 2 m were specific HPAHs that are more characteristic of heavy oil than they are of creosote. Samples from between 0.5 and 2 m from the pilings exceeded the Washington State SQGs for PAHs.

- Near a three-piling dolphin at Fort Ward, the sediment PAH concentration was 11.7 µg/g within 0.5 m of the dolphin and decreased to 0.7 µg/g at 2 m. Background samples contained elevated PAHs at this site.

- Sediment PAH concentrations from around a single piling at Fort Ward and around a three-piling dolphin at Port Townsend's city pier were not significantly higher than at reference sites. However, the reference sites themselves contained PAHs in the sediment (1.9 to 7.6 µg/g).

- At Fort Worden, weak negative correlations were found between the abundance of some invertebrate species and PAH concentrations. Weak positive correlations were also found, particularly between nematodes and PAHs, most likely because nematodes tend to populate the organic-rich sediment found at the base of the pilings. The author states that the effects of biodeposits from the abundant epifaunal community that populates the pilings has a much larger effect on the overall benthic community than do the PAHs that leach from the pilings and accumulate in the sediment.

The most recent study from Dr. Brooks (Brooks, 2004b) examined creosote leaching from railroad ties in wetland areas, with an examination of both PAHs migrating to the railroad bed ballast and PAHs migrating into the wetland. The results of this study showed very little PAH contamination in the wetland. In the second year of the study, PAH concentrations increased by an average of 0.3 µg/g, which was not statistically significant. In 16 wetland sampling events over two years, PAHs were only detected once, and the concentrations were well below toxicity thresholds.

4.3.3 University of Guelph microcosm studies

Researchers at the University of Guelph in Ontario conducted laboratory (microcosm) studies of the distribution of contaminants within the microcosm when exposed to creosote. These include a study where liquid creosote was added directly to the water (Bestari et al., 1998a, 1998b; Sibley et al., 2001b), and another study where recently treated Douglas fir pilings were added to the microcosm (Bestari et al., 1998a; Sibley et al., 2004).

Bestari et al. (1998b) applied 14 different doses of liquid creosote to an aquatic microcosm in a 12,000 L tank, then over the course of several weeks measured the concentration of 15 priority PAHs in water, sediment, and on polyvinyl chloride (PVC) strips within the sediment. In a concurrent study (Bestari et al., 1998a), they applied 6 different doses of creosote to similar microcosms, but rather than apply creosote directly, they used recently impregnated Douglas fir pilings where the creosote leached from the pilings. The results of each study were similar and are summarized below.

- PAH concentrations in water were dose-dependent. In the timber study, the dissolved PAH concentration ranged from 7.3 µg/L with one-half of a piling in the microcosm up to 97.2 µg/L with six pilings in the microcosm.

- PAH concentrations in water decreased exponentially with time after initial dosage. The PAH concentration after the highest liquid creosote dosage decreased from 5,800 µg/L on Day 2 to 13.9 µg/L on Day 84. The 6-timber treatment decreased from the maximum of 97.2 µg/L at Day 7 to 6.7 µg/L at Day 84.

- When liquid creosote was applied at concentrations exceeding 590 µg/L, sediment PAH concentrations increased until Day 28, then decreased thereafter in all but the highest dose. The increase in sediment PAHs was dose-dependent. In contrast, in the piling treatment study there was no increase in sediment PAHs at any of the treatment levels at any time during the study or at any distance from the pilings, though none of the water concentrations approached 590 µg/L in that study. The authors suggested that in the piling treatments the HPAHs adsorbed to the PVC liners, and LPAHs were lost to volatilization and possibly to biodegradation in sediment occurring in equilibrium with the PAH removal rate.

Sibley et al. (2001b, 2004) report the effects of these creosote treatments on phytoplankton and zooplankton communities. The responses were similar for both liquid creosote application and creosote leaching from pilings. Zooplankton abundance decreased after the introduction of creosote in a dose-dependent manner, just as the aqueous PAH concentrations increased in a dose-dependent manner. At concentrations greater than 1,100 µg/L, which were found only in the liquid creosote study, zooplankton species composition changed significantly, perhaps due to a drop in rotifer density (Sibley et al., 2001b). For liquid creosote, the estimated NOEC for the zooplankton community was 13.9 µg/L total PAHs after five days and 5.6 µg/L total PAHs after seven days (Sibley et al., 2001b). For leached creosote, the NOEC was 11.1 µg/L total PAHs (Sibley et al., 2004).

By contrast, the phytoplankton abundance and diversity increased in all treatments in both studies, with phytoplankton abundance increasing to up to twice that in the control microcosms (Sibley et al., 2001b, 2004). The authors attribute this to decreased zooplankton grazing pressure and possibly to growth stimulation from compounds in the creosote. Based on these data, the authors conclude that creosote leaching from pilings may cause short-term toxicity to limnetic or benthic communities shortly after deployment, but that long-term effects are unlikely as PAH concentrations decrease exponentially with time (Sibley et al., 2004).

4.3.4 Other studies

Over the past 30 years, many studies have examined the leaching of creosote from impregnated timbers and the resultant environmental concentrations of PAHs near creosote timbers. Short summaries of some of these studies are included below (some are also discussed in Chapter 2, as relevant to leaching).

- Zitko (1975) found elevated PAH concentrations in mussels, clams, periwinkles, and whelks near a wharf in New Brunswick, Canada. Zitko states that creosote-treated wharf timbers are the only source of PAHs to the bay.

- Dunn and Stich (1976) reported benzo(a)pyrene concentrations three to four times higher in mussels growing on creosote timbers than on nearby rocks and concrete in Vancouver Harbor, British Columbia.

- Ingram et al. (1982) conducted studies of creosote leaching from treated pilings in laboratory tanks, using many different treatments. Dissolved PAH concentrations increased for all 15 PAHs they studied, in both fresh and saltwater. Six compounds (naphthalene, phenanthrene, acenaphthene, dibenzofuran, fluorene, and 2-methylnaphthalene), which comprised 70-80% of their test creosote, were the dominant contaminants in the water. Higher concentrations of leached PAHs were found in freshwater treatments than in saltwater treatments, and higher concentrations emanated from newly treated timbers than from aged timbers. Maximum PAH concentrations occurred within 48 hours of treatment, then concentrations decreased for the remainder of the study.

- Harrington and Crane (1994) found slightly elevated PAH concentrations in clams at and just downstream of a ferry dock in the Sacramento River delta. PAHs were not detectable in surface water or in clams upstream of the dock. PAHs were as high as 0.45 mg/kg in clams on the dock, and 0.20 mg/kg in clams downstream of the dock. The authors concluded that these concentrations were insufficient to cause an adverse effect to the clams.

- Wendt et al. (1996) found slightly elevated PAH concentrations in sediment and oysters growing near creosote-impregnated dock pilings in South Carolina compared with control sites. Oyster growth was somewhat less near the pilings compared to control sites. None of the differences were statistically significant.

- Graham and Johnsen (2002) describe a surface slick from a dock in Poughkeepsie, New York, that required the dock owners to deploy a boom to contain the spill. Creosote-impregnated pilings at the dock were given as the cause of the slick. No specific data were given.

4.3.5 Conclusions

Overall, the laboratory and field studies described above indicate that treated wood structures can leach PAHs and other toxic compounds into the environment. However, the degree of PAH accumulation to sediment associated with these structures appears to be relatively minor in many settings, particularly in well-circulated waters and over time. PAH accumulation also appears to be relatively limited spatially (within approximately 10 m of the structure) and has not generally been associated with measured, significant, biological effects except in close proximity to the structures. The duration of any biological effects also appears to become attenuated within several months of construction (the time period when leaching rates are likely to be highest).

Nevertheless, there are several factors that suggest that a precautionary principle might be applicable to certain treated wood uses. First, the above studies typically have evaluated responses at the community level (e.g., the benthic invertebrate studies) or to tolerant life stages (e.g., adult oysters and mussels). However, the level of environmental protectiveness applied to T&E species (such as endangered salmonids) should occur at the *individual* rather than the *population* or *community* level. Moreover, field studies have indicated that PAHs can accumulate to potentially deleterious concentrations in poorly circulated water bodies or when the density of treated wood structures is high compared to the overall surface area of the water body. As a result, site-specific evaluations of risk should be conducted for treated wood projects that are proposed for areas containing sensitive life stages, species of special concern, or where water circulation and dilution are potentially low. We discuss considerations associated with such site-specific risk assessments below.

4.4 Factors to be Considered in Aquatic Risk Assessments

The analyses presented in this report demonstrate that PAHs that leach from creosote-treated wood have the potential to accumulate in abiotic media and aquatic biota and to cause toxicity to biota. However, the risk of adverse toxicological effects may be limited in spatial scale and time in many environmental settings and treated wood uses, and vary dramatically depending on case-specific factors such as the nature of the wood and its treatment, environmental conditions, and species of concern. Therefore, in certain settings, site-specific risk assessments should be performed to ensure that projects avoid unnecessary risks to sensitive species or species of special concern. Conditions that should prompt consideration of a site-specific risk assessment include:

- Low current velocities (e.g., current speeds < 1 cm/sec) and/or relatively little expected mixing coupled with a relatively high density of construction materials

- The presence of sensitive life stages (typically larvae and juveniles) of aquatic organisms, particularly T&E or special status species, in the project location.

When conducting such site-specific risk assessments, Hutton and Samis (2000) identify the following factors that should be considered:

- **Background water quality variables such as salinity**

  The salinity of the receiving environment should be considered because leaching increases with decreasing salinity, as in estuarine environments.

- **Current velocity and direction**

  Although total leaching rates from treated wood can be relatively low, potential environmental effects will be dictated by local water mixing, with poorly mixed waters at greater risk. Information on current velocities – at the specific micro-environment – of the project location (including the influence of the structure itself on ambient current velocities) should be developed and integrated into a site-specific risk evaluation.

- **Proximity to sensitive fish habitat**

  The presence of sensitive life stages, especially T&E species or their essential prey species, should prompt an evaluation of potential risks at that location. Essential fish habitats for Pacific salmon include all streams, lakes, and other water bodies currently or historically accessible to salmon. This includes essentially all estuarine and marine waters of the Pacific Coast. The most sensitive life stages for these species are fry (particularly post swim-up) and juveniles. Because the initial leach rates are higher for treated wood, risk assessments should consider the timing of PAH releases relative to periods when sensitive life stages of fish are present.

- **Timing of proposed construction**

  Because initial leach rates tend to be greater, the timing of proposed construction should be considered with respect to the presence of sensitive life stages of aquatic receptors, water flow rates and temperature, environmental and climatic factors that can influence mixing and dilution, and the relationship between season, annual hydrograph, and water quality conditions.

- **Size of proposed structure**

  As discussed previously, environmental effects are likely to be greatest when the size of the proposed structure is large relative to the receiving environment. Factors to consider include number and size of pilings, surface area of exposed wood area relative to a mixing zone, density of pilings relative to the mixing zone (to evaluate potential behavioral avoidance responses), and potential effects of structure size on current flows.

- **Application methods**

  Treatment and application methods should be confirmed to meet industry BMPs.

- **Proximity of other treated-wood structures and other sources of contamination that may contribute to cumulative effects**

  In evaluations of site-specific risks, assessments should consider potential effects in light of the cumulative effect of the proposed structure relative to other existing environmental perturbations at the site.

In addition, the Los Angeles District of the U.S. Army Corps of Engineers uses standard permit conditions that apply to creosote-treated pilings placed in navigable waters of the United States. The standard conditions include the following (personal communication, D.J. Castanon, U.S. Army Corps of Engineers, Los Angeles District, November 30, 2004).

- Creosote-treated pilings shall not be placed in navigable waters or waters of the United States unless all of the following conditions are met:

  - The project involves the repair of existing structures that were originally constructed using wood products.

  - The creosote-treated pilings are wrapped in plastic.

  - The use of plastic-wrapped creosote pilings is restricted to marine waters.

  - Measures are taken to prevent damage to plastic wrapping from boat use. Such measures may include installation of rub strips or bumpers.

  - The plastic wrapping is sealed at all joints to prevent leakage.

- The plastic material is expected to maintain its integrity for at least 10 years, and plastic wrappings that develop holes or leaks are repaired or replaced in a timely manner.

These conditions were developed by the Army Corps of Engineers in coordination with the California Department of Fish and Game and NOAA. Furthermore, as presented in Chapter 1, other agencies with jurisdiction over marine waters have begun replacing and restricting the use of creosote-treated wood, including: Washington State Ferries; the Port of Port Angeles, Washington; the Oregon Department of Environmental Quality, State Marine Board; the CCC; the Delaware Department of Natural Resource and Environmental Control; the New York State Legislature; and the Rhode Island Coastal Resources Management Program.

Theses various initiatives, restrictions, and standard permit conditions show that regulatory agencies are increasingly recognizing that creosote treatments in marine environments can cause ecological harm under common enough circumstances that new structures should avoid the use of creosote-treated wood, and creosote should be isolated from the environment wherever it is used. Based on the findings of this report that creosote moves into the environment under a variety of realistic conditions, and environmental levels of contaminants originating from creosote-treated wood are often toxic, precautions to avoid creosote-treated wood where practical, and measures to isolate potential toxic effects appear to be justified. We recommend that similar precautions be implemented by regulating agencies throughout the United States.

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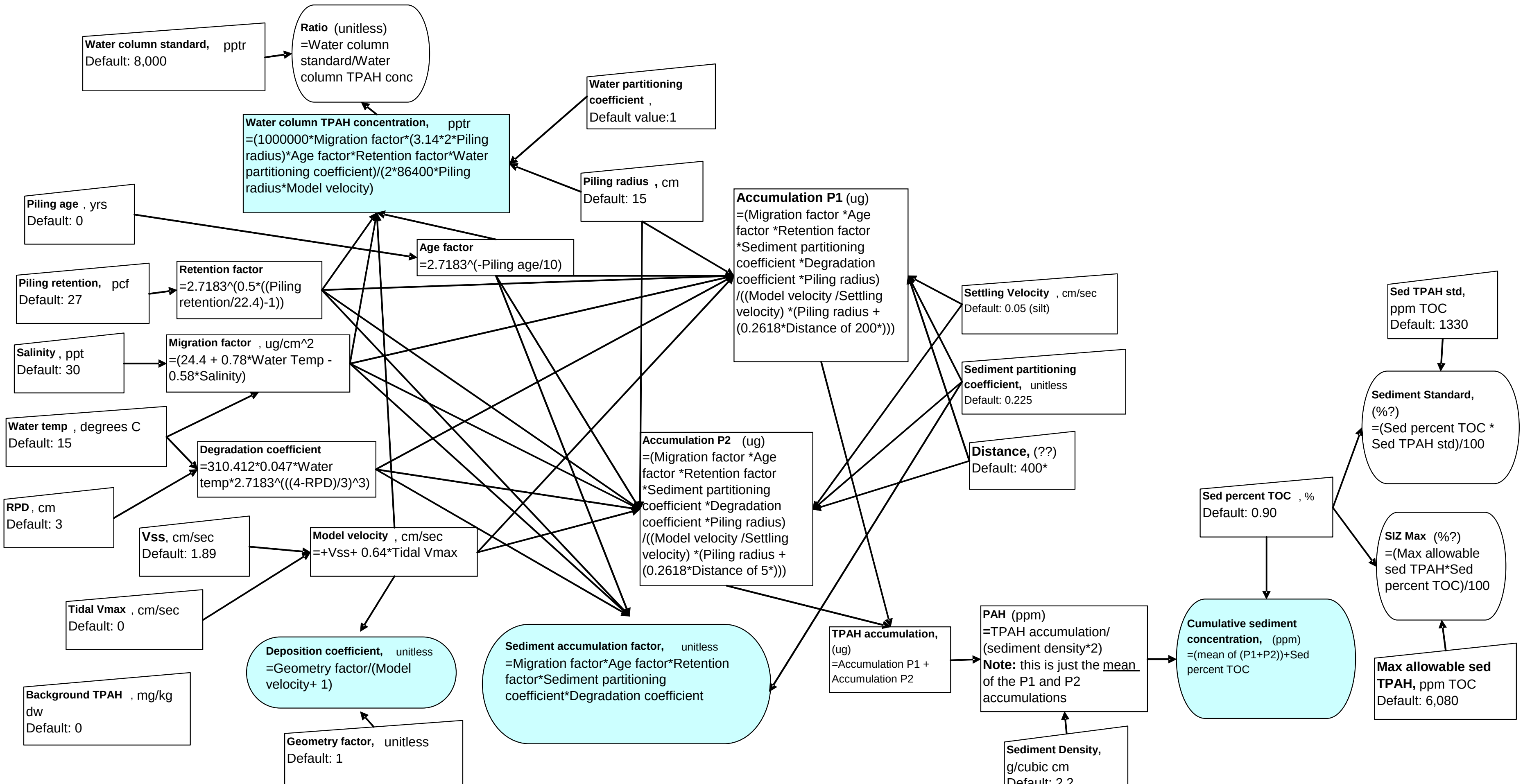
Appendix: CREOSS Model, Dr. K. Brooks



*A range of input values is used in the spreadsheet
Units in parentheses are assumed (not explicit)

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Volume II
Section III
NOAA Guidelines and Comments

Documents in order

1. Federal Register announcement of report and request for comments
2. Comments by Robert L. Alverts for Western Wood Preservers Institute
3. Comments by Dr. Robert A. Perkins, PE, not transmitted to NOAA
4. NOAA Guidelines. (These are in a separate pdf file)

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1. Federal Register announcement of report and request for comments

[Federal Register: January 13, 2009 (Volume 74, Number 8)]
[Notices]
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From the Federal Register Online via GPO Access [wais.access.gpo.gov]
[DOCID:fr13ja09-26]

DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

RIN 0648-XM60

Availability of Draft Guidelines for Use of Pesticide-Treated Wood Products

AGENCY: National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Notice of availability; request for comments.

SUMMARY: NMFS is providing this notice in order to allow other agencies and the public an opportunity to review and provide comments on a draft guideline document regarding the use of pesticide-treated wood products in aquatic environments. The intent of the guidelines is to aid NMFS personnel conducting Endangered Species Act (ESA) and Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) Essential Fish Habitat (EFH) consultations in making consistent determinations regarding projects proposing to use pesticide-treated wood products in habitats utilized by NOAA trust resources. The guidelines attempt to convey a summary of information that should be considered when examining the effects determinations made by the action agency, and to direct personnel to documents containing more detailed information when needed. NMFS is requesting comment on the draft guideline document before it is finalized. All comments received before the due date will be considered before finalizing the guideline document. All comments received will become part of the public record and will be available for review upon request.

DATES: Public comments must be received on or before 5 p.m., Pacific standard time March 16, 2009.

ADDRESSES: Comments on this draft guideline may be submitted by mail to the National Marine Fisheries Service, 777 Sonoma Avenue, Suite 325, Santa Rosa, CA 95409, Attn: Water Quality Coordinator/Treated Wood Comments. Comments concerning the draft guideline may be sent via facsimile to (707) 578-3435. Comments may also be submitted electronically to SWR.treatedwood@noaa.gov.

The reports are available at http://frwebgate.access.gpo.gov/cgi-bin/leaving.cgi?from=leavingFR.html&log=linklog&to=http://swr.nmfs.noaa.gov/ or by calling the contact person listed below or by sending a request to Joseph.J.Dillon@noaa.gov. Please include appropriate contact information when requesting the documents.

FOR FURTHER INFORMATION CONTACT: Joseph Dillon, Southwest Region Water Quality Coordinator at 707-575-6093.

SUPPLEMENTARY INFORMATION: The purpose of the guidance document is to aid NMFS personnel conducting Endangered Species Act (ESA) and Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) Essential Fish Habitat (EFH) consultations to analyze the potential effects and mitigations for

projects proposing to use pesticide-treated wood products in habitats utilized by NOAA trust resources. The guidelines summarize information that should be considered when examining the effects determinations made by an action agency and to direct personnel to documents containing more detailed information when needed. The draft guidelines focus on copper treated wood, primarily ammoniacal copper zinc arsenate (ACZA), as this is the most prominent material used on the west coast of the United States and in Alaska, and creosote treated products.

These products are being examined by NMFS to determine the risks generated by their usage to the living marine resources which NOAA is responsible for managing, referred to as NOAA's Trust Resources. These include anadromous salmonids managed under the ESA and EFH as designated by the Magnuson-Stevens Act. The use of pesticide-treated wood in or near aquatic environments commonly requires a permit issued by the U.S. Army Corps of Engineers. Under the ESA, Federal agencies must consult with NMFS to ensure that any action authorized, funded or carried out by the Federal agency does not jeopardize the continued existence of any threatened or endangered species or result in the destruction or adverse modification of designated critical habitat. The issuance of this permit by the U.S. Army Corps of Engineers requires consultation under Section 7 of the ESA to determine whether its approval action would jeopardize federally-listed species or adversely modify designated critical habitat, and requires an EFH assessment to determine whether its approval action would adversely affect EFH. Since the use of pesticide-treated wood materials in situations that may expose aquatic ecosystems is widespread along the west coast of the United States and in Alaska, development of guidelines from the information presented in these reports should help to streamline the review of permitting processes as well as the permitting processes themselves. In some instances, these reports may be used to update existing policies regarding pesticide-treated wood.

The purpose of the ESA is to provide a means whereby the ecosystems upon which endangered and threatened species depend may be conserved, to provide a program for the conservation of threatened and endangered species and to take steps that may be appropriate to achieve this conservation. Conservation is defined in the ESA to mean using, and the use, of all methods and procedures necessary to bring any endangered or threatened species to the point at which the protections provided by the ESA are no longer necessary. It is the policy of Congress, as declared in the ESA, that all Federal departments and agencies shall seek to conserve endangered and threatened species and shall utilize their authorities in furtherance of the purposes of the ESA.

The Magnuson-Stevens Act established procedures designed to identify, conserve, and enhance EFH for those species regulated under a Federal fisheries management plan. EFH regulates an activity with an eye toward its impact on habitat characteristics. EFH is defined as those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity. ``Waters'' include aquatic areas and their associated physical, chemical, and biological properties that are used by fish and may include aquatic areas historically used by fish where appropriate; ``substrate'' includes sediment, hard bottom, structures underlying the waters, and associated biological communities; ``necessary'' means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and ``spawning, breeding, feeding, or growth to maturity'' covers a species' full life cycle. EFH for salmonids includes their saltwater and fresh water ranges.

Effects of pesticide-treated wood that need to be examined during the ESA and EFH consultations include direct, indirect, and cumulative effects. An example of direct effects includes the acute and sublethal impacts of copper and polycyclic aromatic hydrocarbons to salmonids and the EFH of managed species. An example of an indirect effect includes the adverse impacts to the prey base upon which ESA-listed and EFH-managed species depend. An example of a cumulative effect includes the impacts of multiple structures and contaminants in an area with or without additional loading from urban sources, historic mining, smelters, ships' hulls or any other source. The synthesis of these effects to habitat and to individuals, coupled with local environmental conditions and specific species of concern, defines the risk of a project proposing the use of pesticide-treated wood.

Dated: January 6, 2009.

Angela Somma,
Chief, Endangered Species Division, Office of Protected Resources,
National Marine Fisheries Service.

[FR Doc. E9-369 Filed 1-12-09; 8:45 am]

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Volume II
Section III
NOAA Guidelines and Comments
2.Comments by Robert L. Alverts for Western Wood Preservers Institute

Western Wood Preservers Institute

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March 16, 2009

National Marine Fisheries Service
777 Sonoma Avenue, Suite 325
Santa Rosa, CA 95409
Attn: Joseph Dillon, Water Quality Coordinator

Re: Treated Wood Comments

Dear Mr. Dillon,

The Western Wood Preservers Institute's Endangered Species Act (ESA) Committee is pleased to have the opportunity to provide comments on the Draft Guidelines for Use of Pesticide-Treated Wood Products, in accordance with the Federal Register Notice of January 13, 2009. We understand the chief concern National Marine Fisheries Service (NMFS) has about the use of treated wood in aquatic environments is the effects of wood preservatives on salmonids, which are managed under the ESA, and the Essential Fish Habitat (EFH) provisions of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), as well as the need for guidance to assist biologists for the NMFS to better understand the issues relating to the use of preservative-treated wood in aquatic environments in order to make consistent effect determinations for projects proposing to use treated wood products.

The following comments represent the consolidated viewpoints and concerns regarding the draft guidelines from the Western Wood Preservers Institute (WWPI). The comments also reflect collective input from our national ad hoc working committee, which includes the major preservative producers, wood preserving companies, and industry organizations, including WWPI, The Southern Pressure Treaters' Association, The Timber Piling Council, Treated Wood Council, The Creosote Council III, Penta Task Force and The Railway Tie Association. While the comments represent a consensus viewpoint of the participating companies and organizations, they do not necessarily imply the full concurrence of all the participants, and separate comments may be submitted on behalf of individual entities as they may deem appropriate.

After over a decade of unresolved debate on the appropriate use of treated wood in aquatic environments, WWPI is very pleased to see the release of the Draft Guidelines. The development of treated wood guidelines has been an ongoing matter of concern for the public and government agency users and producers of treated wood products on the west coast and nationally. WWPI has always believed such guidance would be an important environmental tool and, when appropriately applied, can remove the uncertainty about the use of treated wood in certain aquatic environments. The treated wood industry has also consistently been committed to the position that it would accept and support responsible science-based guidelines and policy.

WWPI appreciates NMFS SW Region's efforts in developing the draft guidelines and their willingness to consider scientific data and input from the industry during the review and development process. WWPI believes the issuance of the draft guidelines is a significant step forward in establishing a basis for reaching mutually acceptable guidelines, and though it does not resolve all our differences on the science, it does significantly bring the stakeholders closer to agreement on the parameters for conducting project assessments. We are also pleased that the guidelines accept the use of treated wood under certain circumstances, strongly embrace the use of the BMPs, and recognize the value of industry risk assessment models that were developed by Dr. Kenneth M. Brooks.

WWPI would like to offer the following comments that highlight our recommendation for developing a process to evaluate treated wood proposed for use in aquatic applications; a review of the science; and statements we believe are in error.

GUIDELINE RECOMMENDATIONS

Need For Evaluation Worksheet and Procedures

Over the past decade or longer, the wood preservative industry has frequently observed that the biggest barrier to the use of treated wood in aquatic environments is not the adverse environmental effects of treated wood but rather the uncertainty on the part of regulators and project proponents as to the possibility of such potential effects, and the resulting delay in processing project permits and applications that call for the use of treated wood in aquatic environments. These often-substantial delays due to uncertainty have had the practical effect of putting treated wood at a disadvantage in the marketplace in comparison to competitive products. Some project proponents find it easier to simply avoid use of treated wood in order to expedite the regulatory approval process, regardless of the relative environmental effects of treated wood and its competitors.

The NMFS Guidance document is the best and most concise effort to date to bring together the best available science on all the various factors and tools needed for evaluating and mitigating the environmental aspects of using of treated wood in aquatic applications. However, we believe it still falls short of providing sufficiently clear guidance to the regulator or project proponent that is needed to make an evaluation and issue decisions in an efficient and consistent manner. The next logical step is developing a worksheet decision tool (referred to in the NMFS Guide document as a screening level examination) for use in the field. Please see the comments of Robert Alverts, a former Department of Interior employee, who gives a case study in support of the need for such a screening tool (Attachment 2). As noted in the draft NMFS Guide there are many cases where a determination that treated wood can be used could be a simple decision, where as other cases require a more detailed evaluation with potential limitations or mitigation actions.

Field biologists are of necessity generalists who must deal with a vast array of issues on each project reviewed and cannot be expected to fully understand the various complexities of treated wood. Similarly project proponents are also not experts in treated wood, and need tools to help evaluate the appropriateness of using treated wood before submitting a project application.

The industry feels strongly that NMFS's work to date on draft guidelines have created the tools to shorten and simplify the review process by setting the stage for the development of a screening level worksheet. Such an approach would allow all parties to determine which types of treated wood are environmentally acceptable in specific cases to meet the ESA and EFH criteria, and where further review or actions are needed. The industry is requesting that NMFS initiate action to harmonize the existing guidance (such as SLOPES III), the guidance in the NMFS Guide and the Industry Guidance and Models into a screening level work sheet and evaluation procedure. The industry recognizes that this additional work may be a burden on NMFS staff and budget and, if requested, would be more than willing to provide any needed assistance.

Conceptually, we envision such a document would contain several key sections:

A. An explanation of how the worksheet should be used for ESA and EFH determinations, and to which preservative systems and project types it applies.

B. A standard condition for all projects dictating that the provisions of the Best Management Practices be required including the production, installation, certification and management of treated wood.

C. The basic project description information and specifics of treated wood to be used.

D. Identification of the Basic Environmental Parameters and related regulatory authorities that impact the use of treated wood. This could include documentation on the species of concern, fresh or aquatic application, water flow and quality data, sediment conditions, presence of other treated structures and other regulatory provisions in the area.

E. Level One Screening Examination – Depending upon the preservative system, items in C and D above might require supplementation with information on some additional variables. The user would then be provided with risk evaluation decision tools or tables combining the variables, which would determine if the project is: a) acceptable without further review; b) acceptable with special conditions; or c) requires a Level Two Risk Evaluation to determine if treated wood is appropriate.

F. Level Two Detailed Risk Evaluation. This section would provide guidance for conducting the detailed evaluation. This would include guidance for additional environmental parameter data needed; selecting the appropriate model; using the model; evaluating the model outputs; determination of project is acceptability; and/or what additional actions are dictated.

The use of this screening examination worksheet approach should facilitate prompt and accurate identification of proposed project uses of treated wood that do not raise significant environmental concerns and can proceed without further review or delay. For example, the worksheet could provide the basis for a prompt concurrence with an action agency "not likely to adversely affect" determination, terminating ESA/EFH consultation without additional formal review.

As stated previously, while development of a worksheet and guidance document may not resolve all areas of scientific disagreement, it should identify the specific contested issues that are critical to the process, and afford an opportunity to develop an acceptable resolution of concerns. It may also reveal that some areas of scientific disagreement are not in fact critical and do not constitute a barrier to a prompt and accurate review process.

Currently there is an effort underway to write and publish a peer reviewed book that captures the wealth of existing science on managing preservative treated wood in aquatic environments. Dr. Jeff Morrell of Oregon State University – Wood Science and Engineering is the managing editor of the project. In preparing the chapter on "Modeling the Environmental Risks Associated with Pressure Treated Wood Used in Sensitive Environments", Dr. Kenneth Brooks has expanded and diversified the Timber Bridge Model (Brooks 2005a) to include all eleven currently used types of wood preservatives, including creosote, pentachlorophenol, copper naphthenate, ACZA, CCA-C, CA-B™. Wolman AG™, ACQ-B or C™, Wolman μCu Azole™, MicroPro Azole™, and MicroPro Quat™. The chapter and the model are being peer-reviewed as part of the publication process. Because of the expanded capability of the updated model to evaluate overhead and immersed structures in aquatic environments, the industry recommends the completed model be recognized as a viable modeling tool, as well as including evaluation parameters for all the above mentioned preservatives in any developed screening examination worksheet.

The successful development of such a worksheet would be a great benefit to all participants. It would facilitate efficient and responsible decisions by the regulatory community. It would help proponents bring forth projects which are most likely to be accepted. It would make the responsible use of treated wood more easily available to the market where the structural and economic characteristics are needed.

THE SCIENCE

1. Page 8. In general, the toxicity of dissolved copper is not a great concern. Rather it is the toxicity of cupric ion (Cu2+) that is of greatest concern. Dissolved copper includes copper adsorbed to inorganic and organic molecules that have reduced bioavailability but that pass a 0.45 µM filter. Although we have not yet had the opportunity to obtain and read Hecht et al. (2007), we suspect that the responses referenced are associated with increases in cupric ion concentrations rather than dissolved copper. These are the reasons that EPA uses hardness (mg CaCO3/L) based water quality criteria for most divalent metals. NMFS has previously agreed to use the EPA WQC, which industry continues to support as a standard.

2. Page 8. Hecht et al.'s (2007) definition of background copper as having a maximum of 3 µg dissolved Cu/L is not consistent with USGS data showing background concentrations of 15 to 25 µg dissolved Cu/L in relatively pristine rivers like the Copper River in Alaska, which supports one of the most famous salmon runs in North America.

3. Page 8. While we have inferred that dCu refers to dissolved copper, we recommend inclusion of a proper definition of this acronym in the text.

   Leachate from pressure treated wood contains high concentrations of dissolved organic wood extractives which likely bind the copper reducing its bioavailability. Though we have no data to substantiate a hypothesis, we suspect that the leachate from wood preserved with copper containing preservatives contains little or no cupric ion. NMFS has not identified any evidence substantiating its inference that the leachate from pressure treated wood has any effect on salmonid olfaction. The point of this discussion is that from a technical point of view, the draft guidelines are not clear with respect to what form of copper results in compromise of olfactory responses and for how long the effect lasts. If we are, in fact, talking about concentrations of the cupric ion, then the HydroQual's Biotic Ligand Model (BLM) provides a means of speciating dissolved copper and of defining appropriate WQC. However, to be used accurately, that model requires analysis of numerous organic and inorganic constituents in water – some of which are expensive. Resolving this issue is important because the natural variability in background dissolved copper may exceed 0.79 µg/L, resulting in a denial of the use of copper based wood preservatives in or over water in the Western United States. NMFS has previously agreed to use EPA's hardness-based WQCs, which are nationally accepted criteria, for assessing treated wood projects.

4. Page 12. When citing the Vines et al. (2000) study, which found adverse effects on herring spawn associated with creosote treated wood, the report omits reference to Goyette and Brooks (1998, 2000), which found that spawn from mussels growing directly on the creosote treated piling developed normally to the trochophore stage. While it is true that fish (vertebrates) and invertebrates (with planktonic early life stages) face different contaminant pathways and therefore different challenges, we recommend that either (1) both reports should be discussed or (2) neither report should be included. We are aware that there are some concerns being raised about the protocols used in the Vines et al. study.

5. Page 13. We believe the Threshold Effects Level (TEL) and Effects Range Low (ER-L) are not appropriate sediment quality benchmarks. Washington State has published EPA-approved marine Sediment Quality Criteria (SQC) in WAC 173-204 and is currently developing freshwater Sediment Quality Values (WDOE 2002, 2003). Goyette and Brooks (1998, 2000) conducted a detailed assessment of the efficiency and protectiveness of a range of possible SQC applicable to the Sooke Basin Study. Similar to WDOE (2002, 2003) they found that the TEL and ER-L were unacceptably inefficient because they predicted far too many toxic effects in Sooke Basin Sediments when the very large bioassay database generated in that study did not find toxicity. Goyette and Brooks (1998, 2000) found that the arithmetic mean of the TEL and the Probable Effects Level (PEL) and/or the Washington State SQC were both protective and efficient. Other SQC are available, such as the Consensus SQC proposed by Swartz (1999) and we

recommend that NMFS should review these standards and consider them for inclusion in the guidelines. The reports of Goyette and Brooks (1998, 2000) are particularly appropriate for consideration here because they apply to the mixture of PAH that accumulates in sediments in association with the use of creosote treated wood.

6. Page 17. Regarding dissolved concentrations of PAH adjacent to creosote treated wood projects – it states that, "Water column concentrations were not measured at this time." Water column concentrations of dissolved PAH were measured at significant expense by the Battelle Marine Science Laboratory using semi-permeable membranes placed 15 cm from the piling. The concentrations were determined to be in the 20 nanogram/L range for the ΣPAH at the three piling stations – which was not significantly different from concentrations found at the reference location. In addition, tissue concentrations of PAH in mussels used in the in-situ bioassays were found to be only slightly elevated two weeks after construction and they were low and not elevated in either lipid rich gonadal tissue or in somatic tissue after that.

7. Page 19. It is asserted that, "Replicate samples were not taken, with the exception of artificial substrates that allowed for expeditious sampling." In our opinion this is a significant misperception of the sampling design, which included triplicate sediment (infaunal) samples collected within 0.5 meters of each of the viewing platforms' perimeters on each of the four sampling days. Two levels of control were established in this study. An upstream station provided one level of control and a Mechanical Control Structure, where an additional full suite of 28 macrofaunal samples was collected on each sampling day, provided the second level of control. In total, 192 artificial substrate samples, 192 infaunal samples and 64 vegetation samples were collected during the four sampling events at Wildwood. That is a total of 448 macrofaunal samples collected and analyzed during the eleven month study. Sediments were examined to evaluate infauna and epifauna, artificial substrates were examined to assess the drift community and vegetation samples were examined to assess the invertebrate community in that compartment. This lack of acknowledgement may be due to a misperception of the power of the regression approach taken in this study. We believe a closer review of the study design would show that triplicate samples were available from the perimeter of each viewing platform and from the perimeter of the Mechanical Control treatment on each of the sampling days – allowing for conventional t-tests or analysis of variance.

8. We recommend that NMFS include a discussion of the results of the many macrofaunal studies undertaken in an effort to understand the biological response to the use of pressure treated wood. The results of all of these studies demonstrate no decrease in the abundance or diversity of invertebrates living on or in the immediate vicinity of pressure treated wood structures. The fact is that all of these results from numerous studies demonstrated an increase in the abundance and diversity of invertebrates living on or in close proximity to treated wood structures.

   We recommend that NMFS include a discussion of the abundance and diversity of invertebrates living on creosote treated piling presented in Brooks et al. (2006). The authors observed 64 different taxa in nine 200 cm2 samples collected from the piling. These taxa included 12 mollusks, 13 arthropods and 26 annelid species. The fouling community was found to be exceptionally abundant, containing an average of 79,900 invertebrates/m2. We believe all the information should be rigorously reported in order to gain a better understanding of how a product or activity affects biological resources. In contrast, many citizens in Washington State have recognized the habitat value of creosote treated wood structures and are working vigorously to restrain the Department of Natural Resources from removing them.

GENERAL COMMENTS

1. Page 3. In the first paragraph of "Introduction", components of wood preservatives are referred to as "contaminants". We object to the use of the word "contaminants" as these products are EPA registered chemicals approved for use as a wood preservative system and are not considered "contaminants" under the registration. We request the uniform use of a neutral term.

2. Page 7. In the second sentence under "Copper Toxicity in the Water Column", there is an error in identifying the components of ACZA, it does not include Chromium.

3. Page 21. In regards to the BMPs, it states "At the basic level, this means that the pesticide-treated wood product contains no more than the minimum level of pesticide necessary, as specified by the American Wood Preserver's Association (now called the American Wood Protection Association) retention standards." While this is the stated requirement of the BMPs, in a practical sense, one needs to recognize that it is not feasible to consistently meet the minimum standards precisely to the number due to any number of variables, such as type of wood species, age of wood, moisture content, preservative used, and treatment processes. The intent of treating to the BMPs is to use the minimal amount of preservative that complies with the AWPA standards in order to produce a clean and dry product suitable for use in aquatic environment certified by a third party inspection agency. In simple terms, recommending that the maximum level of preservatives is no more than the minimum necessary to meet industry standards is an impossible criterion.

4. Page 25. It is suggested that, "Since older creosote treated wood materials were likely not produced in accordance with industry BMPs (i.e. they were likely treated to the point of refusal), they should not be reused in aquatic environments." In response, we are unaware of any documentation suggesting that prior to development of production BMPs, creosote treated piling were treated to refusal. In developing the creosote risk assessment model, Brooks (1997b) analyzed recorded creosote retention measured historically in nearly 2000 charges and determined an average retention of 22.4 pcf when 20 pcf was the target retention. The average retention is far less than treatment to refusal. Second, BMPs are designed to produce products that are clean and free of surface deposits of preservative and to insure that the preservative is "fixed" when that is a factor. BMP verification studies have shown that properly designed BMPs can be effective in significantly diminishing elevated loss rates observed shortly after immersion in non-BMP produced wood. Older piling, such as the eight year old piling used in the Weather Piling dolphin in the Sooke Basin Studies, performed nearly as well

as the BMP piling. The evidence is that older pilings removed from service have lost the initial flush of preservative and should perform similar to BMP produced piling.

5. In the title page and throughout the document there are numerous uses of the term "pesticide-treated wood", "pesticide-treated industry" or "pesticide-treated wood products". We strongly believe this choice of terminology should be abandoned in favor of a neutral term, as it is not the commonly accepted or used terminology in the marketplace or by the industry. The term is misleading because it erroneously implies wood treated with a FIFRA-registered wood preservative acts like a pesticide (i.e., controls or repels fungi, insects or other pests). To the contrary, wood is treated with a FIFRA-registered wood preservative in order to protect wood from degradation and is specifically exempt from FIFRA regulation as a pesticide under EPA's treated articles exemption. See 40 C.F.R. 152.25(a). We would recommend the terminology be changed to read "preservative-treated wood".

We greatly appreciate the opportunity to provide comment on the *Draft Guidelines for Use of Pesticide-Treated Wood Products*. Our comments are intended to further achieve what we believe is a common goal of developing guidelines that are science based, fair and appropriate for determining the use of preservative-treated wood in aquatic environments.

Sincerely,

Ted J. LaDoux
Executive Director

Attachments (2)

ATTACHMENT 1

Science References

Brooks. K.M. 1997a. Literature Review and Assessment of the Environmental Risks Associated with the Use of ACZA Treated Wood Products in Aquatic Environments. Second Edition. Prepared for the Western Wood Preservers' Institute 7017 NE Highway 99, Suite 108, Vancouver, WA 98665. 98 pp.

Brooks, K.M. 1997b. Literature Review, Computer Model and Assessment of the Potential Environmental Risks Associated With Creosote Treated Wood Products Used in Aquatic Environments. Published by the Western Wood Preservers Institute, 601 Main Street, Suite 401, Vancouver, WA 98660. 137 pp.

Brooks, K.M. 2000a. Environmental effects associated with the use of CCA-C, ACZA and ACQ-B pressure treated wood used to construct boardwalks in wetland areas. U.S. Department of Agriculture – Forest Products Laboratory, Research Paper FPL-RP-582. 126 pp. plus appendices.

Brooks, K.M. 2000b. Assessment of the environmental effects associated with wooden bridges preserved with creosote, pentachlorophenol or chromated-copper-arsenate (CCA-C). U.S. Department of Agriculture – Res. Pap. FPL-RP-587. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, 100 pp.

Brooks, K.M., D. Goyette and S. Christie. 2006. Sooke Basin Creosote Evaluation – Results of the October 2005 Reconnaissance Survey. Creosote Evaluation Committee, Fisheries and Oceans Canada, Pacific Yukon Region, 201-401 Burrard Street, Vancouver, British Columbia, Canada V6C 3S5. 150 pp.

Goyette, D. and K.M. Brooks. 1998. Creosote Evaluation: Phase II. Sooke Basin Study Baseline to 535 Days Post Construction 1995 – 1996. Published by Environment Canada. 224 West Esplanade, North Vancouver, British Columbia, Canada V7M 3H7. 568 pp.

Goyette, D. and K.M. Brooks. 2000. Addendum Report – Continuation of the Sooke Basin Creosote Evaluation Study (Goyette and Brooks, 1998). Year 4 – Days 1360 and 1540. Published by Environment Canada. 224 West Esplanade, North Vancouver, British Columbia, Canada V7M 3H7. 51 pp.

Swartz, R.C. 1999. Consensus Sediment Quality Guidelines for Polycyclic Aromatic Hydrocarbon Mixtures. Environmental Toxicology and Chemistry, Vol. 18, No. 4. Pp. 780 – 787.

Vines, C.A., T. Robbins, F.J. Griffin, and G.N. Cherr. 2000. The effects of diffusible creosote-derived compounds on development in Pacific herring (*Clupea pallasi*). Aquatic Toxicology, Vol. 51, pp. 225-239.

WDOE, 2002. Development of Freshwater Sediment Quality Values for Use in Washington State. Phasse 1 Task 6: Final Report. Washington Department of Ecology Publication Number 02-09-050. 65 pp. plus appendices.

WDOE, 2003. Development of Freshwater Sediment Quality Values for Use in Washington State – Phase II Report: Development and Recommendation of SQV for Freshwater Sediments in Washington State. Washington Department of Ecology Publication Number 03-09-088.

ATTACHMENT 2

14569 SW 130th Ave.
Tigard, OR 97224
March 13, 2009

National Marine Fisheries Service
ATTN.: Joseph Dillon, Water Quality Coordinator
777 Sonoma Ave., Suite 325
Santa Rosa, CA 95409

Dear Mr. Dillon:

I am pleased to share comments with you concerning the *Draft Guidelines for Use of Pesticide-Treated Wood Products* as identified in the Federal Register Notice of January 13, 2009. I am currently a natural resources consultant, periodically assisting the Western Wood Preservers Institute (WWPI). WWPI asked me to review your document and prepare comments based on my extensive experience with the federal government.

You are to be commended for the extensive work that went into development of the guidelines intended for use by your staff and constituent interests when considering the use of treated wood. The stated purposes of the guidelines are to: 1) assist NMFS biologists understand the issues related to marine use of pesticide-treated wood and make consistent effect determinations for projects proposing to use these products, 2) outline Best Management Practices (BMPs) for projects, and 3) be used in conjunction with site-specific evaluations of other potential impacts.

Now retired, I am a forty year veteran of the US Department of the Interior, where I worked as a natural resource manager, research and monitoring coordinator, and regional science advisor. During the mid-1990s I was actively involved with implementing the Northwest Forest Plan (NFP) and serving as a member of the Regional Ecosystem Office's Research and Monitoring Committee. As a result of that experience, I see several parallels with the Northwest Forest Plan and the intent of your proposed guidelines, and some areas where I believe your guidelines need to be strengthened.

Much like your effort, the Northwest Forest Plan also included an extensive set of standards and guidelines to be used by all the management, research and regulatory agencies involved with plan implementation. While these guidelines were valuable, they were incomplete and lacked specific detail and methods needed for management agencies to consistently meet plan goals while implementing proposed actions. As a consequence, the Interagency Advisory Committee agreed to review them and form a number of interagency-intergovernmental sub-committees to develop more detailed guidance methods and tools for NFP implementation.

These sub-committees did an excellent job, working together to develop useful tools that could be consistently applied. While taking some time initially, they helped improve agency collaboration and cooperation, increased efficiencies, and saved money and time for all involved.

After reviewing your draft document, I see the need to develop comparable additional details and tools that I believe will better assist your biologists, as well as proponents of treated wood make consistent application of your intended goals. I strongly urge you to help lead and coordinate such an effort. I believe you will find the experience invaluable for your agency and all involved stakeholder interests. And I believe it would help cut costs, workload and staff time in the long run.

I appreciate the opportunity to share some thoughts with you and look forward to seeing the successful implementation of your final guidelines.

Sincerely,

Robert L. Alverts
Science and Management Consulting

Volume II
Section III
NOAA Guidelines and Comments

3. Comments by Dr. Robert A. Perkins, PE, not transmitted to NOAA

Comments on NOAA Draft Guidelines

Dr. Robert A. Perkins, PE.

These comments were not transmitted to NOAA

Comments on NOAA's Draft Guidelines for Use of Pesticide-Treated
Wood Products.

NOAA produced a guide document that became available in early January 2009. *The Use of Pesticide-Treated Wood Products in Aquatic Environments : Guidelines to NOAA Fisheies Staff for the Endangered Species Act and Essential Fish Habitat Consultations,* which I'll call "*guidelines*" in this appendix. (NOAA 2009) Public comments were solicited with the comment period closing on March 16, 2009. (FR 2009). The public notice gives a succinct purpose of the document:

> The intent of the guidelines is to aid NMFS personnel conducting Endangered Species Act (ESA) and Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) Essential Fish Habitat (EFH) consultations in making consistent determinations regarding projects proposing to use pesticide-treated wood products in habitats utilized by NOAA trust resources. The guidelines attempt to convey a summary of information that should be considered when examining the effects determinations made by the action agency and to direct personnel to documents containing more detailed information when needed.

The author was unable to get copies of the comments submitted to NOAA, however I was able to get the comments made by the WWPI, which are part of this appendix. The guidelines address all the common types of wood preservatives in use nationwide. Thus the guidelines and WWPI's comments have much that is not pertinent to Alaska. My comments are limited to creosote in Alaska.

The major finding in the conclusions of the Guidelines is:

> Overall, the use of pesticide-treated wood products in aquatic environments with the examined formulations (ACZA, CCA, and creosote) could be acceptable in many proposed projects. However, the products can not be considered categorically safe, and therefore, require project and site-specific assessment. Many projects, that still propose to use pesticide-treated wood, may pass a screen level examination and require relatively little assessment for the pesticide-treated wood impacts. These determinations require a level of local knowledge that may be applied on a case-by-case basis, or through regional watershed based procedures. The variability between locations makes it difficult to provide guidance on the scale of the entire west coast of the U.S. and Alaska.

Elsewhere the conclusions recommend BMP in all situations that involve EFH and TES and appear to limit the requirement for risk assessments to structures with over 100 piles and further imply that if the current exceeds 10 cm/sec (roughly 0.25 mph) likewise a more detailed risk assessment is not needed. This section of the conclusions is vague and probably refers to studies with copper in the Columbia River, but in general, it fits with the WWPI recommendations.

The conclusions seem to recommend copper over creosote, although the conclusions are not specific to Alaska.

Author's Review of *Guidelines*

Because the *Guidelines* covers many situations and at times to appear to present conflicting information, and because these draft guidelines may be pressed into service in lieu of final guidelines, I will present my review of them. The WWPI review and comments that pertain to creosote are listed in this appendix. The entire Guidelines and Comments are copied in Volume II.

Page 6, end of first paragraph, says models are uncertain and therefore need to be used with site specific information – relying on Status [3, and discussed in Appendix D]. The Brooks Model [see Appendix F] has been field tested in several locals and shown to be conservative. That is, it overpredicts the sediment concentration. The Brooks Model does require site specific information.

Page 6, second paragraph, tries to determine the level of impact deduced by a screening that would not require a full risk assessment and further differentiates an ESA issue from an EFH issue. It explains that the screening is similar to an "initial review" in an ESA determination, where a finding that the action "may affect" but is "not likely to adversely affect" an endangered species. If there were established local procedures for making that determination, they could be used to screen the project. The next paragraph then refers this process to local knowledge, rather than the *guidelines*. My comment is that this "local knowledge" would refer to the species under ESA or EFH consideration, not the effects of creosote, which are established by nationwide science.

Page 7, first paragraph, states "concrete pilings are cost-competitive with pesticide-treated wood pilings over the long-term and are competing in those markets." This is often not true. In any case, the choice between wood, concrete, and steel is made by the design engineer. In general, if wood will work for structure, wood is about half the cost of concrete.

Page 12, middle paragraph has some toxicity information that needs to be clarified. Two of the most interesting studies are those of Vines (2000) and Carls (1999) [5]. The main thrust of Vines study was that toxic levels of creosote diffusible material exist in the interior of 40-year old piles. This was determined by taking pieces out of old creosote piles and placing them in static renewal chambers with herring eggs, etc. This is quite unlike the potential exposures from in situ creosote piles, since the cutting the piles into pieces for the laboratory experiment exposes new creosote faces and allows end grain transfer of PAH to the water. In order for the pile to maintain its integrity in water with marine borers, the pile must have creosote within its wood structure. Thus Vines' findings were not unexpected. The most intriguing part of the paper, however, was not those laboratory studies, but rather a study of eggs scrapped from the exterior of old creosote piles. Compared with eggs scrapped from a nearby PVC pipe, the eggs scrapped from the pile had a very low survival. Because this was a preliminary part of the study and not controlled, the eggs may have come from different fish or been exposed to slightly different environmental conditions. However, more interesting, was that Dr. Vines did not note any fouling on the piles. (Vines 2008) Generally piles in marine waters foul very quickly, usually within a year. Lack of fouling may indicate the piles were atypical in other respects. In any case, one would expect that BMP piles underwater would have much less creosote on their surfaces than piles treated 40 years ago. The Carls study used PAHs that were leached from oil contaminated gravel and indicated toxicity in the range of 1 ppb, mostly of heavier PAHs, to salmon larvae. The methods seem quite through and the researchers are well known, thus this study is often quoted to indicate that a PAH level of 1 ppb may be toxic to salmon eggs. However I would note that Neff found levels of PAH in "pristine waters" of 1 to 2 ppb [Neff 1979]. And fish and invertebrates spawn and thrive in non-pristine waters that have much higher concentrations of PAHs. Thus, there may be a disconnect between the Carls study and nature. Two other issues are the nature of the oil and its location. In general crude oil, and certainly ANS from which the PWS oil came, is highly alkylated. Often the parent PAH is present in only very small quantities. On the other hand, creosote is often pure parent PAH and has few alkylated compounds. Alkylated PAHs are metabolized at different rates than the parent and are often assumed to more toxic. The second is that in the natural environment the heavier PAHs are bound to organic particulates or other organic matter and are not bioavailable. Also, see the "Page 12" comments from WWPI below.

Page 13, top paragraph, states that main concern is for PAHs that leach from creosote and they "accumulate in sediments and are assimilated into the food web." This implies that the PAHs that enter the sediment find their way into the food web. That is not the case. In oxygenated sediments most of the PAH are oxidized. Regardless of oxygen state, most PAH do not make it into the food web. Also misleading in that paragraph it says, "chronic and dietary exposure to the higher weight PAHs remain in sediments that cause the [harmful] effects ….[which are] more prominent in benthic species due to their frequent contact with the sediment. (Citing Stratus). The only study that purports this used a sediment that was contaminated with many things other than PAHs. True, toxic PAHs can be extracted from sediments, but this is not their course in nature. Further, that paragraph can be read that pelagic species are affected by PAH in the sediment, and that is simply not true.

Page 13, third paragraph, is key to risk assessment, since it strives to present sediment levels that may be harmful. This analysis for PAHs is always limited, because PAH is not a chemical, but a mixture of many chemicals, all of differing chemical, physical, and toxicity characteristics. The paragraph is not easy to read or interpret but seems to say that levels above some very low conservative limit should not be exceeded. Several problems with that are first, that these levels are frequently encountered in harbors and other habitat that seem to have thriving marine life communities. Second, science shows that the PAH in sediment is limited to the regions very close to the piles. Thus, regarding an EFH, the question would be, “even if the entire area beneath the structure were removed from the fishery habitat, would it affect the fishery?”

Page 20, middle paragraph, again repeats the tumors from sediment issue that is not accurate. It says that if the water body is “impaired” additional PAH from piles should not be permitted. Certainly if the water body is impaired by PAHs, creosote should not be used. This is stated in all the risk assessment paradigms. The third paragraph is particularly poor science. It extrapolates from the work of Vines to pelagic concentrations of creosote, but actual measurements of the pelagic concentration of PAH are essentially zero after a few weeks. It then goes on to cite the Corps of Engineers in Los Angles requiring wrapping of creosote piles, which has no relevance – is not science-based. The last paragraph seems to say that a region could adopt a standard number of piles, below which a risk assessment is not needed. The reference quoted, SLOPES III, used 50 piles as the cut off. That is, a project with less than 50 piles was considered not to require a full consultation – the Corps could grant the permit without NMFS consultations.

Page 22, first sentence, says copper-based and creosote treatments are interchangeable. This is not true in Alaska, as discussed in Chapter 4. Also, they discuss use of creosote in fresh water, which is not recommended anywhere, but is not allowed in Alaska.

Page 25, second paragraph, is erroneous. It seems to recommend coating piles with wraps in projects proposed for “sensitive locations” and could have been written by a supplier of coated piles. It cites “unnecessary environmental risk” which misuses both the words “unnecessary and “risk.” Coatings or wraps are expensive and should not be used unless there is a demonstration that the EFH or ES would be harmed if they were not used. If the currents are slow, sediment anoxic, or background PAH are high, they may be a useful alterative. True Pacific herring may spawn onto wood, but they spawn everywhere, especially on eel grass in Alaska. Only a minuscule proportion would land on piles. The last part about pile replacement does not fit. If they are only replacing a few piles, they will not matter.

Coatings are fine also, but only if somewhere is demonstrated if they are not coated there would be some problem. This section of the guidelines is not science-based.

Page 27, second paragraph, is not appropriate. If another material will be more cost effective, the engineer will specify it. This says nothing and implies that concrete is comparative. If it is, it will be used. It is generally not comparable in Alaska.

Page 28, first paragraph, regarding costs - Status in not competent to estimate prices, which will vary with location. In general treated wood will last a long time. Wood is much more resilient than concrete. Concrete life is quite variable. Intact it may last forever. If it is damaged, the rebar will corrode and the pile may not last long. Steel is more resilient, but needs cathodic protection or coating which may not be benign. In addition, steel needs repainting or coating and this is an operation that can contaminate the environment.

Page 32, first paragraph of Conclusions, says "leaching stays at easily detectable levels." The word "easily" is a poor word choice. PAH can be detected, but "easily" implies there is a lot, which in fact there is not. It is at very low levels. In the Sooke Basin study, which was in a pristine area, the PAH after a year was not different than background, by the most sensitive methods. In the last sentence again implies that PAH from sediment is "most often associated with impacts to benthic species," this not correct. PAH can cause those effects in all species, but there is little evidence that the low levels from creosote in a natural sediment can cause them.. The tests they cite were done in sediment contaminated with other chemicals and/or with PAH extracted from the sediments.

Page 33, top paragraph again refers to Vines study which we discuss above.
Effect would at worst be seen in unfouled piles with eggs laid directly on the wood. The next sentence is incorrect. Heitz et al (1999) dealt with weathered crude oil extracted from gravels not marine sediments. There is no connection between the work of Heintz and the creosote contamination under piles, which diminishes with time.

Page 33, second paragraphs, says models did not over- or underpredict. The model of Brooks consistently overpredicted the concentrations at Sooke and several other sites. In addition all the models take some "site specific" data to work.

Page 35, last paragraph of Conclusions, express a preference for copper over creosote. This would assume that the benefits of either treatment are the same. That is not true for Alaska, where creosote has a much longer service life for most applications. However it does say, "the limited available information shows that, in some specific instances, the proper use of creosote-treated products may not impact ESA listed salmonids in a manner that can be meaningfully measured, detected or evaluated. "

Volume II
Section III
NOAA Guidelines and Comments
4.NOAA Guidelines

THE USE OF PESTICIDE-TREATED WOOD PRODUCTS IN AQUATIC ENVIRONMENTS:

Guidelines to NOAA Fisheries Staff for the Endangered Species Act and Essential Fish Habitat Consultations

Public Review Draft

NOAA Fisheries - Southwest Region
Prepared on:
December 5, 2008

TABLE OF CONTENTS

Introduction

The purpose of this guidance is to assist biologists for the National Marine Fisheries Service (NMFS or NOAA Fisheries) to understand the issues relating to marine uses of pesticide-treated wood and to make consistent effect determinations for projects proposing to use these products. The use of pesticide-treated wood products in aquatic environments is a wide-spread practice developed to protect the wood from degradation by aquatic organisms capable of consuming wood. This guidance briefly discusses the contaminants of concern in these products (copper and polycyclic aromatic hydrocarbons (PAHs)) and their potential to leach into the aquatic environment. This guidance also outlines Best Management Practices (BMPs) to prevent or minimize exposure of NOAA trust resources to these contaminants and describes several potential exposure scenarios that consulting biologists may routinely encounter. Of chief concern in this guidance are the effects of the contaminants on salmonids, many of which are managed under the Endangered Species Act (ESA), and the Essential Fish Habitat (EFH) provisions of the Magnuson-Stevens Fishery Conservation and Management Act (MSA). This guidance is to be used in conjunction with site-specific evaluations of other potential impacts.

The most common treatments for protecting wood used in aquatic applications contain copper or creosote (which is composed of PAHs), both of which are classified as pesticides and regulated under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). FIFRA requires that all pesticides be registered with the U.S. Environmental Protection Agency (EPA) through a registration process that requires a period of data collection to determine the effectiveness and hazards of the particular substance. Some pesticides such as creosote were registered with the EPA as part of the original enactment of FIFRA and were never adequately assessed for risk. The EPA has thus been "re-registering" such pesticides to ensure that their risks are fully evaluated and understood.

However, the FIFRA registration process is not in itself sufficient to address ESA concerns, and the weaknesses of the FIFRA process in this regard have been well documented in the EPA's Overview document (EPA 2004) and in a joint evaluation of the FIFRA process by NOAA Fisheries and the United States Fish and Wildlife Service (USFWS) (NMFS and USFWS 2004). In regard to copper and creosote, in 2004 and 2006 NOAA Fisheries identified specific problems with the re-registration processes for these substances and communicated those concerns in correspondence to the EPA (NMFS 2004a and 2006). Creosote was reviewed by NOAA Fisheries specifically for effects to EFH and was found likely to cause adverse impacts to such habitat (NMFS 2004a). Although NOAA Fisheries requested consultation on the re-registration of creosote, the EPA elected to postpone the re-registration process. The EPA conducted another ecological risk assessment as part of the creosote re-registration process in March 2008 (EPA 2008a and 2008b), but does not plan to initiate ESA or EFH consultations at this time.

Similarly, NOAA Fisheries commented on the EPA's ecological risk assessment for the re-registration of pesticides containing copper (NMFS 2006). In its ecological risk assessment, the EPA did not consider available studies from the large body of information on the sublethal effects of copper to critical sensory functions of salmonids (NMFS 2006); nevertheless, the EPA finalized the Re-registration Eligibility Decision (RED) for coppers despite this important omission (EPA 2006). Moreover, in March 2008, the EPA released draft Ecological Hazard and Environmental Risk Assessment documents as part of the re-registration process for inorganic arsenical wood preservatives, specifically for chromated copper arsenate (CCA), and in that assessment the EPA defers to the copper RED for consideration of impacts to ESA listed salmonids, again despite its noted deficiencies (EPA 2008c). Because these documents do not adequately consider or analyze all the impacts of these substances on NOAA trust resources, the current uses of pesticide-treated wood products cannot be assumed to be protective of those resources.

NOAA Fisheries began to grapple with the issue of pesticide-treated wood use in environments used by ESA listed salmonids in the mid-1990s as research on the topic became prevalent. In 1995, the Portland Oregon District of the U.S. Army Corps of Engineers (USACE) requested that the use of pesticide-treated wood products be covered in an ESA Section 7 biological opinion. In 1998, the Northwest Region (NWR) of NOAA Fisheries issued a position document that included a box model developed by Battell Pacific Northwest National Laboratory to predict contaminant concentrations. The NWR's position document accepted the use of pesticide-treated wood products in waters with ESA-listed salmonids, but required that project managers gather information to verify that the project would not result in unacceptable impacts to salmonids or their habitat and further required that project proposals contain some restrictions on the use of pesticide-treated wood in salmonid habitat (NMFS 1998).

These new requirements and restrictions began a long-running debate with the wood treatment industry. Over the years, as additional species of salmonids have been listed under the ESA, a significant number of new studies have been conducted; numerous agencies have issued guidelines or requirements regarding pesticide-treated wood uses; and retention standards for pesticide-treated wood products have been updated to reflect minimum levels needed for an application. In November 2004, NOAA Fisheries NWR issued a programmatic biological opinion that examined and allows the use of significant volumes of pesticide-treated wood materials (NMFS 2004b) known as SLOPES III.

The State of Washington has been renewing similar programmatic consultations with the USACE on marine uses of pesticide-treated wood products since 2005 (Sibley, Tom, pers. comm. 2008). Currently, the Washington State Department of Fish and Wildlife is developing a Habitat Conservation Plan (HCP) that will likely include BMPs and restrictions for the use of pesticide-treated wood products, when conducting activities covered under the HCP (Kreitman, Gayle pers comm. 2008). The Western Wood Preservers Institute (WWPI) put a BMP program in place, subsequently updated in 2006, to ensure that pesticide-treated wood products are produced in a manner that lessens the impact to aquatic environments and issued their own guidance document for using pesticide-treated wood products in aquatic environments. The WWPI document, Treated Wood in Aquatic Environments (WWPI 2006a), develops retention standards for various preservatives and applications, gives guidance on when individual risk assessments are needed, and discusses BMPs for the manufacture of pesticide-treated wood products, which should prevent unnecessary preservative loading and promote construction BMPs. A second document from WWPI gives more detail on pesticide-treated wood products produced using BMPs (WWPI 2006b).

After the issue surfaced in the mid-1990s, other agencies took actions related to the use of pesticide-treated wood products. The Canadian Department of Fisheries and Oceans issued guidelines in 2000 that recognize treated (and untreated) wood structures have the potential to impact the aquatic environment; however, the use of pesticide-treated wood products is still allowed in Canada with certain restrictions (Hutton and Samis 2000). The WDFW stopped the use of creosote-treated wood in freshwater lakes (Poston 2001, Kreitman, Gayle, pers. comm. 2008) and determined that other restrictions may be appropriate. The U.S. Fish and Wildlife Service's Division of Engineering produced a guidance document for wooden bridge design that requires any pesticide-treated wood be manufactured in accordance with BMPs (USFWS 2001). The USACE Los Angeles District created a standard permit condition requiring that creosote pilings be wrapped in plastic, be sealed at all joints to prevent leakage, and use rub strips or bumpers at friction points (Castanon, David pers. comm., 2004). In their Procedures for Permitting Projects guidance, the Sacramento and San Francisco Districts of the USACE determined that small boat dock, pier, and wharf construction projects that coat pesticide-treated wood materials with impact-resistant, biologically inert material will "Not Adversely Affect Selected Listed Species in California" (USACE 2006).

Acting at the request of San Francisco Bay area stakeholders in the last quarter of Fiscal Year 2004, the Habitat Conservation Division of NOAA Fisheries' Southwest Region (SWR) decided to commission an independent, third party review of the pesticide-treated wood issue. The review was conducted by Stratus Environmental Consulting, Inc (Stratus), to examine the latest data and explore guideline development that reflects the risk of using these products in environments supporting listed salmonids, as well as EFH. Additional funding support was provided by the NWR and Alaska Region Habitat Conservation Divisions. Two reports were prepared: one covering copper-based treatments, focusing on the most prevalent treatments for in-water use: ammoniacal copper zinc arsenate (ACZA) and chromated copper arsenate (CCA) (Stratus 2006a); and one covering creosote-treated wood (Stratus 2006b). These reports were generated by a comprehensive (but not exhaustive) literature review, as well as discussions with NOAA Fisheries and industry. A database containing 523 literature/reference entries was submitted by Stratus to NOAA Fisheries with the final reports. The final reports (Stratus 2006a, 2006b) were peer-reviewed through established NOAA Fisheries protocols and received public review and comment. Some changes resulted from these two review processes, and the completed final reports were submitted to NOAA Fisheries in 2007.

Stratus found that the requirements of various agencies and the recommendations of the pesticide-treated wood industry are in close alignment with one another. Both agency and industry documents note that pesticide-treated wood products can be used safely, but can cause harm if used improperly. Site-specific conditions at the project are very important in influencing and evaluating project impacts. Conditions that need to be considered include background concentrations, density of product installation, location of other pesticide-treated wood structures, and environmental conditions. Among the environmental conditions that need evaluation are flows, sediment composition, sediment oxygen levels and tidal exchange. The simple box model put forward in 1998 and the models subsequently developed by industry were determined to be generally useful for predicting levels of environmental contamination that may result from pesticide-treated wood use. The results from these models are subject to some significant uncertainties, however, and are not sufficiently developed for making precise predictions. The models should therefore be used in conjunction with site-specific information (Stratus 2006a).

The Stratus reports concluded that properly selected pesticide-treated wood can be used safely in many well planned projects, but also recommended that individual screening level assessments be conducted when the use of these products is proposed in habitat supporting ESA-listed salmonids or other anadromous species. This level of risk assessment is analogous to the initial review to determine if a project may affect, but is not likely to adversely affect, a listed species or adversely impact EFH. Levels of risk that are acceptable may be clarified at a regional scale using a programmatic biological opinion, a habitat conservation plan, or guidance. If a project passes this screening level assessment, then a more detailed site-specific risk assessment will not be required. A determination that listed species may be affected requires additional information and a site-specific risk assessment analysis. The threshold for a "not likely to adversely affect" determination requires that impacts to the listed species cannot be meaningfully measured, detected, or evaluated, and that the impact does not prevent designated critical habitat from supporting the recovery of the listed species. An EFH analysis is required to determine if the action will adversely affect the quantity or quality of the habitat. The use of pesticide-treated wood is just one aspect of a project that will be considered in these evaluations (that is, the construction and presence of the project will be evaluated regardless of the construction material for effects).

A level of local knowledge is required to make a defendable determination for these types of projects (NMFS 2003, Poston 2001); therefore, the guidance provided in this document cannot replace local review. This local knowledge can be applied by the biologist on a site-by-site basis, or will be applied by NOAA Fisheries in a programmatic opinion or regional guidance. Local knowledge is critical in determining if a proposed project can be approved informally, without a full risk assessment or biological opinion under the ESA. Documents from NOAA Fisheries, other agencies, and the pesticide-treated wood industry all recognize that individual risk assessments may need to be conducted for some projects, such as those involving installation of numerous pilings, large surface areas (e.g. bulkheads), areas with elevated background levels of contaminants, areas with other pesticide-treated wood infrastructure, areas with little flow or tidal exchange, or other especially sensitive areas (NMFS 1998, 2003, and 2004; Hutton and Samis 2000; USACE 2006; WWPI 2006a). The general acknowledgement that a closer examination may be needed is a good example of how viewpoints on this subject have come closer together in the past several years.

The use of pesticide-treated wood has declined from historical highs. Because concrete and steel have greater load bearing capacity, few wharves and other large structures are currently being constructed on wood pilings (Brooks 2003). In particular, concrete pilings are cost-competitive with pesticide-treated wood pilings over the long-term and are competing in these markets (Stratus 2006a). Most projects using pesticide-treated wood pilings (such as personal use docks), are small and involve two to five pilings spaced at least four meters apart (Brooks 2003). Many bridges are small enough to use pesticide-treated wood for decking, but the abutments are often concrete or steel and are constructed outside of the 100-year flood zone (Hayward, Dennis, pers comm., 2006). Other significant uses of pesticide-treated wood (such as railroad ties, highway sign posts and utility poles) generally only interact with the aquatic environment during flooding or through improper disposal of construction or demolition debris. Yet, despite the overall decline in pesticide-treated wood use, many instances continue to arise where project proponents wish to use pesticide-treated wood.

Contaminants

In pesticide-treated wood products, the main active ingredients of concern for effects to fishery resources are copper, in metal treated wood products, and polycyclic aromatic hydrocarbons (PAHs), in creosote treated wood. This section provides brief discussions of the toxicological concerns of these pollutants to fishery resources. The Stratus reports (2006a, 2006b) and a recent technical memorandum from the NMFS Northwest Fishery Science Center and Office of Protected Resources (Hecht *et al.* 2007) should be consulted for more details. They contain many other useful references and resources.

Copper Toxicity in the Water Column

The two main types of metal treated wood, used in aquatic applications along the west coast (including Alaska) are: ACZA and CCA. ACZA contains copper, zinc, chromium and arsenic. ACZA use is more prevalent on the west coast, because it effectively treats Douglas fir, which grows along the west coast. CCA contains chromium and arsenic, in addition to copper. Copper is the focal point of this examination, because it leaches from pesticide-treated wood products at rates that can affect aquatic resources. Copper is a common contaminant in salmon habitat, where it is deposited by mines, urban stormwater runoff, pesticide-treated wood leachate, diffusion from boat hull coatings and from algicides used in waterways or fungicides applied to cropland (WWPI 1996, Weis and Weis 1996, Baldwin *et al.* 2003, Weis and Weis 2004). Understanding the levels and forms of copper (or any contaminant) already in a system is crucial to determining the potential impact of adding more copper and will be discussed shortly, along with the benchmark concentration analysis from Hecht *et al.* (2007).

Copper leaches from treated wood products in a dissolved state. Once in the aquatic system, it can rapidly bind to organic and inorganic materials in suspension. The adsorbed material may then settle and become incorporated into the sediments. Although copper may stay bound in sediments, it may also be resuspended, dissolved in interstitial water or reenter the water column depending upon biotic, physical, and chemical conditions at the site. This copper may be taken up by organisms that inhabit or ingest benthic sediments. Additionally, the copper could be taken up by some species of plants or algae and reintroduced to the ecosystem via consumption or decomposition of these plants (Weis and Weis 2002, 1992).

Eisler (2000), Stratus (2006a) and Hecht *et al.* (2007) present usable summaries of the impacts of copper to fish and aquatic invertebrates. The breadth of this information is too long to present in significant detail in this document. Environmentally realistic concentrations of free copper are noted to impact the resistance of fishes to disease, cause hyperactivity, impair respiration, disrupt osmoregulation or impact olfactory performance. This last impact will be discussed in some detail because it is caused by lower concentrations of dissolved copper than the other impacts noted here and has implications for ESA listed salmonids. Stratus (2006a) and NMFS (Hecht *et al.* 2007) note that species mean acute 96-hour LC_{50} (lethal concentration to 50% of the test subjects) values of 19-108.1 µg Cu/l (parts per billion) were found for species of *Oncorhynchus* in freshwater environments. Although there are few studies of salmonids in estuarine conditions, the available information indicates that acute copper toxicity (i.e. mortality) typically decreases with increasing salinity (Eisler 2000, Stratus 2006a). Increasing hardness and/or salinity impairs the transport of dissolved copper across the gill membrane and thus affect toxic responses mediated by this mechanism (such as acute mortality). Olfaction mediated behavioral impacts from dissolved copper do not seem to be reduced by increasing hardness of freshwater. This is probably because the olfactory rosette is in direct contact with the aquatic environment and is not protected by a membrane. There is a distinct lack of information in the marine environment regarding potential impairment of olfaction by dissolved copper or other metals (Hecht *et al.* 2007).

A NOAA Technical Memorandum (Hecht *et al.* 2007) on the effects of dissolved copper (dCu) on juvenile salmonid sensory systems was published in October 2007. The purpose of the paper was to summarize information on effects, conduct a benchmark concentration analysis (to generate effect thresholds), and to discuss site-specific considerations of sensory system effects. A large body of scientific literature has shown that fish behaviors can be disrupted at concentrations of dissolved copper that are at, or slightly above, ambient concentrations (i.e. background) (Sandahl *et al.* 2007, 2004, Baldwin *et al.* 2003, Hanson *et al.* 1999a, 1999b). Hecht *et al.* (2007) defined background as surface waters (freshwater) with less than 3 ug/L dCu. This definition was used because the experimental water had background dCu concentrations as high as 3 ug/L dCu. Sensory system effects are generally among the more sensitive fish responses and underlie important behaviors involved in growth, reproduction, and ultimately survival (i.e. predator avoidance). Recent experiments on the sensory systems and corresponding behavior of juvenile salmonids contribute to more than four decades of research showing that dCu is neurotoxic, and directly damages the sensory capabilities of salmonids at low concentrations. These effects can become manifest over a period of minutes or hours and can persist for weeks.

Hecht *et al.* (2007) calculated benchmark concentrations (BMC) for dCu using an EPA methodology, to provide examples of effect thresholds to assist in evaluating effects of activities causing copper inputs to surface waters. BMC's ranged from 0.79 – 2.1 μg/l, corresponding to reductions in olfactory sensitivity of approximately 29.3 – 57% (95% confidence interval). The BMC examples represent the dCu concentration above background (where background is less than or equal to 3 ug/L), that is expected to affect juvenile salmonids' ability to avoid predators in fresh water. These concentration thresholds for juvenile salmonid sensory and behavioral responses fall within the range of other sublethal endpoints affected by dCu such as behavior, growth, and primary production, 0.75-2.5 μg/L. For example, Hansen *et al.* (1999a and 1999b) found that salmon will actively avoid dCu at levels 2 ug/L above background, if their olfactory abilities are not yet impaired. Sandahl *et al.* (2007) found that a three hour exposure to the same concentration of dCu (2 ug/L above background) reduced odor-evoked predator avoidance response in juvenile coho salmon that is triggered through the olfactory system.

Olfactory function becomes impaired if salmon are unable to avoid copper pollution within the first few minutes of exposure. If copper levels subsequently exceed a threshold for sensory cell death, it may take weeks before the functional properties of the olfactory system recover (Baldwin *et al.* 2003). Even transient exposure, lasting just a few minutes to copper at levels typical for surface waters from urban and agricultural watersheds, and within the U.S. Environmental Agency water quality criterion for copper, will cause greater than 50% loss of sensory capacity among resident coho in freshwater habitats (Baldwin *et al.* 2003). While that loss may be at least partially reversible, longer exposures (lasting hours) have caused cell death in the olfactory receptor neurons of other salmonid species (Julliard *et al.* 1996, Hansen *et al.* 1999b, Moran *et al.* 1992). Olfactory cues convey important information about habitat quality, predators, mates, and the animal's natal stream, thus substantial copper-induced loss of olfactory capacity will likely impair behaviors essential for the survival or reproductive success of salmon and steelhead (Baldwin *et al.* 2003).

In summary, dissolved copper (such as that leached from copper-treated wood products) has been determined to decrease salmonid olfactory performance at concentrations as low as 0.79 ug/L above background (95% confidence interval) (Hecht *et al.* 2007). The effect level may be even lower, depending upon the level of confidence selected (e.g. at a 90% confidence interval, the effects level was determined to be 0.59 μg/L above background). The severity of the impact is dependent upon the length of the exposure, as well as the concentration. Behavioral avoidance has been shown at ~2 ug/L dCu above background levels. This information should be used by resource managers and other decision makers to determine if pesticide-treated wood products can generate these elevated levels of dissolved copper, for how long, and over how extensive an area.

<u>Copper Toxicity in the Sediments</u>

For many species, the greatest probability of adverse effects is from long-term accumulation of copper in sediments. This affects prey sources through contamination, or reducing availability (NMFS 2003). Metals leached into sediments near CCA-treated wood in aquatic environments have been found to accumulate in benthic and epibenthic organisms (Weis and Weis 2004). Other animals can acquire elevated levels of copper indirectly through trophic transfer, and may exhibit toxic effects at the cellular level (DNA damage), tissue level (pathology), organism level (reduced growth, altered behavior and mortality) and community level (reduced abundance, reduced species richness, and reduced diversity) (Weis *et al.* 1998, Weis and Weis 2004, Eisler 2000). Trophic transfer from invertebrates to vertebrates is less clear than from algae to invertebrates, or from one invertebrate to another. Weis and Weis (1992, 1993, 2004) found trophic transfer from algae to snails and from oysters to predatory snails. However, researchers found no evidence of trophic transfer from amphipods to fish or higher vertebrates, even in areas with higher contaminant levels that may have impacted species richness (Weis *et al.* in Kelty and Bliven 2003). An experiment conducted by Saward *et al.* (1975 in Eisler 2000) found reduced growth in a juvenile marine flatfish species (plaice), following the food chain transfer of copper from phytoplankton to clam to flatfish. Dietary tolerance in fish may be highly species specific.

Effects of copper on invertebrates are more severe in poorly flushed areas and in areas where the pesticide-treated wood is relatively new. However, effects decrease after the wood has leached a few months (Weis and Weis 2004). Weis and Weis (2004) determined that concentrations of copper in sediments near dock pilings, in moderately flushed areas, did not show accumulation of metals. This presumably occurred because the pilings have less exposed surface area for leaching than the bulkheads. Under current industry guidelines (WWPI 2006a), site-specific evaluations are recommended (for more robust examination of effects) for projects proposing to use large volumes of pesticide-treated wood (such as bulkheads).

The threshold level of copper in sediments that begins to affect habitat functions is variable. Toxicity of sediments is mediated by the presence of acid volatile sulfides and organic matter, which bind metals and greatly reduce their toxicity, as well as by the sensitivity of local species. To consider these factors at site evaluations, project proponents should conduct tests to quantify sulfide, organic matter, pH and redox potential of the sediments to determine the effect on expected copper toxicity. Simple toxicity testing (i.e. amphipod testing) would also help determine if existing conditions are already impacting the quality of the habitat.

There are several common metrics for examining contaminant levels in sediments to determine impacts on aquatic life. Among the most common metrics are two that were generated by NOAA: the effects range low (ER-L), and the effects range median (ER-M) (NOAA 1999). These values were generated from a literature review conducted by the NOAA Status and Trends Program (Long and Morgan 1990) and subsequently updated (Long *et al.* 1995). The ER-L is defined as the 10^{th} percentile of the effects database (from this literature review) for each substance examined, while the ER-M is set at the 50^{th} percentile. Therefore, the ER-L is meant to indicate concentrations below which adverse effects rarely occur, while the ER-M is meant to be representative of concentrations above which effects frequently occur. For copper in sediment, the ER-L was determined to be 34 mg/kg dry weight and the ER-M was determined to be 270

mg/kg dry weight. The data presented in NOAA (1999) shows a percent incidence of effects at concentrations of copper <ER-L of 9.4% and of 83.7% for concentrations >ER-M. For studies with sediment copper values between the ER-L and the ER-M, the percent incidence of effects was 29.1%. A tabular presentation of ER-Ls and ER-Ms is available for downloading at:
response.restoration.noaa.gov/cpr/sediment/squirt/squirt.htm

NMFS (1998) used the ER-L copper threshold level as the effects level threshold. The area examined (lower Columbia River) had a background concentration of 20 mg/kg. This decision to use the ER-L was questioned by the pesticide-treated wood industry as being overly protective, since the NOAA database showed this level of copper in the sediments had only a 10% chance of causing an effect to EFH in the study area. NOAA agreed because of the variability observed in the background concentrations, but determined that keeping an increase of sediment copper to less than 50% is a reasonable management objective for projects (NMFS 2001).

Other sediment quality guidelines have been developed, and a significant debate continues regarding their appropriateness. The threshold effects level (TEL) guideline is defined as the 15th percentile concentration of the toxics effects data set and the median of the no-effect data set. The TEL represents the concentration below which adverse effects are expected to occur (only rarely) and is 18.7 mg/kg for copper (Buchman 1999). The probable effects level (PEL) is the level above which adverse effects are frequently expected. For copper, the PEL is 108.2 mg/kg. The PEL represents the geometric mean of the 50% of impacted, toxic samples and the 85% of the non-impacted samples (Buchman 1999). The TEL and the PEL are used in Florida and Canada. California has proposed the use of a multiple lines of evidence sediment quality guideline system, which requires sediment chemistry measurements, sediment toxicity testing, and measurements of benthic community condition (SWRCB 2008). This system is designed to eliminate uncertainties that typically remain when only sediment chemistry data is collected.

PAH Toxicity in the Water Column

Creosote is a distillate of coal tar and is a variable mixture of 200-250 compounds consisting of simple PAHs, multi-aromatic fused rings, cyclic nitrogen-containing heteronuclear compounds and phenolic substances (EPA 2008a, 2008b, 2003). PAHs are the dominant class of compounds found in creosote and comprise approximately 85% of creosote's mass (EPA 2003, Stratus 2006b). Sixteen of the top 17 PAHs found most commonly in creosote are on the EPA's List of Priority Pollutants, pursuant to the Clean Water Act (EPA 2003). Currently, there are two formulations of creosote in use: P1/P13 (used for aquatic applications) and P2 (used for railroad ties and utility poles) (Stratus 2006b).

PAHs are released from wood treated with creosote and are known to cause cancer, reproductive anomalies, and immune dysfunction; to impair growth and development; and to cause other impairments in fish exposed to sufficiently high concentrations over periods of time (Johnson *et al.* 1999, Karrow et al. 1999, Johnson 2000, Stehr *et al.* 2000, Collier *et al.* 2002, Johnson *et al.* 2002, Sherry et al. 2005, Stratus 2006b). When exposed to creosote-derived PAH concentrations as low as 320 µg/L, Spot (*Leiostomus xanthurus*, also called flat croaker) exhibited fin erosion and epidermal lesions (Sved *et al.* 1992). Embyonic exposures can result in edema (swelling) of the yolk sack, hemorrhaging, disruption of cardiac function, enzyme induction, mutation of progeny, craniofacial and spinal deformities, neuronal cell death, anemia, reduced growth and impaired swimming (Barron *et al.* 2003, Billiard *et al.* 1999, 2002, Brinkworth *et al.* 2003, Marty *et al.* 1997: all cited in Barron *et al.* 2004, Incardona *et al.* 2004, 2005, Wassenberg and Di Giulio 2004a, 2004b). Exposure to sunlight has been observed to result in a 48-fold increase in toxicity of some PAHs to herring larvae (Barron *et al.* 2003), an increased medaka embryo failure rate (Diamond et al. 2006), impacts to invertebrates (Pelletier *et al.* 1997, Swartz et al. 1997) and resulted in as little as 2 µg/L becoming toxic to calanoid copepods (Duesterloh *et al.* 2002)). Impacts to phytoplankton and zooplankton communities have also been reported in the literature (Sibley *et al.* 2004, 2001a, 2001b, Bestari *et al.* 1998a). Traditional LC_{50} testing (24 and 96 hour tests) for invertebrates and fish resulted in a range of effect levels generally between 0.1 and 4 mg/L (parts per million). This concentration is greater than what is typically encountered, even in polluted surface waters (Eisler 2000). Crustaceans tend to be relatively more sensitive in these tests than fish species.

Several studies demonstrate that PAHs harm the egg-larval lifestage of Pacific herring (Vines *et al.* 2000, Carls *et al.* 1999), surf smelt (Misitano *et al.* 1994) and pink salmon (Heintz *et al.* 1999, Bue *et al.* 1998). Vines *et al.* (2000) studied the hatching success of herring eggs (exposed to PAHs leaching from creosote pilings) and found that 0% of the eggs attached to the piece of piling hatched. In addition, 40-50% of nonattached eggs had delayed development and the surviving embryos all had morphological abnormalities. This study established a LC_{50} for creosote leachate of 50 µg/L for the herring embryos, with sublethal effects observed at concentrations as low as 3 µg/L. The applicability of this study, to actual environmental conditions, is weakened by its static water design with small chambers. An additional field observation of toxicity was made by the same author (Cherr and Vines 1997), but mortality may have been affected by other factors (such as temperature and salinity). The creosote formulation and loading at this observation was not reported. Carls *et al.* (1999) showed that total dissolved PAH concentrations from weathered oil of 0.7 µg/L caused morphological malformations, genetic damage, inhibited swimming, decreased size and mortality of larval Pacific herring. Sublethal effects (such as yolk sac edema and delayed mortality) were observed at concentrations as low as 0.4 µg/L total dissolved PAH. Poston (2001) reviews several other studies of the effects of weathered crude oil (high molecular weight PAHs such as those found in creosote contaminated sediments) and other PAHs or sources on various endpoints including the spawning success of pink salmon and herring.

PAHs bioaccumulate in many invertebrate species (Varanasi *et al.* 1989, 1992; Meador *et al.* 1995), but are metabolized significantly by many vertebrates (including fishes) where they are converted to water-soluble forms and excreted (Varanasi *et al.* 1989, Stratus 2006b). Some of the intermediate metabolites in this process exhibit carcinogenic, mutagenic and cytotoxic properties. Metabolic capacity is generally very high in vertebrates, intermediate in crustaceans and limited in bivalves (Meador *et al.* 1995).

PAH Toxicity in the Sediments

The main exposure scenario of concern for PAHs, including those leached from creosote treated wood, occurs as they accumulate in sediments and are assimilated into the food web. As mentioned in the last section, the concentration of creosote derived PAHs required to cause acute mortality to nonlarval fish is generally high enough that the level rarely occurs. More frequently, it is the chronic and dietary exposures to the higher weight PAHs remaining in sediments that cause the effects listed in the last paragraph (i.e. cancer, reproductive anomalies, immune dysfunction, growth and development impairment, and other impairments to fish exposed to sufficiently high concentrations over periods of time or exposed during their egg or larval life stages). Effects are more prevalent in benthic species (such as English sole, winter flounder and brown bullhead), due to their frequent contact with the sediments (Stratus 2006b).

There is a significant debate over what level of PAHs in sediments cause the adverse effects discussed. Research by scientists at the NMFS Northwest Fisheries Science Center (Johnson *et al.* 2002) suggested a sediment threshold level for total PAH of 1 part per million (mg/kg dry weight) would protect estuarine, bottom dwelling fish (such as the English sole examined in the study), from detrimental effects (such as liver lesions, spawning inhibition and reduced egg viability). This level (1 mg/kg) was the lowest at which effects to English sole began to be observed. A model developed as part of this study predicted a 10-fold increase in DNA adducts (a complex formed when a carcinogen combines with DNA or a protein) at 5 mg/kg total PAH compared to control fish, resulting in liver disease to approximately 30% of the exposed fish and increasing failure to spawn. The authors noted a concern that other carcinogenic contaminants (PCBs, chlorinated pesticides, and trace metals) that were present in the sediments of the Puget Sound at the various study locations may be significant confounding factors.

The ER-L for total PAHs is approximately 4mg/kg, while the TEL (approximately 1.7 mg/kg) is closer to the level suggested by Johnson *et al.* (2002). The concentrations of concern are even lower for total high molecular weight (HMW) PAHs, which typically remain in the sediments, with an ER-L of 1.7 mg/kg and a TEL of 0.66 mg/kg (Buchman 1999). These are environmentally realistic concentrations that may be exceeded in industrialized or urbanized areas; however, these are the levels where effects are predicted to begin. The ER-M for total PAHs is approximately 44.8 mg/kg (total HMW PAH = 9.6 mg/kg), while the PEL is approximately 16.7 mg/kg (total HMW PAHs = 6.7 mg/kg). Sediments with PAH levels above the lower thresholds warrant protection from additional contamination in order to protect the function of the sediment for EFH as well as ESA listed species. The next discussion of this information considers if pesticide-treated wood products can generate these elevated levels of PAHs in sediments, for how long and over what area of a waterbody.

Leaching Rates, Subsequent Exposure and Model Evaluation

Now that the toxicity of the contaminants has been summarized, it must be determined if the use of pesticide-treated wood products will result in conditions that may impact NOAA trust resources in a manner which can be meaningfully measured, detected, or evaluated. Conditions should be evaluated for adverse affects to species listed under the ESA, limitations to the functions of designated critical habitat to support recovery of a listed species, or adverse affects to the quantity or quality of EFH. This section will briefly present information on leaching rates of pesticide-treated wood products, models developed to predict leaching rates, subsequent concentrations in sediments and water, and studies of pesticide-treated wood installations. Much more detail is available in the Stratus reports (2006a, 2006b) and their source documents.

Copper Treated Wood – ACZA and CCA

These two copper-based formulations are often used for in-water portions of structures. There are several other prominent formulations of wood treatments containing copper that may be used in over-water applications. These formulations were not examined in significant detail during the Stratus (2006a) literature review, but concerns about their use in over-water structures is considered with ACZA and CCA later in this document.

The leaching of copper from ACZA and CCA treated wood demonstrates a general trend of higher initial leaching rates that decrease rapidly within days. Within a few weeks to months, copper leaching decreases to very small levels; however, this is dependent upon pH, temperature and other variables. ACZA leaching rates in freshwater were very low within 10 days of installation (Brooks 1995b, NMFS 1998, Hutton and Samis 2000). The majority of leaching occurred from CCA pilings during the first 30-90 days after installation (Brooks 1995a, Weis *et al.* 1991, NMFS 1998, Hutton and Samis 2000, Kelty and Blevin 2003). ACZA leaches a greater total mass of copper in freshwater compared to CCA, but ACZA leaches for a shorter time.

The spreadsheet models reviewed by Stratus (2006a) are available for public use on-line at the WWPI website: www.WWPInstitute.org. Models for ACZA (ACZA.xls) and CCA (CCAPRISK.xls) were accessed on December 7, 2007 and results are presented in Table 1. The ACZA model gives both fresh and marine water outputs simultaneously. All other inputs in the model that produced Table 2 were left at their default settings.

Table 1. Leaching Rates (μg/cm^2/day) of a single 15 cm diameter piling, Freshwater salinity 0 ppt, Saltwater salinity 30 ppt

Time		Day 0	1	3	10	30	90
ACZA	Freshwater.	118.79	77.35	32.8	1.63	0.00	0.00
	Saltwater	32.55	10.68	1.15	0.00	0.00	0.00
CCA	Freshwater.	1.39	1.33	1.20	0.86	0.33	0.02
	Saltwater	2.86	2.72	2.47	1.77	0.68	0.04

Table 1 is intended only to illustrate the rapid decline in leaching rates. Project specific information (e.g. piling diameter, tidal velocities, water depth, etc.) can be entered into the on-line spreadsheets to generate more specific predictions of leaching rates.

Problematic exposure scenarios need to be evaluated along with leaching rates. Review of projects affecting juvenile salmonid habitat must consider if problematic concentrations of copper will leach into habitat when salmonids are present. In well mixed areas, dilution is often sufficient to decrease the concentration of CCA or ACZA to inconsequential levels. In other circumstances, the project could be scheduled to allow leaching when salmonids are less likely to be present. The model presentation used in NMFS 1998 (Table 1 in that position paper - acknowledging uncertainties discussed later in this document), shows that installation in an area with a current velocity of 10 cm/sec or more, does not increase water column concentrations of copper more than 0.43 μg/L for 100 or fewer pilings. This applies even in the smallest, most dense cross-sectional area evaluation. For reference, the lowest benchmark concentration calculated by NMFS (Hecht *et al.* 2007), at the 95% confidence interval, for impacts to salmonid olfactory performance was an increase of 0.79 μg/L. NMFS (1998) shows increases of less than 0.79 μg/L are predicted for other projects with greater numbers of piling at this current velocity. However, exceedances of this benchmark typically occur in only the densest installations. There are also multiple regression equations presented in the position document (NMFS 1998) that can be used to generate predictions of copper concentrations for individual projects of different sizes.

The majority of projects proposing to use pesticide-treated wood are smaller than the 100 piling size (at any installation density) which predicts potentially problematic water column concentrations at current velocities of 1 cm/sec or less. Because of the superior weight bearing properties of concrete and steel, most projects currently proposing to use pesticide-treated wood are small-scale (such as personal use docks and rural bridges). These projects typically have between two to five piling bents spaced at least four meters apart (Brooks 2003). Some of these projects use pesticide-treated wood mainly in the decking.

The Poston model utilized in NMFS (1998) and another spreadsheet based model developed by Brooks (1997b) were reviewed in Stratus (2006a). Although there is variability between the predictions of the leaching models and the observed leaching rates in laboratory studies, Stratus determined that there is little or no bias in leaching model under or overpredictions. The subsequent environmental models, which are used to predict water column concentrations and impacts to sediments, appear to capture the overall trends in leaching rates reasonably well. However, the review cautions that site specific conditions need to be known to provide useful predictions (Stratus 2006a). The remaining uncertainty can be addressed in a large-scale or regional guidance through other mechanisms (such as limiting the number of pilings that a project may install), without going through a more thorough analysis. NMFS (2004b) did this in the lower Columbia River and Oregon by essentially pre-approving projects that propose 50 or less copper treated pilings. This effectively serves as a margin of safety from the uncertainties in the 100 pile predictions. Other requirements, such as limiting the width of the structure, address other project related impacts. This level of pre-approvals still captures a large percentage of proposed projects, making it an efficient solution from both regulatory workload and species protection points of view.

NMFS (1998) also presented estimates of total sediment copper concentrations over a variety of project cross sectional areas and current velocities, based upon the Poston box model used by the USACE in their biological assessment (USACE 1996). This is presented as Table 2 in the NMFS (1998) document. A background sediment copper concentration of 20 mg/kg was assumed in the model and this must be adjusted by substituting local background concentrations for the default value (if using the model predictions as a guide). Significantly elevated concentrations are predicted to occur near the pilings, but elevated levels further away from the pilings are negligible. This finding is similar to the Washington State White Paper (Poston 2001), which found that increases in sediment metal concentrations were limited to within 10 feet from small pesticide-treated wood structures in marine and freshwater habitats. Weis and Weis (1996) and Weis *et al.* (1998) measured increases of copper in sediments adjacent to bulkheads (<1m) constructed of CCA treated wood. Additionally, Weis and Weis (1994) examined a number of dock sites (rather than bulkheads) and found that these sites did not have increased metals in sediments adjacent to pilings or any consistent differences in benthic communities. The authors concluded that leachates from pilings in reasonably well-flushed areas do not have negative effects in the immediate vicinity. This is of importance because industry guidelines (WWPI 2006a) state that high surface area or high density uses of pesticide-treated wood products (such as bulkheads) should undergo site-specific assessments. Applicants can be requested to follow industry guidelines by generating necessary background information and monitoring, which is needed to make accurate effects determinations. Stratus (2006a) concluded that metals leaching from pesticide-treated wood structures resulted in only minor accumulation over a limited area (within several meters) in well mixed waters. The resulting accumulations have not been associated with significant biological effects, except in close proximity to the structures (usually bulkheads that also affect the biological community by increasing scour of fine sediments away from the structure due to reflected wave action).

Creosote Treated Wood

Leaching and deposition from creosote-treated wood products were also evaluated in the position paper (NMFS 1998). A number of creosote formulations were used in the past, which complicates the evaluation of leaching studies (Stratus 2006b). There are also fewer studies with modern creosote-treated products than copper-treated products, which results in additional uncertainty when making effects determinations for new projects. Like CCA and ACZA, the most rapid leaching of PAHs from creosote-treated products occurs initially (Sibley *et al.* 2004, Bestari *et al.* 1998b, Ingram *et al.* 1982); however, detectable leaching occurs for years and perhaps much longer (Stratus 2006b). The spreadsheet model available through WWPI, and reviewed by Stratus, uses an age input in years (rather than days). The USACE (1997) biological assessment recognized that leaching of PAHs occurs for years after the installation of pilings and referenced a study by Ingram *et al.* (1982) that determined rates for a 12 year-old pile (8.0 $\mu g/cm^2/day$). NMFS (1998) recognized that the sediment PAH model used by the USACE did not account for resuspension, turbulence, lateral dispersion or biodegradation of PAH compounds over time and may overestimate the accumulation of PAHs in the sediment over the long-term.

Brooks *et al.* (2006) is the latest publication documenting the results of a long-term study conducted with Fisheries and Oceans Canada in the Sooke Basin, British Columbia, to address the longer term PAH leaching from creosote. The study included the construction of three dolphins: each containing six pilings. The study included: untreated wood, non-BMP produced wood (that had been installed elsewhere for 8 years before being moved to this location) and BMP produced piling that was over-treated (27 pounds of product per cubic feet compared to the AWPA standard for marine use of 16-20 pounds of product per cubic foot). The Sooke Basin study site had slow currents (2.3 cm/sec at the surface and < 2 cm/sec at depth (~12 meters)), and low baseline sediment concentrations of PAH, making it a good location to conduct the study. During the first year, creosote[1] accumulated in the sediments, within 7.5 meters of the BMP treated structures at concentrations of <7 to 10 mg/kg TPAH. By the end of the ten year study period (Brooks *et al.* 2006), elevated sediment levels were detected only within 2.5 m from the BMP pilings (5.2 mg/kg TPAH in the upper 3 cm of sediment and declining at 21 cm to 0.140 mg/kg TPAH). The creosote contamination at the 2.5 m distance was not uniform. The authors reported that the initial TPAH release did not seem to be toxic to the local infaunal community (Goyette and Brooks 1998). Toxicity was observed in laboratory tested samples on standard organisms, for sediments within 2 feet of the treated pilings (Goyette and Brooks 1998, 2001). Water column concentrations were not measured at this time.

Exposure from Over-water Use of Pesticide-treated Wood Products

Significant quantities of pesticide-treated wood products are used in above-water structures and decking which warrant examination and sound management recommendations (WWPI 2006a). Pesticide-treated wood structures placed in or over flowing waters will leach copper and a variety of other toxic compounds directly into the stream (Weis and Weis 1996, Hingston *et al.* 2001, Poston 2001, NOAA 2003). These structures can be sources of copper to waterbodies from leaching during rain storms or washing, splashing, from abrasion caused by foot or vehicle traffic, or release of sawdust or other wastes during construction or maintenance procedures. Creosote-treated products can release PAHs from these same mechanisms and from exposure to the sun. Sunny, warm conditions cause creosote to be more mobile and "ooze" or blister out of the product. The droplets can then be released to the waterbody.

Exposures of this type are often sporadic and can occur for a longer period of time because the pesticides do not have a chance to be removed rapidly, except in areas of high precipitation. Weathering is based largely upon rain intensity and duration and is thought to mainly occur during the first year, especially in areas which experience regular rainfall (Brooks 1997b). Although overwater structures will release contaminants, the biologist must assess the situation to determine if the releases will result in adverse effects to NMFS trust resources. Similar to in-water structures of pesticide-treated wood, infrastructure where significant dilution will occur will have sporadic inputs of contaminants that are less likely to have impacts that are measureable, detectable or that can be meaningfully evaluated.

Studies conducted on bridges and boardwalks are useful for examining the potential contribution of contaminants from overwater structures. Two bridges constructed of

[1] Measured as TPAH

CCA treated wood were studied by Brooks (2000) in Florida. One was over freshwater and one in a marine environment. Both sites had some sediment copper contamination, though the levels were low and limited in space (approximately six feet downstream of each bridge). The marine bridge increased copper concentrations from 2.3 mg/kg (background) to 25.1 mg/kg directly below the bridge and the concentration dropped to 7.95 mg/kg at 1.5 feet downstream. Concentrations were at background levels 10 feet from the bridge. The freshwater bridge was two years old when studied. Background concentrations were 0.63 mg/kg in the sediments. They were to 2.1 mg/kg beneath the bridge and for three feet downstream, but were near background concentrations at 20 feet downstream of the bridge. Abundance and diversity of aquatic insects were measured and did not indicate impacts, while bioassays did not indicate toxicity.

A boardwalk study (FPL 2000) was conducted in Oregon on a 1,800 foot long boardwalk, constructed in a wetland area from three different copper treated products, to evaluate the product's environmental effects. The environment was slow moving freshwater, with fine grained sediments and heavy rainfall. The boardwalk was monitored for one year after construction. Copper accumulations from both CCA and ACZA formulations were found to vary temporally and spatially. The baseline levels of copper in the surface sediments varied from 17-24 mg/kg at the CCA treatment site. After two months the maximum copper concentration under the boardwalk was as high as 201 mg/kg, with a median concentration of 64 mg/kg. These levels increased further at 5.5 months, with a maximum detection of 219 mg/kg and a median level of 112 mg/kg. These levels decreased by the 11^{th} month, with a maximum detection under the boardwalk of 115 mg/kg and a median concentration of 85 mg/kg. Copper levels were also elevated two feet from the boardwalk in the surface sediments, with a median concentration of 51 mg/kg. Copper levels in the surface sediments at the next monitoring point (five feet from the boardwalk) remained within background levels, although the data shows a gradual increase in low-level contamination moving away from the structure. This localized pattern of distribution indicates that the majority of leached copper was bound to suspended materials that settled into the sediments. Monitoring of leaching found that the greatest amount leached during initial rainfall. It must be noted that the CCA materials used in this trial were prestained. Experiments on the efficacy of coatings to minimize leaching from CCA-treated wood, found that one coat of latex primer, followed by one coat of oil-based paint or two coats of penetrating, water-repellent deck stain were both effective for reducing the leaching of copper, arsenic and chromium by more than 99% (FPL 2001a). Materials not treated in this manner may leach more copper.

At the ACZA site, baseline copper levels varied from 18-21 mg/kg in the surface sediments. Elevated levels of copper were observed as soon as 10 days after construction. At 2.5 months the median concentration under the boardwalk was 47 mg/kg, although there was a sample containing 569 mg/kg under the boardwalk, and others measuring 122 mg/kg and 226 mg/kg at one foot and five feet away from the boardwalk respectively. The distribution was more heterogeneous than the CCA treated wood site. Concentrations decreased at the six month sampling period, but increased again during the 11.5 month post construction sampling. This was likely due to a large rainfall event that flushed sediments away from the ACZA treated site. This indicates that the dissolved copper, leaching from the boardwalk, was being absorbed and settling into the sediments. At 11.5 months, the mean copper concentrations were elevated above surface sediment levels, within one foot of the structure (95% confidence interval). Concentrations were slightly elevated within 5 feet of the structure, but not at this level of statistical significance. Like the CCA treated wood in this evaluation, initial leaching rates were highest during initial exposure to rainfall, although the mass of copper leached was correlated with total rainfall.

Invertebrate sampling was evaluated to detect potential adverse affects to these communities and habitat quality. Total species richness, sample abundance, dominant sample abundance, and Shannon's and Pielou's indices were calculated. These indices did not show a significant reduction in habitat quality, and no taxa were extirpated from the study area, despite the elevated concentrations near the boardwalk. Replicate samples were not taken, with the exception of artificial substrates that allowed for expeditious sampling. These artificial substrates excluded some taxa; therefore, the sampling design does not allow for a more thorough examination. Differences in abundance and diversity near and far from the boardwalk seem to occur in some datasets, but this could simply be due to natural variability. All of the indices were comparable to the control, within 10 feet of the boardwalk.

The author noted that the high rainfall and large volume of pesticide-treated wood used in construction of the boardwalk represented a severe leaching hazard. A project of this size would likely be considered as an example of a "substantial project having large treated wood surface area," as noted in WWPI (2006a). This would warrant an individual risk assessment and therefore, would generate the data for a more thorough examination. This determination may depend upon the proposed location and potential for direct exposure of salmonids. Affects may not be detectable or measurable in some locations or may be rather limited in area as illustrated by this study.

Exposure from Construction Debris

If pesticide-treated wood sawdust or shavings (generated during construction) are allowed to enter soil or water below a treated structure, they make a disproportionately large contribution to environmental contamination. Impacts from the leaching of construction debris immersed in water are vastly greater than from solid wood (FPL 2001b, Lebow and Tippie 2001, Lebow *et al.* 2004). Construction debris may release 30 to 100 times more preservative than typical submerged pieces, due to the increased surface area available for leaching. Collection of construction debris should be stressed. Storing pesticide-treated wood out of contact with standing water and wet soil, as well as protecting the wood from precipitation significantly reduces the likelihood of chemical leaching during construction (Lebow and Tippie 2001, FPL 2001b).

Linkage of Toxicity, Modeling, Field Studies and Expected Impacts

Copper-treated pilings leach relatively quickly, reaching low exposure levels in a matter of days to several weeks, depending mainly on formulation. For in water uses, the highest leaching occurs in the first few days. Within this time, the resulting water column concentrations may be high enough to affect salmonid olfaction ability (an increase ≥0.79 μg/L dCu), depending upon the size of the project and the available dilution. The biologist will need to determine the likelihood of salmonid early lifestage presence and potential exposure. Sediment contamination is a possibility, but was not noted at problematic levels from dock structures, compared to bulkhead structures. The models used by the NWR of NOAA Fisheries (NMFS 1998, adapted from USACE 1997) and the industry (Brooks 1997a and 1997b) can both over and under predict leaching rates, but do capture the trends. Although they can not be used for exact predictions, the models can provide useful site-specific predictions when used with site-specific information and when BMP produced wood is installed. Overall, the models consistently overestimate water column concentrations because of simplifying assumptions (such as all the piles being installed simultaneously) and the difficulty of accounting for mixing by turbulence (Stratus 2006a). The models should perform well enough for a site-specific or regional examination to determine if a project is likely to have adverse effects on NMFS trust resources because their conservative tendencies help to offset some of the uncertainties. Most projects, which are small enough to not require a more detailed site-specific assessment, are likely small enough to not be a concern (i.e. 2-5 pilings spaced at least 4 meters apart (Brooks 2003), perhaps with some pesticide-treated wood decking).

Creosote-treated wood leaches significantly in freshwater, but has been banned from use in most freshwater areas by the West Coast states. It leaches detectable amounts of PAHs for years to decades in marine environments. The resulting sediment contamination is usually localized near the structure and diminishes over time. Elevated PAH levels in sediments have been implicated in causing tumor growth and reducing fecundity in bottom dwelling fish. Creosote-treated wood can cause these levels in sediment in some habitats over localized areas. There may be many sources of PAH in the environment, causing elevated background concentrations. Numerous waterbodies are listed as impaired, due to excessive levels of PAH. Additional contaminant loading is not advisable in these impaired waterbodies.

Water column concentrations of PAH from BMP creosote treated wood sources are not expected to cause detectable, acute effects under most exposure scenarios. Most vertebrates, including fish, can metabolize PAHs fairly efficiently. Several studies document impacts to herring eggs exposed to PAHs. The Vines *et al.* (2000) study is useful for establishing a LC_{50} for herring hatching success following creosote-derived PAH exposure. Significant uncertainty regarding whether this level of impact will be reached in the field warrants a cautious approach in areas where herring spawn and potentially in areas where the egg and larval lifestages of other species may be similarly exposed. Creosote treated piling installations in the Los Angeles area have been required by the USACE to be wrapped for many years to reduce exposure to the environment (Castanon, David pers. Comm., 2004)

Precedent has been set to permit a predetermined number of pilings to be installed without triggering full ESA and EFH consultations (NMFS 2004b). This more site specific analysis should be done for local areas, in which these types of projects are being proposed. Overwater use is significant enough to warrant the use of BMPs (e.g. construction BMPs, use of BMP treated wood), but is not likely to result in problematic concentrations except in the most sensitive environments. BMPs should be used to minimize unnecessary risk for both in-water and above-water utilizations.

Best Management Practices

The above sections show that the properly planned and executed use of pesticide-treated wood products is unlikely to cause detectable impacts to ESA listed salmonids, in many use scenarios; however, uncertainties remain in the underlying leaching experiments, field studies and modeling efforts (Stratus 2006a). Evaluation of in-service structures show that leaching rates vary by wood dimensions, wood species, treatment practices, fixation, age of the structure, type of exposure, construction and maintenance practices, and site-specific conditions (Lebow 1996, Lebow *et al.* 2004). The potential cumulative effect of these uncertainties has led numerous agencies (NMFS (1998, 2003, 2004), Fisheries and Oceans Canada (Hutton and Samis 2000), USDA (Lebow and Tippie 2001), Washington Department of Fish and Wildlife and Department of Ecology (Poston 2001), USACE (2006, Castanon, D., pers. comm. 2004)) and industry (WWPI 2006a, 2006b) to recommend BMPs to minimize avoidable and unnecessary risks to the environment. The following section on BMPs should be considered by the project proponent, the permitting agency (usually the USACE for NMFS purposes) and the reviewing agency (NMFS), and all warranted practices put into place for a project. Some districts of the USACE have standardized several of these BMPs resulting in an increased regulatory certainty for project proponents and more expedient review and approval processes.

Proper Material Selection – BMP Pesticide-treated wood

Perhaps the most important BMP is simply proper selection of pesticide-treated wood materials for a project. At the basic level, this means that the pesticide-treated wood product contains no more than the minimum level of pesticide necessary, as specified by the American Wood Preserver's Association retention standards Higher retention levels do not lead to extra durability. They only lead to increased leaching and subsequent impacts (Lebow and Tippie 2001).

The simplest way to ensure that the wood to be used has been properly treated is to require the project proponent to use products that have been BMP certified through a third party inspection process. The WWPI has set up such a procedure, so that products can be verified as being produced in compliance with production BMPs (WWPI 2006a). This means that they will be treated to proper retention standards and be processed to maximize fixation of the product. This would result in lower leaching rates (as used in the environmental exposure models). This is crucial to insuring that predicted levels of contamination are in fact those which are likely to occur. BMP pesticide-treated wood is denoted with a written certification from a company accredited by the American Lumber Standard Committee (in compliance with regulations of the U.S. Department of Commerce), or through the presence of a BMP mark as seen in the WWPI documents (2006a, 2006b). However, in the event that an improperly labeled material arrives at a job site, a visual inspection and rejection of materials (with visible residues or bleeding) requirement is still recommended.

Proper Material Selection – Environmental Conditions
Proper selection of pesticide-treated wood products is also based upon environmental conditions. Creosote-treated wood and copper-treated wood seem interchangeable in marine environments and selection of materials is often a matter of personal preference. Use of creosote-treated products is already restricted, or not recommended, in many freshwater environments in California, Oregon, Washington and Canada (Stratus 2006b, Hutton and Samis 2000). If a project proponent insists on using creosote-treated wood in spawning habitats of vulnerable species and lifestages (such as Pacific herring or pink salmon), or in a PAH impaired waterbody, then wrapping the pilings to form a physical barrier between the leachable material and the aquatic environment may be appropriate mitigation. This treatment is required by the Los Angeles District of the USACE (Castanon, David pers comm., 2004), to protect fish habitats. In areas without such restrictions, the condition of the sediments needs to be examined to determine if creosote could be used with minimal impact. Creosote-treated wood pilings should not be installed in anoxic sediments or areas with low dissolved oxygen concentrations, as the PAHs will degrade more slowly due to lack of oxygen and can accumulate to problematic levels. These are site-specific assessments where local knowledge is vital. In other less sensitive areas, it is important to remember that the long-term study of modern BMP creosote-treated wood in the field (Sooke Basin study), found limited contamination only in areas adjacent to the structures (Brooks *et al.* 2006, Goyette and Brooks 1998, 2001).

If pesticide-treated wood is used in overwater structures, BMP pesticide-treated wood can minimize effects to sensitive environments. For example, bridges or decks built over low- flow areas that support salmonids may need to be BMP treated to minimize leaching into a waterbody with minimal available dilution. This may be especially important if the structure will be cleaned during the low flow season. Cleaning and maintenance activities (such as aggressive scrubbing, power-washing, or sanding) can also remove particles of pesticide-treated wood and deposit them in soil or water beneath the structure (Lebow and Tippie 2001). Wooden bridges built without a wearing surface (so that vehicles ride directly on a pesticide-treated wood deck) may abrade because vehicle traffic wears away the preservative treatment over-time and exposes new surfaces of the wood to leaching (Brooks 2000, Ritter *et al.* 1996a and 1996b). Similarly, foot traffic will abrade pesticide-treated wood used in pedestrian bridges unless prevented by a wearing surface such as synthetic mats, coatings, metal sheets, or sacrificial plywood sheets (DeVenzio undated in NMFS 2004b, Lebow *et al.* 2003). Coatings will be discussed later in this document. Otherwise, products which leach the lowest amount of copper should be encouraged. In general, this seems to be CCA (Kennedy 2004, Stefanovic and Cooper 2004, Stratus 2006a), although the use of products with arsenic is now limited by EPA due to human health concerns in some applications.

Require Site Specific Assessments for all Larger Scale Projects
Table 1 in NMFS (1998) presents an adaption of information from the Poston box model, developed for the USACE biological assessment (USACE 1997) for the lower Columbia River. It was reviewed by Stratus (2006a) and determined to be useful in providing site-specific predictions where site-specific conditions are known. It can be used as a

screening tool to predict increases in dCu above background concentrations if current velocity, the cross-sectional area of the projects, pH and the number and size of pilings to be installed is known. For copper-treated products, water column increases of <0.79 µg/L dCu were consistently predicted at current velocities of 1 cm/sec for projects with 24 or fewer pilings only at the smallest cross sectional area (i.e. cross sections ≤ 200 m^2). This may show that the pesticide-treated wood impacts of many smaller projects (such as personal boat docks) do not generally cause problematic levels of copper in the water column. If current velocities are 10 cm/sec or greater, all modeled installations up to 100 pilings were acceptable showing the importance of dilution to determining a measurable or detectable level of impact. All installations of 100 pilings or less were found to not have problematic sediment impacts (i.e. <50% increase over the background concentration of 20 mg/kg copper) at current speeds of 1 cm/sec or greater.

A key assumption to the environmental exposure model (NMFS 1998) is that all pilings are installed simultaneously, which does not accurately reflect the logistics of construction. A project that uses 100 pilings will require several days to install, under the best of conditions. That means that the water column concentrations, projected by the model for the 100 piling scenario, are conservative and are likely to be lower in reality. Multiple regression equations, found on pages 10 and 11 of NMFS 1998, can be used for projects proposing between 24 and 100 pilings if the project is not in an area where a more thorough analysis has been conducted or programmatic consultation is in place. The SLOPES opinion (NMFS 2004b), covering the State of Oregon and lower Columbia River, is an example of this and effectively pre-approved projects installing 50 pilings or less (with some other restrictions). The WWPI (2006a) recommends conducting a site-specific assessment if more than 100 pilings are proposed for a project. This recommendation can be provided to the action agency and project proponent if more information is needed to determine the potential impacts of larger projects.

Timing of Installation

Restricting when an action can take place is a well established method of preventing or minimizing impacts to listed species and/or sensitive habitat components. The timing of use of an area by federally managed, or ESA listed species, should be determined. If a proposed project is of sufficient scope (that it may release contaminants at problematic levels), construction timing windows may be useful. In California, there are often time periods in larger rivers, bays and estuaries when salmonids are not present and other periods when only migrating adults are present. In the Northwest Region and Alaska, many of rivers and estuaries are used extensively by incubating and rearing juvenile salmonids; therefore, there may be nearly constant juvenile emigration. Timing restrictions (sometimes called work windows), may already be in place for other activities (e.g. dredging), or for related impacts (e.g. pile driving, turbidity).

Construction BMPs

As noted previously, elevated contaminant releases from pesticide-treated wood materials can occur during the construction process. This is due to the high surface areas of debris (such as sawdust) and the exposure of the inner portions of the wood where the chemicals may not be as strongly fixed initially. The use of construction BMPs reduces unnecessary risks to aquatic habitats and is recommended by numerous agencies (NMFS (2004, 2003), Fisheries and Oceans Canada (Hutton and Samis 2000), USDA (Lebow et al 2000, Lebow and Tippie 2001)), industry (WWPI 2006a, 2006b) and subject reviews (Poston 2001, Stratus 2006a). These documents call for minimizing unnecessary risks by reducing the potential for construction debris to enter waterways.

Construction BMPs begin with proper storage of materials onsite. The materials should be stored in an area that does not freely drain to the waterbody, free from standing water or wet soil, and protected from precipitation (Lebow and Tippie 2001, NMFS 2004b). If necessary, materials should be stored on skids or support timbers to keep them off the ground. Although the wood should be BMP certified in many proposed applications, it should still be inspected on site and any pieces found to have visible residues or bleeding of preservative should be rejected. If ammoniacal treated wood has a noticeable odor, then it has not been properly processed or aged and the preservative may not be properly fixed. The wood should be rejected and the failure of the BMP certification process reported.

Maximum prefabrication should be done before the structure is placed over-water. This minimizes cutting and boring discharges of debris into the waterway. If prefabrication is done on-site, construction debris must be salvaged and disposed of properly. Cutting stations can be set up with a large tarp to capture debris. The cutting station should be kept well away from the water to minimize transport of sawdust by wind. Applications of field preservative treatments to cuts and bore holes, water repellants or other coatings, if not applied by the manufacturer at their facility, should take place at the cutting station before the wood is taken to the overwater area. These applications must be allowed to dry and/or cure.

If minimal cutting, boring or touch-up preservative applications must be performed over water, then tarps, plastic tubs or similar devices should be used to capture debris, spills or drips. Vacuums may also be used during construction to capture debris. Any excess field preservative should be wiped off and not applied in the rain. Any debris which falls into the water should be promptly removed. Debris should be stored in a dry place until it is removed from the project site. Lebow and Tippie (2001) contains useful pictures of construction BMPs.

<u>Demolition BMPs</u>

BMPs for demolition of pesticide-treated wood structures are very similar to construction BMPs. Both are meant to minimize unnecessary exposure of the aquatic environment to debris. It is recommended that minimal cutting and boring should take place over the water. Tarps, tubs and/or vacuums should be used to capture the debris. Any debris that falls into the water should be promptly removed. Additionally, wood should be stored in a dry place where the debris will not be swept away by any rising waters.

If pilings are removed, disturbance of sediments should be minimized to prevent the spread of any contamination. Sediments adjacent to the project should be analyzed to determine if they warrant removal or clean capping. Problematic sediment contamination is not necessarily from pesticide-treated wood in the infrastructure being removed, but may result from historic use at the facility (i.e. discharges from boats or industry at the site). The piles should be pulled, if possible. If pulling is not possible, the pilings should be cut at or below the sediment line and capped as warranted. Dispose of the used pilings properly with all other debris in a manner that does not expose or affect aquatic resources. Since older creosote treated wood materials were likely not produced in accordance with industry BMPs (i.e. they were likely treated to the point of refusal), they should not be reused in aquatic environments. Local requirements for disposal may vary but need to be followed.

In-water Coatings and Wraps

Another method to minimize unnecessary environmental risk is coating the pesticide-treated wood products with impervious materials to minimize the loss of metals or PAHs to the environment (Stillwell and Mustane 2004). Coatings or wraps should be used in projects proposed for sensitive locations, or areas with limited currents and/or high background concentrations (NMFS 2003, Hutton and Samis 2000). Examples of sensitive locations include areas with vulnerable species. These species include: Pacific herring, which may spawn onto the creosote treated wood, or pink salmon, which spawn in areas that may have maritime development (i.e. they spawn within a few miles of the coast or even within the intertidal zone). Additionally, areas determined to be important EFH for juvenile rearing should be examined carefully and coatings considered to prevent contamination especially if background levels are significantly elevated. Coatings and wraps may also be useful for piling replacement projects when a facility desires to replace a few pesticide-treated wood pilings that have been damaged, but the scale is small enough that the entire facility does not need replacement. Wraps may also be used as mitigation, to minimize impacts from existing creosote treated facilities.

There are numerous coating materials available commercially that encapsulate wood and prevent leaching of contaminants. A full review of coatings is beyond the scope of this document. The important considerations for the local biologist to consider are that the coating be inert, impervious and long lasting. The requirements are typically written for "an impact-resistant, biologically inert coating that lasts or is maintained" for a specified amount of time. Construction materials can be ordered that arrive on-site already encapsulated, or polymers may be applied by the company with the construction contract. Once dried, many coatings used in marine applications allow the piles to be driven (like an uncoated pesticide-treated wood piling). An internet search will reveal several types of products and purveyors. These types of coatings have been successfully used on projects with pesticide-treated wood pilings in San Francisco Bay since 2005 (David Woodbury, pers. comm., 2007) and in New Jersey to protect shellfish beds since that late 1990s (Stanley Gorski, pers. com., 2008). Similarly, the USACE Los Angeles District requires that creosote treated pilings used in the Ports of Los Angeles and Long Beach be wrapped to minimize the leaching of PAHs (Castanon, D. pers. Comm., 2004). Wrappings are installed and then sealed (traditionally to prevent the flux of oxygen into the wood), killing marine borers, which are already present. High density polyurethane wear strips can be used to protect the wrapped piling from damage from scraping by vessels or other objects. In California, if a project proposes to treat both in-water and above-water portions with a coating product, then it falls under the local area programmatic ESA and EFH consultation (USACE 2006) and does not require further examination by NOAA Fisheries (NMFS 2007).

Over-water Coatings

Exposed wood, used in overwater applications (such as decking) should be protected from the weather and an application of water repellent sealer is recommended by industry (WWPI 2003) and agencies (NMFS 2004b, 2003, Lebow and Tippie 2001, USDA FPL 2001). Application of finishes, such as semi-transparent penetrating stains, latex paint, or oil-based paint, decrease environmental releases (FPL 2001a and 2001b, Lebow *et al.* 2004). In general, opaque polyurethane and acrylic finishes form the most durable coatings, probably because they protect wood from ultraviolet radiation, although for some surfaces (such as those subjected to foot traffic) use of a penetrating stain that results in a slow wearing of the coating may be preferable (Stilwell and Musante 2004). Experiments on the efficacy of coatings to minimize leaching from CCA-treated wood, found that one coat of latex primer, followed by one coat of oil-based paint or two coats of penetrating, water-repellent deck stain were both effective for reducing the leaching of copper, arsenic and chromium by more than 99% (FPL 2001a). Coatings and any paint-on field treatment must be carefully applied and contained to reduce contamination (Lebow and Tippie 2001, FPL 2001b). Coatings which are likely to blister and peel or require sanding and scraping (such as varnish) should not be used for these applications. Leaching will still take place (although at a highly reduced rate) and will increase as the coating degrades. However, the rate of leaching will be greatly reduced over-time, leading to lower levels of exposure. The biologist will have to determine if the waterbody into which the contaminants are leached is sensitive enough to require that a water-proof seal or barrier must be maintained for the life of the project.

It is recommended that good construction practices, as noted elsewhere in this document, are followed with the maximum amount of construction (including coating) taking place away from any waterbodies. Lebow and Tippie (2001) of the U.S. Forest Service noted that several manufacturers of CCA and the manufacturer of another copper-treated product (known as ACQ-D) offer formulations which incorporate a water repellent into the treating solution.

Alternate Materials

Using a material other than pesticide-treated wood is another potential BMP and would eliminate the impacts of the pesticide-treated wood. Using alternative materials; however, does not eliminate the more general impacts of a structure. General structure impacts could include: shading aquatic vegetation, providing ambush cover for predatory fish and perches for piscivorous birds, introduction of pollutants from the supported vessels or industries (e.g. copper from boat hulls, PAHs from gasoline, oils and grease, turbidity from prop wash, sewage and other wastes from the vessels, industries and associated parking lots). Additional impacts from the structure may include: altering flow patterns around the vicinity of the project, changing the character of the project area (by introducing hard substrate that may be colonized by organisms not typically present) and construction impacts (such as dredging and pile driving) (NOAA 2005).

Stratus (2006a) examined several potential alternate materials. The materials have advantages and disadvantages, which are detailed in that document (Stratus 2006a). Some have their own pollutant concerns (such as leaching of potential endocrine disrupting chemicals from plastic based materials or zinc from cathode protected steel) (Xie *et al.*, 2002, Weis *et al.* 1992). However, many of the dilution based arguments and assessments hold true for these materials as well. Other alternative materials may be considered nonleaching because they are made of, or coated with, nonreactive materials, but there is often a lack of data to evaluate these claims. It may be possible to use alternative materials in many of the same situations as pesticide-treated wood materials, but their prescription may not be necessary depending upon the level of impacts expected by the biologist.

Cost is often an argument brought forward in support of using pesticide-treated wood as a building material and it must be addressed here. Stratus (2006a) contains a cost comparison between pesticide-treated wood, concrete, steel and plastic pilings, which was generated by a marine construction firm under a subcontract to Stratus. The analysis concluded that concrete pilings are very cost competitive with pesticide-treated wood on an equivalent annual cost basis over the life of the project. Steel was more expensive when the analysis was conducted in 2005 and has continued to rise in price since that time. Although it is used in large projects, it may not be considered a minor change in many smaller scale projects. Plastic piling materials also had higher costs at the time of the analysis and some products may not be appropriate for some weight bearing uses. There are an expanding number of choices and capabilities in alternate materials which have improved weight bearing capacity including reinforced plastics, fusions of glass and wood and wood species which are not treated with pesticides.

Stratus (2006a) did find that concrete has a higher up-front cost (i.e. cost per pile) than pesticide-treated wood at a ratio of 2.5 to 1. However, larger scale projects that utilize concrete typically require fewer pilings. This could be attributed to the superior weight bearing properties of concrete. Some projects may be small enough that the difference in the number of pilings is inconsequential. EPA's 2008 assessment work for creosote and CCA wood preservatives includes two qualitative economic impact assessments (EPA 2008d, 2008e). However these documents do not include independent analysis of project costs using these pesticide-treated wood products compared to alternative materials. Instead, they only briefly mention one industry sponsored study (Smith 2003 in EPA 2008d, 2008e) which determined that using concrete or steel pilings was 1.96 times more expensive than using treated wood. This ratio is close to that presented by Stratus, but it can not be determined from EPA (2008d, 2008e) what factors the study considered. EPA (2008d) notes that CCA products are slightly less expensive than creosote and that creosote only accounts for 4% of the pilings market. Two case studies from the WWPI (WWPI 1998, undated) discuss two projects which also found the upfront costs of concrete piling projects to be between 2 and 2.5 times more expensive than treated wood project. These case studies do not present data examining the annual cost basis of the projects over their expected lifetimes.

The installation cost was also determined to be an important factor (Stratus 2006a). Costs may be competitive in an area with multiple pile driving companies, resulting in available equipment that can handle both pesticide-treated wood and concrete piling installations. On the other hand, areas without equipment readily available to handle the higher weight concrete pilings may see significant increases to the cost of a concrete piling project. Concrete was predicted to last longer than pesticide-treated wood (20 years compared to 15 years) by Stratus (2006a), leading to the lower cost over-time. However, these lifetime projections seem short for both products and a difference of five years may make the long term advantage less important to many smaller projects.

<u>Miscellaneous BMPS</u>
There are several other BMPs that can be beneficial in areas where the use of pesticide-treated wood products may affect a listed species or adversely impact EFH.

- Incorporate design features, which minimize abrasion of pesticide-treated wood pilings and decking. High density polyethylene wear strips can be installed on the pilings to prevent scraping by the floating docks, vessels, etc. Brooks (2004a) recommends strips that are one half-inch thick, installed down the length of the piling. As the pilings are abraded, new wood with higher leaching rates are exposed, which leads to continual unnecessary exposure to the environment. In addition to water repellent coatings (discussed earlier), decking can be protected through the use of wear guards.
- Use untreated wood for temporary structures or naturally rot resistant wood (e.g. some cedar species) for the project.
- Use top caps on creosote treated piles to minimize their exposure to the sun and subsequent losses of creosote. This should be required for all creosote treated pilings regardless of projected impact.
- Shading would also greatly reduce the amount of creosote discharged by a structure. Covering a dock will minimize the exposure of all wood products to precipitation and slow down any resultant leaching. If the project is proposed in an area with submerged aquatic vegetation (SAV), the biologist evaluating the project must take into consideration the potential impacts of shading the SAV that could result from using this BMP.
- Eliminate the use of pilings by using anchors for floating dock structures.

<u>Mitigation for Remaining Impacts</u>
Mitigation can be required, under the Magnuson-Stevens Act, for remaining impacts to EFH that can not be eliminated from a project. Mitigation may also be proposed by the project applicant as a means of reducing the uncertainty in their impact analysis, in order to facilitate the permitting process. There are a few pesticide-treated wood related mitigation options that can be considered to offset the effects of installing new pesticide-treated wood. The first is removal of old pesticide-treated wood. This can be done by removing an abandoned or unnecessary structure, or by removing pesticide-treated wood that has washed downstream as a result of flooding. NMFS (2003) contains pictures of depositional areas showing how large the old pesticide-treated wood problem can be in some locations. Another pesticide-treated wood related mitigation could involve

wrapping the already installed creosote-treated pilings in the vicinity of a project. This option is limited to creosote-treated wood. Copper-treated pilings are expected to have lost the majority of leachable copper if they have been in place for any significant period of time. Creosote-treated products, on the other hand, are expected to leach significant amounts of PAHs for years or decades, as seen in USACE (1997) and in the input parameters of the creosote leaching models. Benefits at a localized scale may be possible if a project proponent proposes to wrap pilings in the vicinity of the project, as mitigation for the unavoidable affects of the project.

Potential Exposure Scenarios

Now that the basics of pesticide-treated wood use and potential impacts have been presented, this section will present some examples of typical projects and environmental combinations that a NOAA Fisheries biologist may be asked to evaluate. Given the wide range of habitat conditions and specific life history variables that may be encountered across the Western United States, suggestions contained in this section must be coupled with site-specific information in order to make an informed decision.

Personal Use Boat Docks

A common proposed use of pesticide-treated wood is for the construction of smaller boat dock facilities. These facilities usually are constructed on waterbodies of sufficient size to provide for significant dilution potential, but it is likely that cumulative effects will need to be considered, as there are often numerous docks in these areas. Therefore, primary factors to be considered include background concentrations and stream or tidal currents. Research by Weis and Weis (1994) noted that contaminant levels in sediments associated with dock pilings, in moderately flushed areas, did not show accumulation of metals in contrast to higher surface area uses such as bulkheads. Therefore, if a personal use boat dock project can show that background levels of copper are not problematic and that densities of marine related infrastructure utilizing (or potentially utilizing) pesticide-treated wood are lower, then an individual risk assessment is not likely to be necessary. This scenario of approving smaller scale projects has already been put into place by the SLOPES III opinion (NMFS 2004b) in the lower Columbia River and the state of Oregon.

If a pesticide-treated wood bulkhead is proposed as part of the dock project, then the project may require an individual risk assessment, as recommended by industry (WWPI 2006a). In this event, there are numerous options available to the project proponent to reduce leaching. These options could include: coating the pesticide-treated wood product (just the bulkhead portion, or the whole thing), constructing the bulkhead with rock or another alternate material, or protecting the natural shoreline with vegetation or large woody debris rather than constructing the bulkhead. This could potentially eliminate the need for a site specific assessment, or in depth data gathering related to the use of pesticide-treated wood. The other potential impacts of water facilities mentioned earlier (e.g. shading of aquatic vegetation, dredging, introduction of habitats used by predatory species in the shoreline area, etc) will still need to be considered.

Marinas

Like the personal use boat dock, the construction of a marina will presumably occur on a larger waterbody. However, marinas are typically protected from currents and tidal exchange and this may result in significantly reduced dilution potential. New facilities, or facilities undergoing major renovations, are more likely to trigger some of the industry recommendations for an individual risk assessment. Examples of these projects include: installation of more than 100 pilings, construction at potentially problematic densities, or proposing a large amount of pesticide-treated wood surface area. The consulting biologist should make the project proponent aware of industry guidelines as a tool for procuring a proper effects analysis if necessary. Building or renovating marinas to "clean marina" standards is also recommended (e.g. restricting hull scraping in water, stormwater BMPs for shoreline facilities such as repair yards and parking lots, installation and mandatory use of sewage pump out stations, etc.).

Vehicle Bridges

Studies related to bridges and other overwater structures were presented earlier. The main concerns for bridges are the size and flushing rates of the waterbodies beneath the bridges, as well as the size of the bridge. The data presented earlier indicates that bridges of pesticide-treated wood are typically small enough that the footings of the bridge are not located in the water and may not even be in the 100 year floodplain. Therefore, pesticide-treated wood will only be used above the water. For a waterbody with sufficient dilution, the studies indicate that this should not be problematic and the potential impacts to salmonids are not likely to be meaningfully measured, detected or evaluated. However, extra caution may be warranted if bridge construction is proposed over a low flow stream, where significant dilution is not a given, or over a pool in a stream that supports rearing salmonids and is often disconnected during dry portions of the year. BMPs to minimize leaching (such as coatings, shading and maintenance requirements) and that minimize potential exposure, may be necessary to prevent impacting salmonids and degrading habitat.

Foot Bridges/Boardwalks

The potential impacts here are similar to the larger bridges, although some of these structures (such as long boardwalks) are more likely to use pesticide-treated wood footings that may be in the water. The main concern is for streams with periods of very limited flow, or loss of flow connectivity between pools, which lead to unacceptable exposure levels. For smaller facilities in this situation, the biologist will need to determine if coating the overwater lumber would sufficiently decrease any remaining uncertainty, or if the environment is so sensitive that an alternative decking material, such as a coated catwalk, naturally rot-resistant species of wood or plastic lumber, should be considered.

Larger facilities, such as the boardwalk examined in the Wildwood study (FPL 2000), are likely to require the generation of additional information as part of their planning process. Although the study was conducted in a sensitive environment and looked at an important potential indirect effect to salmonids (reduced prey availability), the study did not evaluate potential direct effects to salmonid olfaction. Providing technical assistance to the project proponent in earlier stages of project planning may eliminate the need for an extensive individual risk assessment in such a project.

Railroads

The vast majority of creosote treated wood (approximately 70% of all creosote use) is used in railroad construction and maintenance (EPA 2003). It is common for railroads to follow the contours of large streams and rivers in the western United States. This leads to the potential exposure of salmonid habitats from the creosote treated wood leachate. However, railroads constructed within a floodplain are typically built to minimize their chance of interacting with the water (i.e. flooding). The most likely interaction between the waterbody and railroad occurs when significant dilution is available. The most likely sources of PAHs from railroads come from normal operations (e.g. exhaust from the engines, oils and greases, herbicides used along the tracks) and from coal dust. Coal is a common cargo on many lines serving mines or coal-fired power plants.

Brooks (2004a) conducted a peer reviewed study focused on the migration of creosote from railway ties. The study showed initial leaching of creosote from new railway ties into the ballast (the rock and dirt platform upon which the tracks are laid) to approximately 60 cm in depth. This mostly occurred during the first summer after installation. There was little movement horizontally toward a constructed wetland. Following the first summer, PAH concentrations in the ballast declined (due to degradation) to background levels (at depths more than 10 cm).

PAH concentrations within the constructed wetlands' sediments were similar across treatments (new, weathered and untreated ties), indicating that atmospheric deposition of PAHs was having a large effect on the sampling results. Brooks (2004b) indicates that a small amount of PAH may have migrated into one wetland cell during the second summer of the study, as indicated by an increase in PAH of approximately 0.3 mg/kg in the sediment. In comparison, the ER-L for total PAHs is 4.0 mg/kg, making an effect from this exposure unlikely. Surface water in the wetland cells was sampled at various intervals (10 days, 2, 3, 12, and 15 months) and all samples had non-detectable concentrations until one positive sample at the 15 month stage. This sample from a new tie mesocosm contained 0.19 µg/L of benzo(a)anthracene and 0.66 µg/L of phenanthrene while a sample from an untreated tie mesocosm contained 0.16 µg/L of benzo(a)anthracene that day. These levels were not expected to be problematic as determined by the $\sum$TPAH methodology presented in NMFS (1998).

Brooks (2004b) does make some railroad related recommendations in order to reduce unnecessary exposure and risk to aquatic environments from railroad infrastructure. Brooks observed that numerous derelict railway crossties were discarded in the right-of-way and recommended that ties taken out of service should be disposed of properly. Due to the initial leaching observed in the study, Brooks recommended that the storage of newly treated railway ties in sensitive environments should be avoided, and the storage should occur on the ballast or on railway cars. Additionally, Brooks recommended that railway ties should be produced using management practices which minimize deep checking in the wood and excess surface deposits.

Highway Related Uses and Utility Poles

There are uses of pesticide-treated wood products in highways and roads (such as for sign posts), in addition to bridges. Utility poles are another major use of creosote-treated products, making up some 15-20% of all creosote usage (EPA 2003). These pesticide-treated wood products may be placed within the riparian area. However, like the railroads, waterways are not likely to significantly interact with these categories of pesticide-treated wood, except during flood situations. The pesticide-treated wood products may leach some contaminants when exposed to rain, or through exposure to the sun for creosote products. However, unless these products are placed over-water, or leach onto a roadway when it is raining, the leachates will likely become bound to the sediments. Contributions of copper or PAHs from these sources may not be detectable compared to the contributions coming from the road itself (e.g. oils, grease and exhaust from vehicles, copper from brake pads, spills of hazardous materials, etc.).

Conclusion

It is widely acknowledged that creosote and copper-treated wood products leach contaminants into the aquatic environment. The rate of leaching for both categories of products drops off rapidly following installation. For copper-treated products, the leaching, and resultant water column concentrations, drops off to very low levels within a few weeks to a few months, depending upon the exact product and environmental conditions. Effect level thresholds may only be exceeded for short periods of time. Copper can accumulate in sediments, where its bioavailability depends upon site-specific conditions. While the initial rate of leaching from creosote-treated pilings drops off rapidly, leaching stays elevated at easily detectable levels for many years and perhaps decades. The exact length of time this occurs is difficult to determine because the product loading and formulation of creosote utilized in the past was variable. PAHs from creosote also accumulate in sediments, where they are subject to degradation. However, the high molecular weight fraction can take a long time to degrade and contains known mutagens, teratogens, and carcinogens, which are most often associated with impacts to benthic species (e.g. tumors).

The main contaminants of concern from these products are copper and PAHs. For copper, the most sensitive sublethal endpoint may be salmonid olfaction. This may be impacted by an increase in dissolved copper concentrations as low as 0.79 µg/L above background levels. Copper may also affect salmon and EFH by reducing the quality and productivity of the benthic habitat. However, the models and studies related to copper treated wood products show the impacts are localized and only prevalent with large surface area uses (such as bulkheads) in many cases. For creosote, the main impact of concern is accumulation in the sediments. This could lead, or contribute to, elevated levels that affect the productivity of EFH, especially for groundfish species. Sediment accumulation impacts are also expected to occur on a localized scale. The impacts may occur for a longer period of time and at lower pesticide-treated wood densities than the potential impacts of copper-treated products. Water column concentrations of PAHs from creosote-treated wood are not expected to reach problematic levels, except in situations of very high density installations, or in freshwater applications. Impacts have been observed only at the most contaminated PAH sites (Eisler 2000). However, creosote-treated pilings also have the potential to impact sensitive species, which lay their eggs on the pilings (e.g. Pacific herring (Vines *et al.* 2000). Impacts could also occur in the immediate vicinity of pilings, where the PAHs accumulate in the sediments (e.g. pink salmon in Heintz *et al.* 1999). High density and/or high volume pesticide-treated wood use projects are not likely to be proposed often, due to changing patterns in pesticide-treated wood use (Brooks 2003). These types of projects are highly likely to trigger full risk assessments, and formal consultations, as recommended by industry (WWPI 2006a).

Numerous leaching studies have been conducted over the years to determine leaching rates from a variety of pesticide-treated wood formulations and for a variety of environmental conditions. The results of many of these studies were used to develop leaching models. The review of the leaching models by Stratus (2006a) found that they did an acceptable job of capturing the leaching trends and did not seem to consistently generate over or under predictions. These leaching models have been adapted into environmental prediction models, which incorporate a variety of factors (such as flow rates) to predict resultant water column concentrations and areas of sediment contamination. These models can not be relied upon to produce dependable predictions without site-specific information. However, the models seem to be useful for risk assessments, when site-specific information is available. This is due to some conservative assumptions of the models (e.g. all piles are installed simultaneously, all contaminants are considered dissolved in the water column and remain bioavailable, no dilution through turbulence of lateral dispersion, etc.(NMFS 1998))(Stratus 2006a).

The most important factor in the models' predictions is the current velocity. If significant water exchange is available to dilute the leached contaminants, then they are not predicted to increase contamination to a problematic level. Background concentrations of the contaminants are also an important consideration along with pH and project specific information (such as the number of pilings and density when installed). Especially sensitive sites are defined by species utilization (e.g. critical rearing area, entrance to a tributary), as well as environmental conditions (e.g. sediment characteristics). These sites may require special management consideration, regardless of the construction material chosen for the project.

The Poston box model, adapted by NMFS (1998), has been in use for a decade. It shows that installation of 100 or less copper-treated piles, at current velocities of 10 cm/sec or more, are not likely to result in problematic water column concentrations. However, impacts are possible with 100 piles at lower current velocities. Increases in sediment concentrations of 50% or more were not anticipated with a project of this size. 100 copper-treated pilings is also the threshold recommended by industry (WWPI 2006a) to trigger a site-specific risk assessment.

Installation of creosote-treated pilings is uncommon in the NWR and SWR of NOAA Fisheries, but is more common in the Alaska Region. Background PAH concentrations in the water column are not generally found at problematic levels with the exception of the most contaminated areas. However, NMFS (1998) predicts problematic concentrations from the installation of 100 or more creosote pilings, at most modeled installation densities, with the exception of locations with current velocities of 10 cm/sec or greater. NMFS (1998) did not present a box model for sediment contamination by PAHs because the work conducted by the USACE (1997) did not model a long-enough time span. Despite this, the effects on sediments must be considered and may affect EFH, especially for Pacific groundfish. Observed contamination at the Sooke Basin study site decreased over-time and was mostly confined to close proximity of the structures, but did result in potential effect levels in the sediments. Background concentrations need to be considered and installation of creosote in areas with elevated backgrounds should be discouraged.

Overwater uses of pesticide-treated wood products can also contribute contaminants into the aquatic environment and may be used at a high enough volume to warrant examination in a project. Copper-treated products are expected to leach most of their contamination during the first year as a result of rainfall. Creosote-treated wood will also leach in this manner, but may be expected to discharge PAHs for a longer period of time. Exposure to direct sunlight may result in the discharge of contaminants, even during the dry season, from creosote-treated products. Both categories of products may contribute additional contaminants through wear of their exposed surfaces.

BMPs are recommended as a way to reduce risk to ESA listed species and EFH. An underlying assumption in most of the leaching studies and models is that pesticide-treated wood products installed in aquatic environments will be manufactured in accordance with industry production BMPs. BMP produced wood should be used in all situations involving potential exposure to ESA listed species or EFH and is already recommended or required by several other state or Federal agencies. Conducting site-specific risk assessments, for larger projects proposing to use pesticide-treated wood, is also recommended. Industry and NMFS guidelines for copper-treated products both focus around the 100 piling size. NMFS (1998) indicates this size would be acceptable at current velocities of 10 cm/sec or greater, but can not be assumed to be protective at lower current velocities without utilizing the multiple regression equations for initial screening. Site-specific considerations on the lower Columbia River have lead to a lower threshold there (50 pilings) and many projects which typically use pesticide-treated wood (e.g. personal use boat docks) are routinely approved through this process. Potentially lower thresholds are recommended by industry in their guidance (WWPI 2006a) for some products and situations. For example, a project proposing to use 25 or more ACZA pilings parallel to the currents is recommended for a risk assessment by WWPI (2006a). The WWPI has spreadsheet based models available for use by the public (through their website) and the models were also reviewed by Stratus and found to be acceptable with the same caveats as the models used in the NMFS 1998 document.

Other BMPs, which should be routinely required, include: construction and demolition BMPs, minimization of abrasion on pilings (through the use of wear strips), use of untreated wood for temporary structures, top caps for all creosote treated pilings and proper disposal that eliminates risk to aquatic environments (while following local disposal requirements). Restricting the timing of the installation may be advisable in some locations and a simple way to eliminate potential impacts to ESA listed species. The use of coatings or wraps for pesticide-treated wood products is an acceptable method for minimizing impacts and uncertainty associated with larger-scale projects, or in especially sensitive environments. This is a necessary practice for using pesticide-treated wood products in the Southeastern U.S., because of the presence of marine borers (gribbles – *Limnoria*), which are not wholly deterred by many wood treatments. Coatings and wrappings are often used along the West Coast as well, and can even be used on the overwater portions of projects that may cause problematic levels of contamination in the aquatic environment. Exposed wood is already recommended by industry and agencies to receive an application of water repellent sealer and to be protected from the weather. The use of alternate materials can eliminate the potential impacts of pesticide-treated wood products, but can contribute some contaminants of their own. Recommending or requiring alternative materials is warranted in those situations where adverse effects can be meaningfully measured, detected or evaluated. Other BMPs may be sufficient to minimize the effects of the project making this requirement unnecessary. Mitigation options for any remaining impacts from the project should be analyzed and may be presented as EFH or ESA conservation recommendations.

Overall, the use of pesticide-treated wood products in aquatic environments with the examined formulations (ACZA, CCA and creosote) could be acceptable in many proposed projects. However, the products can not be considered categorically safe, and therefore, require project and site-specific assessment. Many projects, that still propose to use pesticide-treated wood, may pass a screening level examination and require relatively little assessment for the pesticide-treated wood related impacts. These determinations require a level of local knowledge that may be applied on a case-by-case basis, or through regional or watershed based procedures. The variability between locations makes it difficult to provide guidance on the scale of the entire west coast of the U.S. and Alaska.

The selection of copper-treated or creosote-treated products seems to be a personal preference in areas where creosote is still permitted for use. Copper-treated products are a better choice, in many instances, for minimizing impacts to NOAA Trust Resources. This is due to the rapidly diminishing level of impact and the higher sediment contamination levels needed before impacts begin to be observed. However, the limited available information shows that, in some specific instances, the proper use of creosote-treated products may not impact ESA listed salmonids in a manner that can be meaningfully measured, detected or evaluated. However, the choice of a creosote-treated product over a copper-treated product may be considered to have a greater adverse affect to the quantity or quality of EFH, especially if the product is proposed for an area which supports vulnerable species or valuable benthic habitat.

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Volume II
Section IV
WWPI Documents

Documents in order

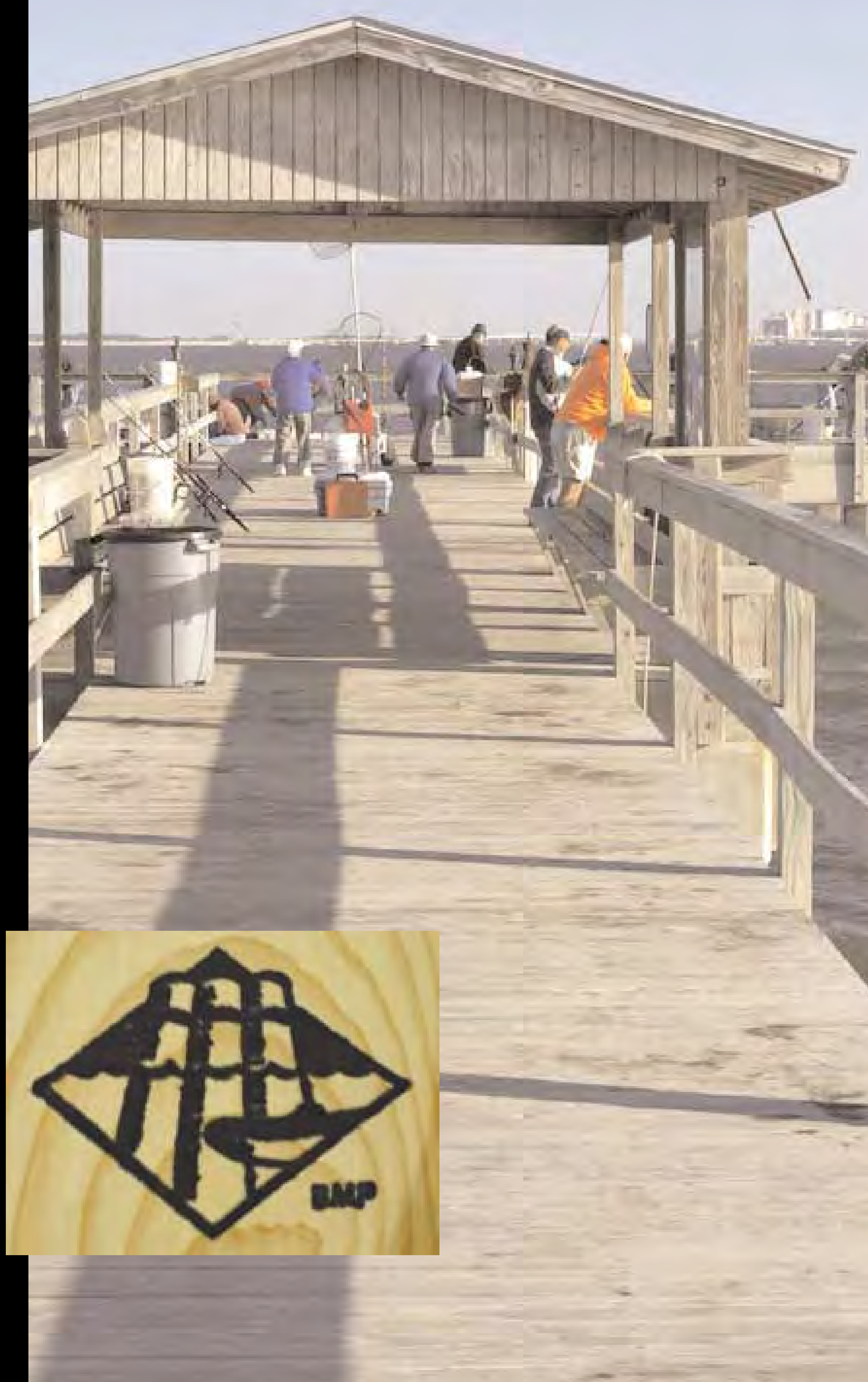
1. Best Management Practices. Descriptive brochure. Includes general information and information not specific to creosote.
2. Best Management Practices. More technical than 1.) above. In specification format.
3. Treated Wood in Aquatic Environments. Semi-technical document. Has section on selection of preservative with retention recommendations. Also has WWPI risk matrix.

Volume II
Section IV
WWPI Documents

1. **Best Management Practices.** Descriptive brochure. Includes general information and information not specific to creosote.

Best Management Practices

For the use of treated wood in aquatic and other sensitive environments



Wood Preservation Canada
Préservation du bois Canada

TIMBERPILINGCOUNCIL
FOUNDATION & MARINE PILING

REVISED August 1, 2006

Developed for the United States and Canada by:

Western Wood Preservers Institute • Wood Preservation Canada • Southern Pressure Treaters' Association • Timber Piling Council

TABLE OF CONTENTS

Mussels (Mytilus trossulus) and bryozoans (Phylum bryozoa)

PLEASE NOTE:

The marine organisms shown in this document represent a small subset of the 67 different invertebrate species that were identified in six inch square samples collected from treated wood piling.

Chapter One: The Importance of BMPs

Introduction

Protection of the quality of water and the diversity of life forms found in lakes, streams, estuaries, bays, wetlands and other sensitive environments of North America is a goal and responsibility shared by every inhabitant of the continent. An endless list of human activities can impact these environments: storm waters that run off our streets, exhaust from our boats and cars, municipal and industry discharges, and construction of our homes, docks and piers, to name but a few. Maintaining the quality of our treasured resources requires that everyone do their part.

Pressure treated wood is a building material widely used to construct piers, docks, buildings, bridges, walks and decks used in or over aquatic and sensitive environments. The pressure treated wood products industry is committed to assuring its products are manufactured and installed in a responsible manner that minimizes any potential for adverse impacts to these important environments. To achieve this objective the Western Wood Preservers Institute (WWPI), Wood Preservation Canada (WPC), the Southern Pressure Treaters Association (SPTA) and the Timber Piling Council (TPC), hereafter referred to as the "Supporting Organizations," have developed and encourage the use of these BEST MANAGEMENT PRACTICES (BMPs).

What are the Best Management Practices?

The BMPs are recommended guidelines for the production and installation of treated w ood products destined for use in aquatic and other sensiti ve environments. The guidelines were developed by the Supporting Organizations through a consensus process, based on the core philosophy of chemical minimization. Both environmental and economic concerns support the goal of placing enough preservative into a product to provide the needed level of protection while also minimizing use of the preservative above the required minimum to reduce the amount potentially available for movement into the environment.

Specification Considerations

There are a variety of preservative systems and treated wood products approved for use in or above aquatic and sensitive environments. **The first step** in specifying a particular treatment is to assure the preservative is approved for the intended application through the U.S. Environmental Protection Agency (U.S. EPA) and Canadian Pest Management Regulatory Agency (Canada PMRA) registration and/or review process. These government agencies establish the legal parameters for use of wood preservatives. To meet any BMP guideline a treatment must comply with these restrictions. The common goal of using the BMPs is to produce products having effective levels of protection with minimum environmental impact by minimizing the potential for migration or leaching of the preservative chemicals from the treated wood products.

The second step in specifying involves the application of the appropriate product standard from the Use Category System developed and maintained by the American Wood-Preservers' Association [AWPA] (U.S.) or Canadian Standards Association [CSA] (Canada); or the customer-specific treatment standards. These product specifications establish the minimum amount of chemical (retention) and depth of injection (penetration) that is needed to assure effecti ve

performance against decay or other wood destroying organisms. The BMPs along with the additional processing requirements are separate from and in addition to the product standards. There is a shared responsibility between the specifier and treater to assure the level of chemical application selected will meet the goal of minimizing the migration or leaching of the treating chemicals into the environment.

BMP Product Production Systems

The material preparation, treatment and post treatment procedures and technologies for achieving the BMP objectives vary among preservatives and individual treating plants. A treating plant may choose to produce some or all products in compliance with production BMPs or a purchaser may specify compliance with BMPs in a particular purchase agreement. In either case compliance with production BMPs for products leaving the plant that are designated for use in aquatic or sensitive environments is the responsibility of the treating firm.

It is not recommended for a specifier or regulator to designate a specific BMP treatment process for a product where more than one method of meeting a performance goal is available. It is the quality of the final product that matters, not how that end result is achieved.

BMPs are in a state of evolution. While this document incorporates the best available production technologies and knowledge, efforts are continuing to better understand the performance of wood preservatives in the environment, develop better treatment procedures and improve the BMP quality assurance processes. Research continues in several areas including understanding the environmental impacts of the products, improved treating systems, opportunities to reduce the amount of chemical needed to achieve performance and development of new preservatives. As knowledge and technology advance, the BMPs will be updated through amendment or at the time of the regular five-year scheduled reviews. Amendments will be posted at www.WWPInstitute.org.

BMP Applicability

The BMPs have been developed by the “Supporting Organizations” and are applicable to product processes and species produced in the United States and Canada.

Added time, additional cost and sourcing constraints may result from meeting the production and quality assurance BMP guidelines; and a user or permit regulator should specifically require compliance with BMPs where it is determined there is a sufficient need or justification. The focus of these BMPs is on uses in aquatic and sensitive environments; their use is not germane for any treated wood application in a non-aquatic/non-sensitive area.

NOTE: *This document is designed to serve market needs in both the U.S. and Canada even though there are some slight differences in product standards established by the American Wood-Preservers’ Association for the U.S. market and the Canadian Standards Association for Canada.*

BMPs Quality Assurance

Quality oversight and inspection to assure compliance with production standards is important in any manufacturing process. For BMPs this is accomplished at two levels: Internal Quality Control at the production level; and inspection with certification by an independent third party agency. Inspection standard and protocols have been established in **Quality Assurance Inspection Procedures for Best Management Practices (BMPs) for the Use of Treated Wood in Aquatic and Other Sensitive Environments**, included in Appendix A.

A specification for BMPs is not complete or accurate unless it includes a requirement for independent third party inspection by an accredited agency, and certification documented by either the BMP Mark or a letter issued by the agency certifying inspection and compliance.

Virtually all softwood lumber, including treated wood, traded in North America is inspected by agencies accredited by the American Lumber Standard Committee, Inc. (ALSC) in compliance with regulations of the U.S. Department of Commerce. While ALSC does not accredit BMP inspection since the requirements are outside AWPA and CSA standards, those agencies accredited to inspect treated wood are most qualified to apply the BMP inspection guidelines and determine compliance. ALSC accredited agencies are the only firms accepted for the BMP Mark Program. A list of ALSC accredited treated wood agencies may be found at www.alsc.org/contacts_treatedlist_mod.htm.

BMP User Responsibilities

Achieving the shared goal of the BMPs cannot be accomplished unless the user of the product follows the appropriate guidelines regarding transportation, handling, inspection, storage, installation, demolition, maintenance and disposal of the product. These recommended guidelines are contained in **Chapter 4** of this document.

Chapter Two: Guide to Selection, Specification and Quality Assurance

Preservative Selection

A key step in designing a project in an aquatic or sensitive environment is the specification of the treated wood to be used. There are a variety of available treated wood products approved for use in and/or above such environments depending upon the intended use, species, required performance and environmental conditions. The specifier should carefully consider the options in terms of required retention levels (AWPA or CSA Standard) as well as potential environmental impacts. The industry treats only with preservative chemicals registered for the specific uses by the federal, provincial or state agencies. The most common products, addressed by this document, are those treated with ACQ (Alkaline Copper Quaternary), ACZA (Ammoniacal Copper Zinc Arsenate), CA-B (Copper Azole), CCA (Chromated Copper Arsenate), Creosote, Copper Naphthenate, and Penta (Pentachlorophenol).

Performance

The purpose of treating wood products is to provide protection from wood destroying organisms or decay, thus extending the useful life and structural performance of the material. The appropriate applications of each product, the minimum penetration, and the minimum retention (amount of preservative in the **assay zone** – the zone in which wood is subject to testing) are established by the AWPA in its Use Category System and by the CSA 080 Standards, which delineate the various limitations and results of product treatment.

Environmental and Aesthetic Considerations

In designing a project, one needs to consider the characteristics of various treated wood products in relation to the purpose of the project and the environmental characteristics of the site. Products used in a heavy industrial application will likely be different from those used in a public boardwalk. Similarly, the use of a moderate amount of treated wood in a fast flowing river is likely to pose a minimal risk; whereas, the use of large amounts of treated wood in stagnant water may pose greater risks.

The best available science shows that pressure treated wood poses minimal risk to aquatic environments when: used in accordance with the AWPA and CSA specifications; used following the guidance provided by the appropriate required documents, such as the Consumer Information Sheets or Consumer Safety Information Sheets or the treated wood Material Safety Data Sheets (MSDS); and produced using the BMPs.

Help is Available

Risk assessment documents and models have been developed for the use of most preservative systems used in aquatic applications. Projects designed to use large volumes of treated wood immersed in and/or above poorly circulated bodies of water should be evaluated on an individual basis using risk assessment procedures. A complete set of guide materials to help evaluate environmental risks, select preservative systems and specify products are available on line at www.WWPInstitute.org.

Specifying the Best Management Practices

There are three steps to assuring that products to be used in aquatic and other sensitive environments are produced in compliance with the BMPs.

1. **Specify the appropriate material in terms of preservative and performance as defined in the American Wood-Preservers' Association (U.S.) or Canadian Standards Association (Canada).**

   Information on properly selecting and specifying treated wood may be obtained from AWPA, WWPI, WPC, SPTA or TPC. See the end of this chapter for website links.

2. **Specify that the material must be produced and utilized in compliance with the BMPs.**

   Suggested language for inclusion in project specifications: Following the product and treatment specifications per #1 above insert:

   All treated wood products in this project shall be produced in compliance with the "Best Management Practices for the Use of Treated Wood in Aquatic and Other Sensitive Environments" (BMPs) published by the "Supporting Organizations," August 1, 2006 or the most current version including published amendments.

3. **Require third party independent inspection agency assurance that the products are produced in conformance with the BMPs.**

   Language suggested for inclusion to project specifications. Following the specification in #2 above, insert:

   All treated wood in this project shall be certified by an independent third party inspection agency to have been produced in compliance with the BMPs.

   Compliance will be documented by either Item A or B below:

   A. Producers Participating in BMP Mark Program
   The presence of the BMP Mark legibly stamped, branded, marked, end tagged or an equivalent designation on each piece of material or lot arriving on site.

   Or

   In lieu of placing the BMP Mark on each piece of material or lot, a certificate of compliance issued and signed by an accredited, independent, treated wood inspection agency (see discussion of BMP Mark Program – next page) certifying that the material and/or its production was inspected in compliance with the "Quality Assurance Inspection Procedures for Best Management Practices for the Use of Treated Wood in Aquatic and Other Sensitive Environments" published by the "Supporting Organizations," August 1, 2006 or the most current version including published amendments. The BMP Mark shall be shown on the certificate of compliance.

   B. Producers Not Participating in BMP Mark Program

   A certificate of compliance issued and signed by an inspection agency certifying that the material and/or its production was inspected in compliance with the "Quality Assurance Inspection Procedures for Best Management Practices for the Use of Treated Wood in Aquatic and Other Sensitive Environments" published by the "Supporting Organizations", August 1, 2006 or the most current version including published amendments. An independent wood inspection agency of the producers choice and acceptable to the purchaser can be used to provide the inspection service.

What is the BMP Mark Program?

WWPI owns and has sole rights to authorizing the use of the BMP Logo. The application or display of the logo on material is authorized to producers with which WWPI has a current contract allowing its use. As a condition of the agreement, treating companies must demonstrate in writing that they have a contractual relationship with an American Lumber Standards Committee (ALSC)[1] accredited treated wood inspection agency with which WWPI has a contractual agreement authorizing their oversight services of the use of the BMP Mark under the BMP Quality Assurance Inspection Program. The presence of the logo is thus a tool to show the user that the materials were produced in compliance with the BMPs; however WWPI is not an inspection agency and conducts no oversight of the treating or inspection processes per se. Any unauthorized use of the 'Mark' is subject to civil and criminal actions. A list of producers currently authorized to use the BMP Mark and the approved agencies can be found on WWPI's website at www.WWPInstitute.org. WWPI should be notified immediately if the 'Mark' is used by any firm not on the list.

A producer wanting to treat to the BMPs, but choosing not to participate in the BMP Mark Program, is not permitted to use the 'Mark' but is required to provide a certificate of compliance issued and signed by an independent treated wood inspection agency of its choice and acceptable to the purchaser.

In addition to production guidelines, these BMPs also include guidelines that purchasers should use for installation of treated wood products. To specify full compliance with the BMPs, the specifier should provide for on-site inspection prior to installation and conformance with applicable Installation and Maintenance Guidelines found in Chapter 4.

Suggested language for inclusion in project specifications:

Project managers, contractors and sub-contractors on this project shall be familiar with and apply as appropriate the Installation and Maintenance Guidelines of treated wood as outlined in the "Best Management Practices for the Use of Treated Wood in Aquatic and Other Sensitive Environments" published by the "Supporting Organizations," August 1, 2006 or the most current version including published amendments.

Further information on uses and specifications for each preservative treatment system can be found at the following web links.

Western Wood Preservers Institutes website:
http://www.wwpinstitute.org

Wood Preservation Canada website:
http://www.woodpreservation.ca

Southern Pressure Treaters Association website:
http://www.spta.org

Timber Piling Council website:
http:// www.timberpilingcouncil.org

American Wood-Preservers' Association website:
http://www.awpa.com

[1]The American Lumber Standard Committee (ALSC) which oversees the inspection of treated lumber and plywood products does not endorse, oversee or provide any quality control services in regard to BMPs and has no responsibilities regarding the program. In the BMP quality assurance procedures ALSC accreditation is used only as a tool to identify agencies which would most likely be qualified and able to perform the BMP inspection and certification services.

Chapter Three: BMPs for the Production of Treated Wood

PART A: General BMPs for the Production of Treated Wood

General

The following BMP procedures are applicable to the production of treated wood using all preservative systems. Additional preservative-specific BMPs are listed in Part B of this chapter. Treaters may obtain additional information in AWPA standard M20-01 (Guidelines for Minimizing Oil-Type Wood Preservative Migration) or may develop specific technologies based upon their unique plant facilities that meet or exceed the BMP criteria.

Preservatives

The preservative chemicals used to treat wood in accordance with these BMPs shall be those listed in AWPA Use Category System (UCS) Standard U1 Section 4: Standardized Preservatives and shall comply with the requirements referenced therein or as appropriately specified by the Canadian Standards Association (CSA 080).

Preservative Treating Solution

Specific solution requirements for each preservative listed in Standard U1 Section 4 can be found in the specific 'P' Standard referenced. Compliance with the AWPA treating solution requirements is a BMP treating criteria.

Plant and Product Cleaning Standards

- Follow good housekeeping practices in the plant to minimize sawdust, wood shavings, dirt and debris or residue collecting on the wood surface prior to treatment.
- The treatment cylinder (retort) should be kept clean and free of debris.
- Clean treating solutions are necessary and shall be used to produce clean products. Several process techniques have been utilized to maintain treating solutions in an acceptable condition (see individual BMPs in Chapter 3, Part B). These include, but are not limited to: filtering, turnover of tank inventory, controlling tank temperatures, using cone or dome shaped tank bottoms, minimizing storage and treating tank levels, using high quality solvents and preservatives, and periodic draining and cleaning of work tanks when residues are present.

Anemones (Metridium senile) and a featherduster annelid (Schizobranchia insignis)

Processing

- Wood products should be sorted and treated by charges containing wood of similar sizes, classes, species, species groupings, moisture content, conditioning methods, treating characteristics and retention levels.
- Use appropriate seasoning and conditioning methods for the specified preservative treatment (i.e. air seasoning, kiln drying, steam conditioning, heating in oil, Boultonizing).
- Follow AWPA Standard T1 procedures and process limitations as appropriate for preservative and materials being treated.

- Treating should be conducted in such a manner as to seek to minimize the amount of chemical placed into the wood while assuring conformance with the AWPA retention and penetration requirements.

- Treat using a standard pressure process such as Bethel full cell, modified full cell, Lowry (modified empty cell) or Rueping empty cell as appropriate for preservative type and final application of treated product.

- Final vacuum time is recorded only after attaining a minimum 22 inches Hg (75 KPa) sea level equivalent and maintaining that minimum for the duration of the vacuum cycle.

- Apply appropriate post-treatment conditioning techniques to minimize preservative loss after treatment. These processes are generally preservative specific with specific systems based upon plant equipment characteristics and capabilities at the treating facility. The following techniques or methods are shown as examples and are usually more applicable when treating with oil-type preservatives:

    – Transition between various phases of the treating process (e.g. pressure to final vacuum or final vacuum to atmospheric pressure) should be at a rate which allows the wood and preservative to reasonably adjust to such changes. Slow transitions generally result in a product with less surface exudations. The rate of transition varies with the size of the material being treated.

    – At the conclusion of the pressure period, and prior to removing preservative from the cylinder, the sealed cylinder should be allowed to remain sealed while the pressure in the cylinder equalizes with the treated wood. When the pressure has stabilized, a very slow release of pressure should be facilitated.

- Document the BMP treating techniques used with a permanent treating record document and maintain all records and procedures in accordance with the Quality Assurance Inspection Procedures for BMPs.

Inspection

The following inspection guidelines are key factors in producing and providing a quality treatment and a clean BMP product.

- **Inspection** To the degree practical material should be inspected to assure it is reasonably clean and free of dirt and sawdust prior to treatment.

- **Monitoring of Treating Solutions** The plant operator shall inspect treating solutions and plant process filters to assure the treating solution is free of debris and meets the requirement for the specific preservative.

- **Post Treatment Visual Inspection** A visual inspection shall be performed to verify the treated product meets the criteria specified for BMP processed material and that no excessive residues or surface deposits are present. If the criteria are not met, the product shall be rejected or reprocessed using appropriate post treatment conditioning techniques to meet the BMP surface appearance criteria.

- **Re-inspection Option** Since the occurrence of natural variability of wood sampled in a charge or production lot is recognized, re-inspection is permitted when there is a dispute over BMP treatment conformance. This should be conducted prior to a decision for re-treatment.

- **Pre-shipment Inspection and BMP Certification** A final visual inspection shall be conducted prior to the material leaving the treating facility to ensure the surface and treated product have no excessive residue or preservative deposits present, have not developed any excessive bleeding and to verify the presence of the BMP trademark on the material or treating certification. Any problems detected shall be corrected prior to shipment.

Chapter Three: BMPs for the Production of Treated Wood

PART B: 1
BMPs for Specific Preservatives Used in the Production of Treated Wood

ACQ – Alkaline Copper Quaternary

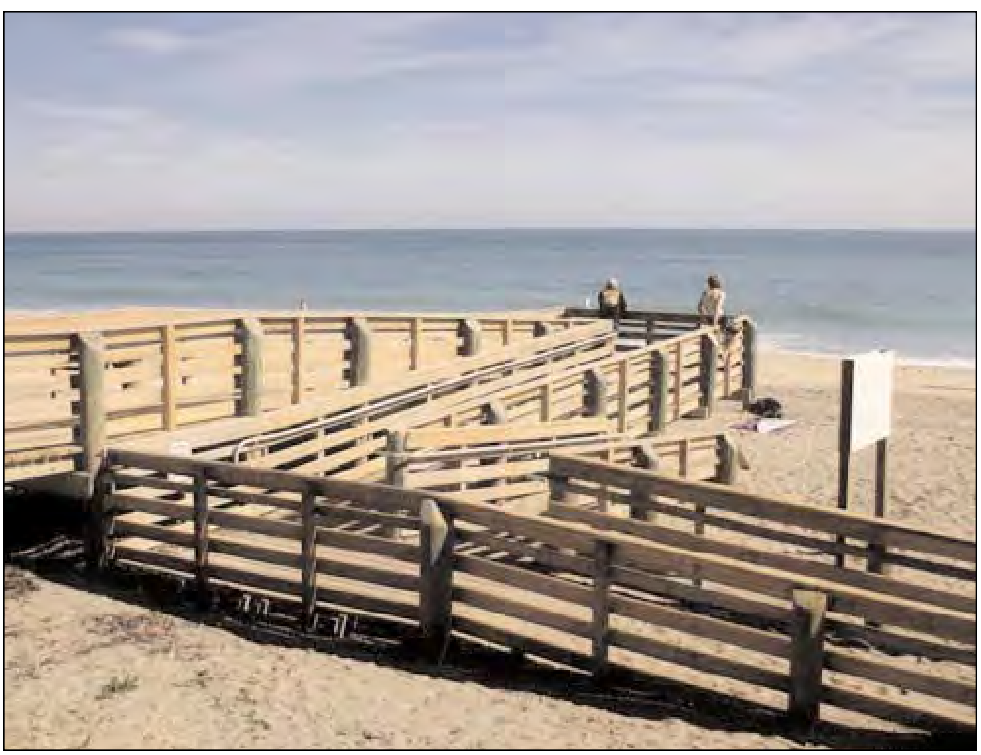
Best Management Practices

The BMPs for ACQ are intended to minimize preservative migration from ACQ treated wood. In order to achieve this, the following BMP, as well as the general guidelines referenced in **Chapter 3, Part A**, shall be followed:

Post-Treating Procedures

Select appropriate post-treatment procedures to minimize preservative loss by using one of the following technologies, which may be chosen as a function of time, temperature and humidity, and must be adjusted based on the characteristics of the material and the process.

- Air Seasoning
- Kiln Drying
- Steam Conditioning
- Other Artificial Heating



Technical Notes

ACQ is considered an excellent treatment for many western softwoods including Hem-Fir and Douglas-fir because of its ability to achieve standard penetration and retention of preservative in these difficult-to-treat species.

Specifiers and installers should follow the guidance in the ACQ treated wood Material Safety Data Sheets (MSDS) and hazard labels as required by OSHA. Consumer Information Sheets are not required for ACQ.

ACQ is not recommended for salt and brackish water immersion applications.

ACZA – Ammoniacal Copper Zinc Arsenate

Best Management Practices

The BMPs for ACZA are to allow an acceptable level of chemical stabilization to occur prior to the material leaving the treating facility. In order to enhance the process of stabilization and assure clean, residue-free surfaces, the following BMP procedures, as well as the general guidelines referenced in **Chapter 3, Part A** shall be followed:

Treating Techniques

- If the Lowry (modified empty cell) process can be used to obtain the specified product retention, it is the preferred process for BMP products.
- Following treatment using a full cell or modified empty cell process, a minimum final vacuum of 22 inches Hg (75 KPa) sea level equivalent shall be applied for a minimum of two hours. If possible, the retort should be heated between 180°F and 210°F (82°C – 99°C) during the vacuum process.

Post-Treating Procedures

All ACZA BMP material shall be processed using any one, or a combination of the following procedures. The selection will be at the discretion of the treater.

- **Minimum Plant-Holding Time** Products (with treating stickers in place for sawn and plywood products) shall be held in a storage area with free air circulation for a minimum of three weeks when average ambient temperatures equal or exceed 65°F (18°C). If the ambient temperature is less than 65°F (18°C), kiln drying or another source of artificial heat shall be used to achieve the minimum temperature requirement.*
- **Post-Treatment Kiln Drying** Products shall be kiln dried to a maximum moisture content of 30% (ASTM Method D 4442 oven dry basis) in the specified treated zone used for assay per AWPA product standard by employing a kiln cycle of 120°F – 160°F (50°C – 70°C) dry bulb temperature.
- **In-Retort Ammonia Removal Plus Plant-Holding Time** After the final vacuum period with heat, the retort door shall be opened and ambient air drawn through the treated wood charge from the door to the rear of the retort, vented to a scrubber at a rate of 250 cfm (7.08 m3/minute) minimum, for a period of three hours. The material is then handled in the same manner as under "minimum plant-holding time" described above except the minimum holding time is one week at the specified average temperatures.

NOTE: As an option, the material may also be placed into a separate closed conditioning vessel in order to draw the ambient air with appropriate vacuum and time to remove the ammonia vapors.

- **Aqua-Ammonia Steaming Cycle** Following the normal post-pressure period vacuum to draw excess preservative solution from the wood, the material is subjected to a post-treatment steam-conditioning process. The heating coils are covered with a minimum 2% solution of ammonia in water, which is heated for about 3 hours. A minimum temperature of 190°F – 200°F (88°C – 93°C) shall be maintained for at least 1.5 hours. The heating process is followed by a final vacuum of 2 hours, then an hour of drawing fresh ambient air through the retort to remove excess ammonia vapors and to cool the surface of the material. Material will then be processed with a minimum one-week plant-holding time at the average temperature requirements as stated above in that procedure.

- **ACZA Solution Bath/Rinse Procedure** Following an appropriate time to allow surface deposits to establish and equalize in ambient conditions, the treated material is loaded into the treating retort and covered with an ACZA treating solution (concentration of active chemical is not a significant factor) and circulated for a minimum one-hour bath. The rinse is followed by a one-hour vacuum after which the material can be removed to storage or prepared for shipment. This process contributes to the visual appearance and stability of the surface conditions in many ACZA treated products while providing more consistency of surface color and removal of residues. This process has not been verified as a means to achieve or improve chemical stabilization in treated wood.

*Average ambient temperature is determined over a 24-hour period using the high and low temperature recorded locally for that day.

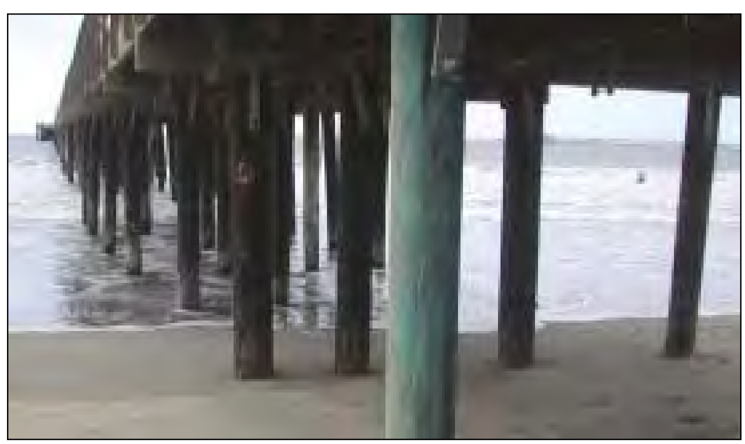
Technical Notes

ACZA

Specifiers and installers should follow the guidance in the ACZA treated wood Material Safety Data Sheets (MSDS) and hazard labels as required by OSHA and use the product in conformance with the Consumer Safety Information Sheet for Inorganic Arsenical Pressure Treated Wood and product labeling.

Because of its ability to treat the refractory Douglas-fir heartwood to meet the AWPA penetration and retention standards, ACZA is most prevalent on the West Coast for use in industrial product treatment of timbers, commercial decking for walkways and bridges or piling used in all sensitive or aquatic environment applications.

Chemical stabilization is the term applied to the chemical reaction in which the active ingredients of a waterborne treating solution become attached to the wood cells resulting in leach resistance and durability of the product. A key to the treating process for ACZA is the presence of ammonia, which facilitates carrying the active ingredients into the cell structure of the wood during treatment. Evaporation and removal of the ammonia following treatment is critical for the remaining ingredients to become stabilized, thereby minimizing the opportunity for leaching from the product in its end use. The BMP procedures are designed to accelerate the removal of ammonia and aid in the completion of the stabilization of the chemicals in the wood and provide lasting protection from the wood destroying organisms in service.



At the time of the revisions to this document there were no approved test methods or standards developed to accurately define the level of chemical stabilization in ACZA. This is being studied and when an acceptable test is established it will be incorporated into the ACZA BMP.

CA-B – Copper Azole

Best Management Practices

The BMPs for Copper Azole are designed to minimize preservative migration from Copper Azole treated wood. In order to achieve this, the following BMPs, as well as the general guidelines referenced in **Chapter 3, Part A** shall be followed:

Post-Treating Procedures

Apply appropriate post-treatment procedures to minimize preservative loss by using one of the following technologies, which may be chosen as a function of time, temperature and humidity, and must be adjusted based on the characteristics of the material and the process.

- Air Seasoning
- Kiln Drying
- Steam Conditioning
- Other Artificial Heating

Technical Notes

Specifiers and installers should follow the guidance in the copper azole treated wood Material Safety Data Sheets (MSDS) and hazard labels as required by OSHA. This information is available from your lumber supplier.

Copper Azole is considered an excellent treatment for many western softwoods including Hem-Fir, Western Hemlock and Ponderosa Pine. Achieving the required penetrations in Douglas-fir may require the addition of ammonia to the copper azole treating solutions, elevated treating temperatures and extended pressure periods.

Copper Azole treated wood is not recommended for salt and brackish water immersion applications.

CCA – Chromated Copper Arsenate

Best Management Practices

The BMPs for CCA are designed to minimize preservative migration from CCA treated wood. The following BMP, as well as the general guidelines referenced in **Chapter 3, Part A**, shall be utilized.

Treating Procedures

Full Cell (Bethel) Pressure Treatment is recommended for most western species. Modified Full Cell procedures should be limited to sapwood species, e.g., Southern Yellow Pine. Preservative solution quality should be closely monitored.

Post Treating Procedures

Apply appropriate post treatment procedures to maximize preservative fixation by using one of the following technologies, which may be chosen as a function of time, temperature and humidity, and must be adjusted based on the characteristics of the material and the process.

- Air Seasoning
- Kiln Drying
- Steam Conditioning
- Hot Water Bath

The best available technology for confirming fixation in CCA treated material is the Chromotropic Acid Test (AWPA Standard A3-11, Method for Determination of the Presence of Hexavalent Chromium in Treated Wood, [1995]). If testing shows that fixation has not been achieved according to the Chromotropic Acid Test, the material should not be shipped until fixation according to the Chromotropic Acid Test is confirmed.

Technical Notes

Specifiers and installers should follow the guidance in the CCA treated wood Material Safety Data Sheets (MSDS) and hazard labels as required by OSHA and use the product in conformance with the Consumer Safety Information Sheet for Inorganic Arsenical Pressure Treated Wood and product labeling.

CCA is considered an excellent treatment for most softwood species. Achieving the required penetrations in Douglas-fir may be extremely difficult. CCA is not recommended for Douglas-fir marine piling (except as the first treatment in "dual treatment") or for treatment of interior Douglas-fir.

Fixation In the CCA treating process, water is the carrier to move the metals or active ingredients into the wood where they become fixed to the wood. Once the chemical reaction called "fixation" occurs, the potential for migration of active ingredients is minimized.

While a complex reaction, fixation, which is a function of temperature and time, essentially involves the reduction of the hexavalent chromium to trivalent chromium with the formation of a complex mixture of insoluble chromates. In the process, insoluble arsenates of copper and chromium are also precipitated in the treated wood.

Chromic acid or Chromium VI is the component in the CCA process which is the basis for the Chromotropic Acid test. The procedure can detect Chromium VI at concentrations as low as 15 parts-per-million. Material passing the test (i.e., no detection of Chromium VI) for use in aquatic environments will be 99.5 to 99.95% fixed. The Chromotropic Acid test is a rigid qualitative procedure specifically for CCA treated wood.

Fixation Period The following post-treatment processing limits have been found to significantly enhance preservative fixation while also avoiding conditions which would cause losses in mechanical properties.

The time-temperature limitations specified below are appropriate for all species and can be found in the appropriate AWPA Specification.

a. Hot Water Bath (Liquid Fixation Processes), Maximum Temperature: 220°F (105°C) Duration: Until the outer 0-0.5 inches (0-12mm) portion in 4 out of 5 borings per charge pass the Chromotropic acid test. (AWPA Standard A3, Method 11) or not to exceed the maximum time-temperature combination listed below.

Temperature/Time:

- 220°F (105°C) 6 hr.
- 203°F (95°C) 9 hr.
- 185°F (85°C) 12 hr.
- 167°F (75°C) 18 hr.
- 149°F (65°C) 24 hr.

b. Air and/or Kiln Drying Processes, Maximum Dry-bulb Temperature: 160°F (70°C), Maximum wet-bulb Depression Temperature: 20°F (10°C) Until the outer 0-0.5 inches (0-12mm) portion in 4 out of 5 borings per charge pass the Chromotropic acid test. (AWPA Standard A3, Method 11).

c. Steaming Processes, Maximum Temperature: 220°F (105°C) Duration: Until the outer 0-0.5 inches (0-12mm) portion in 4 out of 5 borings per charge pass the Chromotropic acid test. (AWPA Standard A3, Method 11) or not to exceed the maximum time-temperature combination listed below.

Temperature/Time:

- 220°F (105°C) 6 hr.
- 203°F (95°C) 9 hr.
- 185°F (85°C) 12 hr.
- 167°F (75°C) 18 hr.
- 149°F (65°C) 24 hr.

Copper Naphthenate

Best Management Practices

The BMPs for Copper Naphthenate are designed to assure a clean product and minimize the potential for chemicals to enter the environment. In order to minimize the amount of Copper Naphthenate material available to migrate into the environment, the following guidelines, as well as the general guidelines referenced in **Chapter 3, Part A**, shall be used when treating material for use in aquatic, above water, or other sensitive applications:

Treating Techniques

- The empty-cell process should always be used for full-length pressure treatment with oil-borne preservatives if it will provide the desired retention. Either the Rueping process (empty-cell with initial air) or the Lowry process (empty-cell without initial air) can be used.
- Full length and butt thermal treatment of naturally durable species such as Western Red Cedar for poles can also be used to minimize the potential for chemicals to enter the environment.
- Following treatment using an empty-cell process a minimum final vacuum of 22 inches Hg (-75 KPa) sea level equivalent shall be applied for a minimum of two hours. If possible, the retort should be heated between 180°F and 210°F (82°C – 99°C) during the vacuum process.

Treating Procedures

- **Solution Filtration** The Copper Naphthenate solution in use shall be filtered regularly or otherwise kept clean to remove solids, which may otherwise be deposited on the wood during treating.
- Any accumulation of moisture in the preservative work tank should be drained off prior to treatment.

Post-Treating Procedures – Oil Carrier

For Copper Naphthenate treated products with an oil carrier to be used in sensitive environments or where bleeding of preservative is objectionable, use one of the following BMPs:

- **Expansion Bath** This process increases the temperature of the preservative solution surrounding the wood for the purpose of recovering excess preservative and improves surface cleanliness of the product. Follow the general procedures described in AWPA UCS Standard T1-05, section 2.7. Use a minimum expansion bath of one hour. The maximum temperature

of the expansion bath shall be 220°F or 230°F (104°C to 110°C) depending on the specific commodity standard limitations. The expansion bath shall be followed by a vacuum period using a minimum of 22″ of Hg (-75 kPa) for a minimum of two hours.

- **Final Steaming** Following the pressure period and once the Copper Naphthenate has been pumped back to the storage tank, a vacuum shall be applied for a one-hour minimum at not less than 22″ of Hg (-75 kPa) of vacuum to recover excess preservative. Following the vacuum period, the wood shall be subjected to steaming for a two-hour time period for lumber and timbers and three hours for piling per the limitations of the AWPA Commodity Standards. The minimum temperature during steaming shall be 200°F (93°C) and the maximum shall be 240°F to 245°F (116°C to 118°C) depending on the species being treated. After steaming, apply a final vacuum for a minimum of four hours at 22" of Hg (-75 kPa) of vacuum.
- **Extended vacuum cycle** This technique involves the use of extended vacuum cycle time or double vacuum cycles where a second vacuum is pulled after allowing the retort to equalize to atmospheric pressure following the "break" from the first vacuum cycle. Preservative collected in the cylinder during the first vacuum cycle should be pumped to the work tank before initiating the second vacuum cycle.

Additional treating information to minimize environmental exposure of oil-type wood preservatives in pressure treated wood can be found in AWPA Standard M20-01, or latest revision.

Post Treating Procedures – "Light" Solvent Carrier

For Copper Naphthenate treated products with a light solvent carrier, such as AWPA Standard P9, Type "C" solvent for sensitive environment applications, use the following BMP:

- A final vacuum shall be used for a minimum of 1 hour at a minimum of 22″ of Hg (-75 kPa) of vacuum.

Additional treating information to minimize environmental exposure of oil-type wood preservatives in pressure treated wood can be found in AWPA Standard M20-01, or latest revision.

PART B: 6

BMPs for Specific Preservatives Used in the Production of Treated Wood

Creosote

Best Management Practices

The BMPs for Creosote are intended to minimize the amount of preserv ative material available for migration into the environment. The following guidelines, as well as the gener al guidelines referenced in **Chapter 3, Part A**, shall be used when treating material for use in sensiti ve environment, aquatic or marine applications:

Treating Procedures

- Follow recommendations in AWPA M20-01 (or most recent publication) Standard providing Guidelines for Minimizing Oil-Type Wood Preservation Migration as appropriate for Creosote P1/P13 and product treated for Sensiti ve Environment exposure.
- Treat using preservative specified in AWPA Standard P1/P13, "Standard for Coal Tar Creosote for Land and Fresh Water and Marine (Coastal Water) Use."
- The "in use" Creosote inventory maintained by the treating firm at the plant for BMP-treated applications shall be purchased, managed and/or processed such as to maintain a xylene insoluble (XI) of 0.5% maximum and to maintain moisture content within specifications. (Exception – A xylene insoluble (XI) level of 1.5% will be allowed for facilities treating Ponderosa or Southern Pine due to the higher lev el of extractable sap and resins associated with these species).
- Techniques shall be incorporated into the treating process to minimize the amount of residual Creosote, which may occur on the surface of the treated product. (Techniques may vary depending upon the product type and wood species).
- On Southern Pine, if plant equipment allows, steam conditioning is an alternati ve to conditioning by kiln drying. Steam conditioning may result in energy savings by shortening post-treatment cycles while producing desired cleanliness and dryness.

Post-Treating Procedures

Prior to shipment, material for aquatic applications shall be processed under one of the follo wing procedures as determined by the producer:

- **Expansion Bath** Following the pressure period the Creosote should be heated 10 °F to 20°F (6°C to 11°C) above press temperatures (following the preservative and species temperature limitations set by AWPA) for a minimum of one hour. Pump Creosote back to storage and apply a minimum vacuum of 24 inches of Hg (610 KPa) for a minimum of 2 hours.

- **Steaming** Following the pressure period and once the Creosote has been pumped back to the storage tank, a vacuum shall be applied for a minimum of two hours at not less than 22 inches of Hg (560 KPa) of vacuum to recover excess preservative. Release vacuum back to atmospheric pressure and steam for a two-hour time period for lumber and timbers and three hours for piling. Maximum temperature during this process shall not exceed 240°F (115.5°C). Apply a second vacuum for a minimum of four hours at 22 inches of Hg (560 KPa) of vacuum.
- **Vacuuming** Following the pressure period and once the Creosote has been pumped back to the work tank, a vacuum shall be applied for a minimum of one and half hours at not less than 22 inches of Hg (560 KPa) of vacuum to recover excess preservative. Then, depending on plant equipment: 1.) vacuum for a minimum of one and half hours at not less than 22 inches of Hg (560 KPa) or 2.) steam material for one-hour minimum and then pull not less than 22 inches of Hg (560 KPa) vacuum for a minimum of one and half hours. Maximum temperature during steaming shall not exceed 240°F (115.5°C).

Mussels (Mytilus trossulus)

Technical Notes

The purpose of the BMP for Creosote is to minimize the amount of surface residues which are available to migrate to the environment. The purchase of low xylene new Creosote and management processes to maintain low XI levels will assure that there are a minimum of contaminants on the surface of the finished product. The post-conditioning requirements (e.g. steaming or expansion bath and vacuuming) help to assure that excess Creosote is removed from the product while maintaining the required amount in the assay zone to meet the product specification after treatment. Surface Sheen – when driving Creosote piling, visible oil sheen will often develop on the water surface. This sheen represents only a trace quantity of Creosote preservative and in most all instances it will dissipate within 24 – 48 hours through biodegradation, evaporation or oxidation of the Creosote. Available data indicates this sheen, which decreases rapidly following installation, will not harm aquatic life nor will it enter the food chain.

Specifiers and installers should follow the guidance in the Creosote treated wood Material Safety Data Sheets (MSDS) and hazard labels as required by OSHA and use the material in conformance with the Consumer Information Sheet for Creosote pressure treated wood. Creosote should not be used in those portions of projects subject to frequent public contact, i.e., handrails, sunbathing decks, etc.

Dual Treated Marine Piling

Best Management Practices

The BMPs for Dual Treating requires that individual BMPs for each preservative be specified for the treatment unless the same objectives can be obtained through a combined practice. In addition to the individual BMPs for each preservative specified, the general guidelines referenced in **Chapter 3, Part A** shall also be utilized.

Dual treatment is generally only specified on the Pacific Coast in coastal areas south of San Francisco, California, the Atlantic Coast between New Jersey and Florida, and along the Gulf Coast.

Treating Procedures

- Refer to the BMP for the waterborne preservative being specified and for Creosote.
- Techniques shall be incorporated into the Creosote treating process to minimize the amount of residual Creosote, which may occur on the surface of the dual treated product. Techniques will vary depending on experience, equipment, product type and wood species.

Post-Treating Procedures

After initial treatment but prior to the second treatment, follow the post-treating procedures for the waterborne preservative specified.

Prior to shipment but after the second treatment with Creosote, the material shall be processed under the following procedure by the producer:

- **Vacuuming** Following the pressure period and once the Creosote has been pumped back to the work tank, a vacuum shall be applied for a minimum of three hours at not less than 22 inches of Hg (560 KPa) of vacuum to recover excess preservative and dry the material surface.

Colonies of plumose anemones (Metridium senile), tubeworms (Spirobids) and coralline algae (Lithothamnium)

Pentachlorophenol (Penta)

Best Management Practices

The BMPs for Penta are to ensure responsible treatment and product use. Its use in marine projects should be limited to above the splash zone because Penta does not protect against marine organisms. In order to minimize the amount of Penta material available to migrate into any sensitive environment during its use, the following guidelines, as well as the general guidelines referenced in **Chapter 3 Part A**, are recommended when treating material for these applications. Following these procedures should result in a clean and dry treated wood product:

Treating Procedures

Manage the treating plant's "in-use" Penta by continuous filtration or other available methods to maintain the solution with minimum particulate matter. Such processes will result in less surface deposits, minimizing the amount of material which may be released from in-service wood.

Post-Treating Procedures

Surface treatment Following the pressure period, incorporate one of the following procedures into the treating process to minimize the amount of residual treating solution which may occur on the treated product surface. Techniques may vary depending upon the product type and wood species.

- **Steaming** Material may be cleaned by final steaming within the limits specified for that commodity in AWPA, T-1 – Section 8.
- **Expansion Bath** When final steaming is not utilized the treater may use an expansion bath. Perform this expansion bath in accordance with AWPA T1, Section 2. This generally involves heating the preservative 10°F to 20°F (-12.22°C to – 6.67°C) above pressure temperatures for a minimum of one hour, followed by pumping the preservative back to storage and applying a minimum vacuum of 22 inches (55.88 centimeters) for a minimum of two hours.
- **Extended vacuum cycle time** This technique involves the use of extended vacuum cycle time or double vacuum cycles where a second vacuum is pulled after allowing the retort to equalize to atmospheric pressure following the "break" from the first vacuum cycle.
- Preservative collected in the cylinder during the first vacuum should be pumped to the work tank before initiating the second vacuum.

Before removal of material from the treating area, the treater should verify the material is free of surface deposits and/or drippage of excess preservative. Drippage is generally the result of product continuing to adjust to ambient conditions of temperature and pressure.

Technical Notes

Surface Sheen Occasionally when installing Penta-treated wood in or over water, a visible oil carrier sheen may develop on the water surface. This sheen contains a negligible quantity of Penta as there is generally less than 1% Penta in Penta-treated wood. In nearly all instances this sheen will cease in less than 24 hours through bio and photodegradation. Available data indicates that this sheen does not represent any harm to aquatic life nor will it enter the food chain. It is basically an aesthetic concern which decreases rapidly following installation

Steaming Steaming may produce contaminated process water requiring waste water treatment before discharge to meet local, state or federal regulations. Consult AWPA Treatment Standards to determine if this procedure is allowable, and for the duration and temperature limitations.

Pentachlorophenol-treated wood is not recommended for salt and brackish water immersion applications.

Chapter Four: Installation and Maintenance Guidelines

Achieving the goals of the Best Management Practices can only be fully achieved if the users of the products are also engaged. The following guidelines are suggested practices, but other applicable practices may be determined by the specifier or project managers.

Design and Purchasing

It is recommended that any order for the purchase of treated wood materials should involve communication between the purchaser/specifier and the seller or treating company whichever is most practicable or customary, and that the order, including the environmental concerns with the project, should be reviewed in detail with the producer.

- Projects should be designed and specified to provide for the maximum amount of cutting, prefabrication and framing prior to treatment. This allows for better treatment of product and minimizes the need for field cutting and treatment.

- Where treated wood may be subject to continual abrasion, such as floating docks against piling, the project should incorporate design features to prevent the ongoing contact. This will increase the life of the project and minimize treated material entering the environment.

Transportation

- When additional protection from precipitation is desired or warranted it is recommended preservative-treated sawn wood material be top wrapped or covered while being transported to its designated location.

- Care should be taken during the loading and unloading of the preservative-treated wood to prevent or minimize damage to the product that causes untreated areas to be exposed. If untreated areas become exposed by damage they should be field treated with an approved preservative (Copper Naphthenate) as per AWPA Standard M4.

Inspection, Acceptance, Rejection

- As soon as practical after receipt, the material and the accompanying paper work should be inspected to assure it has been treated to specified AWPA standards and certified to have been treated under the BMP program by either the presence of a BMP Mark with a legible stamp, brand, mark, end tag or equivalent designation on the material or by a letter of certification from an independent third party inspection agency. If any problems exist, the supplier should be contacted immediately.

- BMP materials should be inspected to assure they are reasonably free of surface debris and excess surface chemical. Material treated with oil-type preservatives should be examined for signs of preservative migration, and excessive residues or bleeding.

- Where the products are of concern they should be rejected from installation and the treating company should be contacted immediately for corrective action.

Storage

- **On-site** The material should be stored away from the water until it is needed for installation. When preservative-treated wood is stored on the jobsite for an extended period and/or there is a threat of the material being exposed to precipitation, it is recommended the material be stacked above the ground. The area where the material is to be stacked should be free of debris, weeds and dry vegetation and should have adequate drainage to prevent the material from being subjected to standing water. Also, if warranted, all stacked material designated to be removed from service should be covered for disposal and material designated for use should remain covered until used.

- **Off-site** In situations where preservative-treated wood material is being inventoried prior to distribution to the jobsite or when material removed from service is taken to a storage site prior to its disposal or reuse, it should be stacked in a well-drained area free from debris, weeds and dry vegetation above the ground on bunks or pallets. The stacked material may be stored under a covered area or top wrapped with a tarp to minimize exposure to precipitation.

Field Treating Guidelines

Copper Naphthenate-based solutions are commonly used in field treating of holes, cuts or injuries, which occur to the treated product. The objective of field treatment is to assure complete product treatment.

The following guidelines should be followed in field-treating projects in sensitive environments:

- Follow the procedures outlined in AWPA Standard M4, Standard for the Care of Preservative-Treated Wood Products.

- When field treating by brushing, spraying, dipping or soaking do so in such a manner that the preservative does not drip or spill into the sensitive environment.

- Whenever possible, apply field treatments prior to assembling the structure over the body of water or sensitive environment.

- Conduct the application of the preservative so that any overspray or drippage of preservative can be recovered or retained.

- Specifiers and installers should follow the directions for use on the Copper Naphthenate-based end cut solution label and Material Safety Data Sheets (MSDS) for the product.

Jellyfish (Aglantha digitale)

Installation

- When field cutting, drilling or fabrication is necessary, it should be done away from the water or sensitive area to the degree practical and all waste, including sawdust, should be collected and disposed of appropriately. (See Disposal next page). There are many approaches to ensuring that the debris from field fabrication and maintenance activity is properly collected and removed, but the choice will depend on the situation and the construction or maintenance crew. It is recommended in most cases that fabrication be done at specific cutting stations in order to consolidate the collection of debris. The use of a tarp is suggested for collecting sawdust from circular saws and chainsaws, and plastic tubs or similar containers are suggested for collecting debris created from drilling holes on-site. The importance of collecting debris from construction and maintenance activities should be stressed in planning and budgeting for projects so that the crews clearly understand that debris collection is an integral part of the construction and maintenance process in order to minimize the release of preservative into the environment.
- Installation of oil-borne type preserved products may initially result briefly in a thin oily sheen on the water surface. Such sheens are generally of an aesthetic rather than biological concern and will dissipate in a relatively short period of time. Absorbent booms or barriers can be used to control and collect the sheens.

Demolition

The removal of existing treated wood structures from aquatic and sensitive environments should be done with care to minimize the potential for treated debris to enter the environment. The guidelines used in construction of new projects should be applied to demolition wherever applicable and the added effort should be considered in costing the project.

- Wherever practical the treated wood structure or as large a portion as practical should be removed well away from the sensitive environment for final demolition.
- All scraps and sawdust from the demolition should be collected and removed for appropriate disposal. In aquatic applications absorbent booms should be considered if needed to control drift of scrap materials from the work area or to control sheens which may develop with the disturbance.
- **Piling** If not otherwise specified by the regulatory permit or project plan, treated wood piling may be: 1) left in place; 2) pulled and moved off site; 3) cut off at the mud line; 4) cut off below the mud line and capped with clean material.
- **Salvage and Reuse** Depending upon the condition of the treated wood materials removed, the product may retain enough of the structural and preservative characteristics to make it suitable for reuse in a manner compatible with its original purpose. Common secondary applications include use as posts, landscape timbers and retaining walls. Distribution of such materials to the market, through sale or donation, should be done with great care to assure the structural and treatment integrity of the product and to assure that the new user is provided information on the use of the material including applicable EPA-approved Consumer Safety Information Sheets. Note: It is extremely difficult to detect internal degradation in any materials intended for reuse and it may be prudent to avoid the use of salvaged marine piling in foundation piling or structural applications.

Disposal

Treated wood scraps and sawdust as well as material for disposal that is not reused must be disposed of appropriately in a timely manner. The disposer should check with local authorities that have jurisdiction over this process to assure disposal is accomplished in compliance with all applicable requirements, which may supersede the following guidelines.

For a detailed discussion of Federal and State requirements see "Disposal of Treated Wood" at www.WWPInstitute.org.

- NEVER BURN TREATED WOOD IN OPEN FIRES OR FIREPLACES!
- Do not use treated wood as mulch.
- Do not leave the waste material on site or in stockpiles for extended time periods.
- Under federal regulations treated wood waste is classed or managed as a non-hazardous material and may be disposed of at municipal landfills approved to receive such material by state, provincial and local authorities.
- A few state or provincial governments have more stringent requirements for classification of wastes. However, in such cases the issue of treated wood has been addressed in law and/or regulations allowing for disposal in approved municipal landfills. For specifics, local state and provincial authorities should be contacted.
- There are various incinerators, waste-to-energy burners and industrial furnaces across the country, which are approved and permitted for utilization of Creosote and Pentachlorophenol-treated wood waste.

Graceful crabs (Cancer gracilis) in a mating grasp

Appendix A: Quality Assurance Inspection Procedures For Best Management Practices (BMPs) For the Use of Treated Wood in Aquatic and Other Sensitive Environments

Unless otherwise defined, all terms and definitions in these procedures shall be as found in the American Wood-Preserver's Association (AWPA) Book of Standards.

1. SCOPE

These Quality Control and Inspection Procedures are applicable to all pressure treated wood products produced under the BMPs for use in, above or in the vicinity of aquatic and other sensitive environments and are supplemental to the requirements of AWPA and/or other product specifications. Inspection in regard to product specification or treating standards is separate and in addition to the BMP inspection requirements.

Producers that choose to treat to the BMPs, but choose not to participate in the WWPI BMP Mark Program are not permitted to use the 'Mark,' as described in Paragraph 2.2 of this document, but will be required to provide a certificate of compliance issued and signed by an independent treated wood inspection agency of its choice and acceptable to the purchaser for each lot.

2. DEFINITIONS

2.1 BMPs

Best Management Practices are published guidelines developed for use in specifying and producing material for use in aquatic and other sensitive environment projects in the United States and Canada. The BMPs were developed and published by the Western Wood Preservers Institute (WWPI), Wood Preservation Canada (WPC), Southern Pressure Treaters Association (SPTA) and Timber Piling Council (TPC).

2.2 BMP Quality Mark

2.2.1 A mark registered under the Federal Trade Marks Act, as indicating certification of conformance to pressure treated processing and pressure treated product rules. A mark which when stamped or affixed to wood products, certifies that all the actions and quality certification requirements under these Quality Assurance Inspection Procedures have been met by both the treater and the Quality Control Agency which licenses the use of the mark by pressure treating plants.

2.2.2 A register protected logo which, when included with the 'MARK,' denotes compliance to the BMPs:

This mark remains the property of WWPI and shall only be used by authorized agencies and producers.

2.3 **Quality Control Agency**

An organization that either (1) is acknowledged by WWPI as authorized under the BMP Mark Program; or (2) designated acceptable by agreement between the purchaser and producer to issue a certificate of compliance for lots, to audit, by testing and sampling, the quality marked or certified BMP products treated in accordance with these Quality Assurance Inspection Procedures to assure conformance.

The Quality Control Agency shall have no financial interest in any company producing any portion of the products inspected and tested. The Quality Control Agency shall not be owned, operated or controlled by any such company.

2.4 **Residence Quality Supervisor (RQS)**

An individual designated by the treater and approved by the Quality Control Agency who performs the functions and meets the requirements of Paragraph 3.1.2. The Quality Control Agency shall initially and continuously thereafter determine that the Resident Quality Supervisor can demonstrate satisfactory knowledge of all manufacturing, sampling and testing requirements.

2.5 **Seller**

As used in these Quality Assurance Inspection Procedures, a seller is each owner of the products described by the Quality Assurance Inspection Procedures beginning with the treater and including intermediate sellers between manufacture and use.

2.6 **Purchaser/User**

Entities, individuals or representatives who are responsible for the acquisition and installation of BMP treated wood products.

2.7 **Treater**

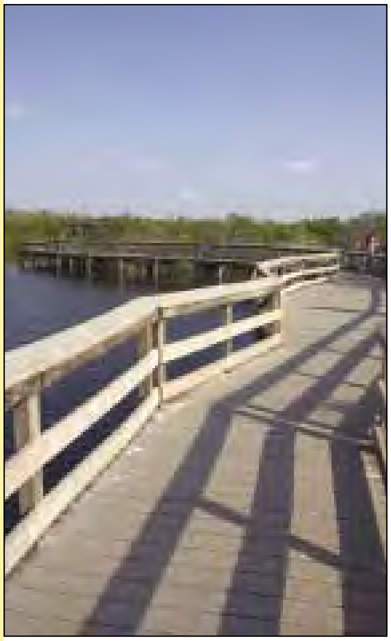
A company or firm engaged in the treatment of the products covered by these Quality Assurance Inspection Procedures.

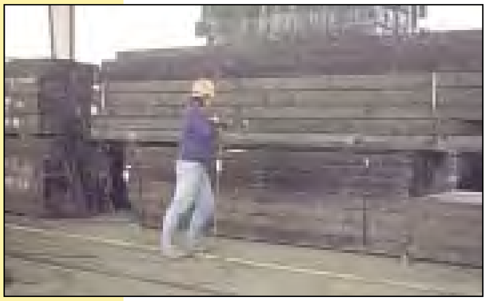
2.8 **Lot and Lot Inspection**

A lot for inspection at plants will be a single charge or a shipment, whichever is less. A lot for inspection at plant storage yards, at sales yards, in transit, or at jobsites will be that material available at the time and place of inspection which contains products from only one treating plant and will contain only one species or species group and one preservative treatment.

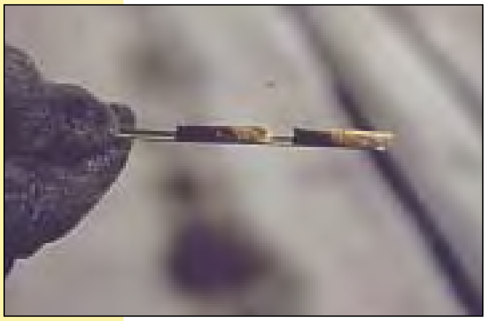
2.9 **Suspended for Cause**

The suspension of production required by an agency when it determines that a continuous non-conformance in treating to BMPs has been identified.





Core samples are removed by a hollow drill bit called an increment borer.



Lumber under five inches thick requires a minimum of 0.40 inch penetration; lumber over five inches thick requires a minimum of 0.50 inch penetration.

3 REQUIREMENTS

3.1 Quality Control

Products conforming to this procedure shall be produced under a system of quality control with the following requirements:

3.1.1 Treating Equipment and Records

The following are both initial and continuing minimum treating plant equipment and record requirements. The Quality Control Agency shall initially and continuously thereafter determine that the manufacturing equipment meets the minimum requirements described in these Quality Assurance Inspection Procedures.

Procedures:

(a) An effective operating system or procedure to remove residuals and debris from preservative solutions.

(b) Facilities at either the plant or at a central laboratory for making all BMP test requirements.

(c) 1. An operating system of BMP record keeping which shall include records of consecutively numbered treating charges showing the basic data required in AWPA Standards M2, including the volume of wood, solution concentration, gallons absorbed, and the results of the inspection of each completed charge. Records shall be retained for one year after shipment.

2. Track and code all post treatment processes and testing to assure compliance with BMPs.

3. A statement of compliance will be attached to each program treating charge report stating conformance to BMPs.

4. A copy of the treating record and RQS report shall also be kept in a separate file and available to the quality control agency's representative during normal working hours.

(d) An internal quality control program maintained by systematically checking treated wood for conformance to these Quality Assurance Inspection Procedures, and applicable AWPA Commodity Standards.

3.1.2 Resident Quality Supervisor (RQS)

An individual shall be appointed by the treater and approved by the Quality Control Agency to oversee and/or perform plant quality control and:

(a) Shall be responsible for conformance of all quality marked or certified products to the requirements of these Quality Assurance Inspection Procedures.

(b) Must understand all requirements of these Quality Assurance Inspection Procedures and be able to recognize these requirements in each class of material produced.

(c) Must understand the capabilities of the treating equipment and procedures in use and be able to judge its proper function in achieving the BMPs.

(d) Shall have authority to stop any operation found to be causing non-conformance attributes.

(e) Shall have authority to correct any operation found to be causing non-conforming attributes.

(f) Must determine that all requirements contained in these Quality Assurance Inspection Procedures are continuously met by reviewing treatment records and performing any and all necessary tests prescribed.

(g) Record findings certifying compliance and attach a copy to the treating records.

(h) Notify the Quality Control Agency of the availability of BMP material for review.

3.1.3 Quality Control Agency Duties

Quality Control Agency described in Paragraph 2.3 shall check and approve the plant equipment, Resident Quality Supervisor and the first five charges and shall thereafter perform continued checking and testing as specified by these quality Assurance Inspection Procedures:

(a) Initially and continually thereafter, determine that procedures and requirements of these Quality Assurance Inspection Procedures are being adhered to by the Treater.

(b) Review plant quality control records noting any deficiencies.

(c) Check plant equipment for compliance with Paragraph 3.1.1 at least once each six months.

(d) Perform the sampling and testing required by WWPI's BMPs at a ratio of 1:10 BMP charges produced or portion thereof.

(e) Generate a report of findings to be reviewed with RQS.

3.1.4 Compliance Documentation for Producers Participating in BMP Mark Program

(a) The presence of the BMP Mark legibly stamped, branded, marked, end tagged or otherwise on each piece of material or lot or;

(b) A certificate of compliance for each lot as defined in Paragraph 2.8.

3.1.5 Compliance Documentation for Producers Not Participating in BMP Mark Program

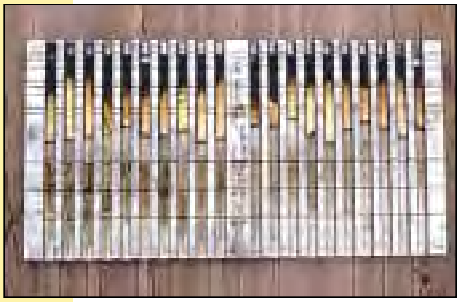
(a) A certificate of compliance for each lot as defined in Paragraph 2.8.

3.1.6 Non-conformance

If a product non-conformance is found by the Quality Control Agency or the Treater, at either a point under the Treater's jurisdiction or at a location not under his jurisdiction, the Treater will correct the non-conformance or remove the Quality Mark under the supervision of the Quality Control Agency. The Treater should be afforded every opportunity to correct non-conformance. Where applicable, material may be re-treated, and all re-treatment shall be in accordance with the appropriate AWPA Standards and these Procedures. If the lot fails to conform after re-treatment, the Quality Mark shall be removed from all pieces in the non-conforming lot and any certificate of compliance shall be withdrawn for the materials.

3.1.7 Suspension and Warning

A treating plant participating in the WWPI Mark Program suspended for cause from applying the Quality Mark to its products while under license of one Quality Control Agency shall not apply the Quality Mark under license of another Quality Control Agency until it has successfully re-qualified with the original Quality Control Agency. A treating plant placed on warning for cause by its licensing Quality Control Agency shall not apply the Quality Mark under the license of another Quality Control Agency. Upon suspension and warning WWPI will be notified.



A minimum of twenty core samples are randomly taken from each charge of treated wood to measure depth of penetration.

Plumose anemones (Metridium senile) and compound ascidians (Dispaplia occidentalis)

4 MARKING

4.1 Proper Identification

To insure that treated material produced by producers participating in the WWPI Mark Program is properly identified as being produced in compliance with these Quality Assurance Inspection Procedures, it shall be legibly stamped, branded, marked, end tagged, or otherwise have permanently affixed a quality mark containing the following information:

4.1.1 Identity

Identity of the treating plant.

4.1.2 Preservative

Preservative code and retention as specified.

4.1.3 Mark

BMP registered logo where authorized, i.e.:

4.1.4 Arrangement

The information required by this procedure shall be arranged in the Quality Mark format in compliance with the AWPA Standard M-6 and generally accepted industry formats. The BMP Mark may be included with other quality information or placed separately.

4.1.5 Material Packaging

A Treater may not mix in one package material which bears the Quality Mark with material that does not bear the Quality Mark.

4.1.6 Location

The location of the quality marks shall be according to industry standards and/or user requirements.

5. REINSPECTION

5.1 Reinspection in General

5.1.1 The settlement of a dispute between the producer and the customer or user of the product, as to any BMP attribute, shall be made by the Quality Control Agency.

5.1.2 Reinspection privileges shall be available to both buyer and seller upon request for the purpose of determining compliance with purchaser BMP specifications and effecting the settlement of compliance and invoices.

5.1.3 Product compliance with the requirements of the applicable BMPs is the responsibility of the Treater for 90 days after receipt of the shipment provided the shipment is not in use. Partial use of the shipment shall not prejudice the right to re-inspection of the remaining portion as long as the unused portion is in the form in which it was shipped.

5.2 Procedure

5.2.1 In performing Reinspection for treatment attributes, the Agency shall employ those tests approved in the applicable AWPA M or A standards (latest edition).

5.2.2 All attributes of treatment appearing on the Quality Mark or certificate shall be checked.

5.2.3 Complaints may be filed for illegible marks, incorrect marks and no marks where the Quality Mark has been specified. The Agency Quality Marks may be applied by qualified personnel of the Agency after compliance to applicable BMPs has been confirmed. Where material has been marked incorrectly, the mark shall be removed by any suitable means and any certificate of compliance shall be amended.

5.2.4 Lots failing to conform to BMP requirements shall be clearly marked as non-conforming and when possible separated from conforming material.

5.3 Compliance Variance

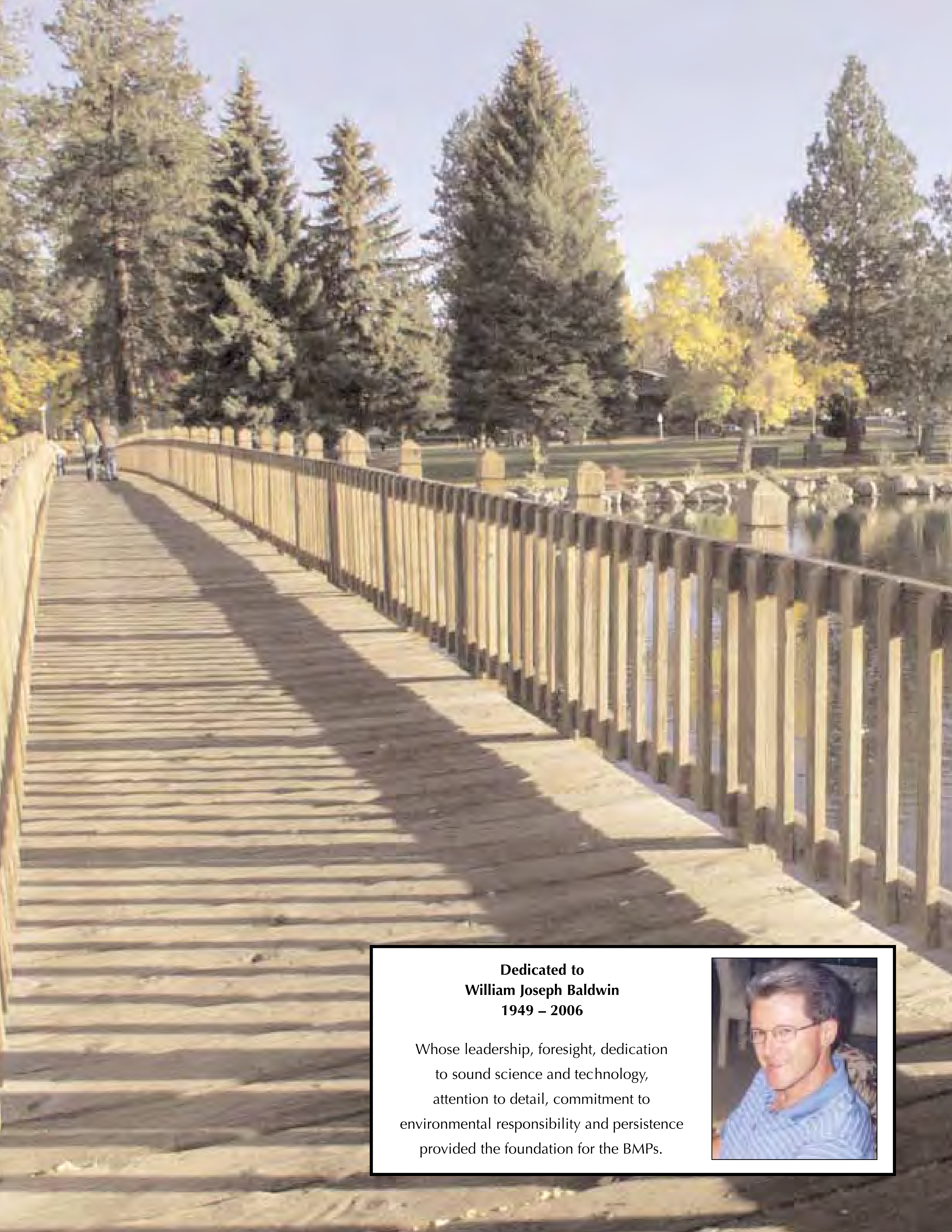
5.3.1 When 95% or less of a shipment or individual lots in a shipment conforms to the BMP requirements, the shipment or each lot of the shipment which fails shall be considered non-conforming and the Treater shall pay the cost of re-inspection. When a shipment or the lots within a shipment is more than 95% in conformance with the BMP requirements, the shipment or the lots within the shipment shall be considered conforming and the user shall pay the cost of Reinspection.

5.3.2 A customer is not required to accept non-conforming material. Non-conforming material found at reinspection shall be corrected or have the quality mark removed or the certificate of compliance withdrawn.

5.4 Records

Reports shall be issued to all parties to the compliant and copies shall be kept by the Agency for a minimum period of two years.

Sunflower starfish (Pycnopodia helianthoides) and a leather star (Dermasterias imbricata)



Dedicated to
William Joseph Baldwin
1949 – 2006

Whose leadership, foresight, dedication
to sound science and technology,
attention to detail, commitment to
environmental responsibility and persistence
provided the foundation for the BMPs.

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WWPI Documents

2. Best Management Practices. More technical than 1.) above. In specification format.

BEST MANAGEMENT PRACTICES

FOR THE USE OF TREATED WOOD IN AQUATIC ENVIRONMENTS

®

USA VERSION • REVISED JULY, 1996

Developed For Use In Specifying Materials For Use In Aquatic Projects
in the Western United States and Canada by:

Western Wood Preservers Institute • Canadian Institute of Treated Wood

BEST MANAGEMENT PRACTICES
TABLE OF CONTENTS

BEST MANAGEMENT PRACTICES FOR THE USE OF TREATED WOOD IN WESTERN AQUATIC ENVIRONMENTS

INTRODUCTION

PURPOSE

Protection of the quality of the water and diversity of the various life forms found in the lakes, streams, estuaries, bays and wetlands of North America is a goal and responsibility shared by every citizen. An endless list of human activities can impact the aquatic environment: storm waters that run off our streets, exhaust from our boats and cars, municipal and industry discharges, and construction of docks and piers, to name but a few. Maintaining the quality of our treasured aquatic resources requires that everyone do their part.

Pressure treated wood is a major material used to construct the piers, docks, buildings, walks and decks used in and above aquatic environments. The pressure treated wood products industry is committed to assuring its products are manufactured and installed in a manner which minimizes any potential for adverse impacts to these important environments. To achieve this objective the industry has developed and encourages the use of **BEST MANAGEMENT PRACTICES or BMPs.**

There are a variety of treatments and treated wood products approved for use in or above aquatic environments. Because of inherent differences in the treatment chemicals and the processes there are also a number of BMPs. While the goal of the BMPs are common, i.e., to minimize the migration or leaching of treating chemicals into the environment, the methods for achieving the goal vary and are discussed in detail. **It is the responsibility of the treating firm to assure that materials leaving the plant destined, and so designated, for use in aquatic environments have been produced in compliance with the BMPs.**

BMPs are in a state of evolution. While this document represents the best available technologies and knowledge, efforts are continuing to develop better methods for risk assessment, to improve the BMPs themselves and to develop a quality assurance process for use by specifiers and regulatory agencies. Research continues in several areas including understanding the environmental impacts of the products, improved treating systems, opportunities to reduce the amount of chemical needed to achieve performance and development of new preservatives. As the knowledge increases the BMPs will be updated and improved.

BEST MANAGEMENT PRACTICES
UTILIZING the BMPs

There are four steps to assure products utilized in aquatic environments incorporate BMP produced materials.

1. Specify the appropriate material in terms of performancas defined in the American Wood-Preservers' Association Standards.

2. Specify that the material be produced in compliance with these BMPs.

3. Require assurance that the products were produced in conformance with the BMPs.

4. Provide for on site inspection prior to installation and conformance with any recommended installation practices.

BEST MANAGEMENT PRACTICES
SPECIFYING MATERIALS

A key step in designing a project in an aquatic environment is the specification of the treated wood to be used. There are a variety of available treated wood products approved for use in and/or above aquatic environments depending upon the intended use, species, required performance and environmental conditions. The specifier should recognize that, in terms of required retention levels (AWPA Standard) as well as potential environmental impacts, materials specified for applications above or over the water are distinctly different than splash zone or in water applications. The industry treats only with preservative chemicals registered for the specific uses by the Environmental Protection Agency. The most common products are those treated with Creosote, ACZA (Ammoniacal Copper Zinc Arsenate), ACA (Ammoniacal Copper Arsenate) and CCA (Chromated Copper Arsenate). Other preservatives approved for some uses in or above water are Penta (Pentachlorophenol), Copper Naphthenate and ACQ (Alkaline Copper Quaternary).

PERFORMANCE

The purpose of treating wood products is to provide protection from organisms that can attack or decay the wood, thus extending the useful life and structural performance of the material. The appropriate applications of each product, the required penetration, and the required retention (amount of preservative in the assay zone) are established by the American Wood-Preservers' Association in their Commodity (C) Standards which delineate the methods and results of product treatment. A brief description of appropriate applications for each preservative in aquatic environments is included in each specific BMP.

ENVIRONMENTAL AND AESTHETIC CONSIDERATIONS

In designing a project, one needs to consider the characteristics of various treated wood products in relation to the purpose of the project and the environmental characteristics of the site. For example, the environmental risks associated with treated wood placed directly in the water are different from those associated with wood placed over the water. Products used in a heavy industrial application will likely be different from those used in a public boardwalk. Similarly, the use of a moderate amount of treated wood in a fast flowing river poses minimal risks; whereas, the use of large amounts of treated wood in stagnant water may pose significantly greater risks.

Based on the best available science, pressure treated wood poses minimal risk to aquatic environments when used in accordance with the AWPA specifications; installed following the guidance provided in the treated wood Material Safety Data Sheets (MSDS); used in conformance with the Consumer Information Sheets; and produced using WWPI's Best Management Practices (BMPs). Where a large treated wood project is proposed in a poorly flushed body of water, WWPI recommends a site specific environmental risk assessment. The Western Wood Preserver's Institute will help you determine if an individual risk assessment is necessary.

For Further discussion of the environmental aspects of BMPs and specification, see "ENVIRONMENTAL CONSIDERATIONS AND FOR USING BMP TREATED WOOD IN AQUATIC PROJECTS" on Page 29.

BEST MANAGEMENT PRACTICES

for

CREOSOTE

USES AND SPECIFICATIONS

Creosote is accepted for a full range of salt and fresh water applications in the American Wood-Preservers' Association (AWPA) Book of Standards. The specific commodity standards that should be used to specify the preparation and use of various Creosote treated products used in and above aquatic environments are:

- C2 -- Lumber, Timbers, Bridge Ties and Mine Ties, Pressure Treatment
- C3 -- Piles
- C14 -- Wood for Highway Construction
- C18 -- Material in Marine Construction
- C28 -- Laminated Beams

Specifiers and installers should follow the guidance in the Creosote treated wood Material Safety Data Sheets (MSDS) and hazard labels as required by OSHA and use the material in conformance with the Consumer Information Sheet for Creosote pressure treated wood. Creosote should not be used in those portions of projects subject to frequent public contact, i.e., handrails, sunbathing decks, etc.

BEST MANAGEMENT PRACTICES

In order to minimize the amount of Creosote material available to migrate into the environment, the following guidelines shall be used when treating material for use in marine applications:

TREATMENT PROCEDURES

• Treat using preservative specified in AWPA Standard P1/P13, “Standard for Coal Tar Creosote for Land and Fresh Water and Marine (Coastal Water) Use.”

• Follow good housekeeping practices to minimize sawdust and other surface residues on the wood products prior to treatment.

• The “in use” Creosote inventory maintained by the treating firm at the plant for aquatic applications shall be purchased, managed and/or processed such as to maintain a xylene insoluble (XI) of 0.5% maximum. (Exception -- A xylene insoluble (XI) level of 1.5% will be allowed for facilities treating Ponderosa or Southern Pine due to the problems associated with the sap and resins in these species).

• Techniques shall be incorporated into the treating process to minimize the amount of residual Creosote which may occur on the surface of the treated product. (Techniques may vary depending upon the product type and wood species).

• Conditioning — The wood must be conditioned using one of the techniques recommended in Standard C2 or C3 of the AWPA Book of Standards.

POST TREATMENT PROCEDURES

Prior to shipment, material for aquatic applications shall be processed under one of the following procedures as determined by the producer:

• Expansion Bath -- Following the pressure period the Creosote should be heated 10 to 20˚F above press temperatures for a minimum of one hour. Pump Creosote back to storage and apply a minimum vacuum of 24" for a minimum of 2 hours.

• Steaming — Following the pressure period and once the Creosote has been pumped back to the storage tank, a vacuum shall be applied for a minimum of two hours at not less than 22" of vacuum to recover excess preservative.

Release vacuum back to atmospheric pressure and steam for a two-hour time period for lumber and timbers and three hours for piling. Maximum temperature during this process shall not exceed 240˚F. Apply a second vacuum for a minimum of four hours at 22" of vacuum.

MAXIMUM CHEMICAL LOADING

Treating shall be conducted in such a manner as to seek to minimize the amount of chemical placed into the wood while assuring conformance with the AWPA retention and penetration requirements.

VISUAL INSPECTION

The Creosote product shall be inspected visually to insure that there are no excessive residual materials or preservative deposits. If the material does not appear clean and dry it shall be rejected. Once on site and prior to installation the materials should be visually inspected in accordance with the above directions. Materials which have developed areas of “bleeding” or do not meet the criteria of a clean and dry appearance should be rejected. Good housekeeping is essential to avoid surface deposits and keep the product clean until shipment and installation.

TECHNICAL NOTES

The purpose of the BMPs for Creosote is to minimize the amount of surface residues which are available to migrate to the environment. The purchase of low xylene new Creosote and management processes to maintain low levels will assure that there are a minimum of contaminants on the surface of the finished product. The post conditioning requirements (e.g. steaming or expansion bath) help to assure that excess Creosote is removed from the product. This must be accomplished in a manner which does not reduce the amount of Creosote in the assay zone (retention) below that specified for the particular product and application.

Surface Sheen — When driving Creosote piling, a visible sheen will often develop on the water surface. This sheen represents a trace quantity of Creosote. In almost all instances the sheen will dissipate within 24-48 hours through biodegradation, evaporation or oxidation of the Creosote. Available data indicates that this sheen, which decreases rapidly following installation, will not harm aquatic life nor will it enter the food chain.

Earlier efforts to set precise maximum chemical loading levels have proven technologically unachievable due to the inherent variability found in wood including cell structure and amount of sap versus heartwood. Industry remains focused on conducting the necessary research to reduce required chemical levels in the AWPA standards consistent with maintaining the needed protection provided by treating.

BEST MANAGEMENT PRACTICES
for
CCA

USES AND SPECIFICATIONS

CCA (Chromated Copper Arsenate) is accepted for a full range of salt and fresh water applications in the American Wood-Preservers' Association (AWPA) Book of Standards. The specific commodity standards that should be used to specify the preparation and use of various CCA treated products used in and above aquatic environments are:

C2 -- Lumber, Timbers, Bridge Ties and Mine Ties, Pressure Treatment
C3 -- Piles
C14 -- Wood for Highway Construction
C18 -- Material in Marine Construction

Specifiers and installers should follow the guidance in the CCA treated wood Material Safety Data Sheets (MSDS) and hazard labels as required by OSHA and use the product in conformance with the Consumer Information Sheet for Inorganic Arsenical Pressure Treated Wood.

BEST MANAGEMENT PRACTICES

The BMPs for CCA are to assure that fixation occurs prior to the material leaving the treating facility. In order to assure fixation, the following BMPs shall be followed:

TREATMENT PROCEDURES

• CCA-C treating solutions should be used in accordance with AWPA Standard P5, C2, and C3 for Waterborne Preservatives.

• Follow good housekeeping practices to minimize sawdust and other surface residues on the wood products prior to treatment.

• Treat according to AWPA Standard C-1.

POST TREATMENT PROCEDURES

Apply appropriate post treatment procedures to achieve fixation. Achieving fixation using one of the following technologies is a function of time, temperature and humidity and must be adjusted based on the characteristics of the material and the process.

• Air Seasoning
• Kiln Drying
• Steaming
• Hot Water Bath

The best available technology for confirming fixation in CCA treated material is use of the **Chromotropic Acid Test** (AWPA Standard A3-11 [1995]). If testing shows that fixation has not been completed, the material should be withheld from shipment and/or installation until fixation is confirmed.

MAXIMUM CHEMICAL LOADING

Treating shall be conducted in such a manner as to seek to minimize the amount of chemical placed into the wood while assuring conformance with the AWPA retention and penetration requirements.

VISUAL INSPECTION

The CCA treated product shall be visually inspected prior to leaving the treatment plant to insure that no excessive residual materials or preservative deposits exist.

TECHNICAL NOTES

CCA is considered an excellent treatment for many western softwoods including Hem-Fir, Western Hemlock and Ponderosa Pine. Achieving the required penetrations in Douglas Fir may be extremely difficult. CCA is not recommended for Douglas Fir marine piling (except as the first treatment in "dual treatment") or for treatment of interior Douglas Fir.

FIXATION — In the CCA treating process, water is the carrier to move the metals or active ingredients into the wood where they become fixed to the wood. Once the chemical reaction called "fixation" occurs, the active ingredients become highly insoluble.

While a complex reaction, fixation essentially involves the reduction of the hexavalent chromium to trivalent chromium with the formation of a complex mixture of insoluble chromates. In the process, insoluble arsenates of copper and chromium are also precipitated in the treated wood. Fixation is a function of temperature and time. It can be achieved in several hours in a high temperature environment (176˚F) but can take several weeks at a low temperature (40˚F). Studies show that at 77˚F, 98% fixation can be achieved in 120 hours.

Chromic acid or Chromium VI is the fixative in the CCA process. An absence of Chromium VI indicates that the reaction is complete. This relationship is the basis for the Chromotropic Acid test for evaluating fixation. The procedure can detect Chromium VI at concentrations of 15 parts per million or less. Material passing the test (i.e., no detection of Chromium VI) for use in aquatic environments will be 99.5 to 99.95% fixed. The Chromotropic Acid test is a rigid qualitative procedure specifically for CCA treated wood.

MAXIMUM CHEMICAL LOADING -- Earlier efforts to set precise maximum chemical loading levels have proven technologically unachievable due to the inherent variability found in wood including cell structure and amount of sap versus heartwood. Industry remains focused on conducting the necessary research to reduce required chemical levels in the AWPA standards consistent with maintaining the needed protection provided by treating.

BEST MANAGEMENT PRACTICES for ACZA

THIS SECTION SUPERCEDED BY AMENDMENT # 1 April 18, 2002

USES AND SPECIFICATIONS

ACZA (Ammoniacal Copper Zinc Arsenate) and ACA (Ammoniacal Copper Arsenate) are accepted for a full range of salt and fresh water applications in the American Wood-Preservers' Association (AWPA) Book of Standards. Because of its ability to treat Douglas Fir (as well as other species) ACZA/ACA is most prevalent on the west coast. The specific commodity standards that should be used to specify the preparation and use of various ACZA and ACA treated products used in and above aquatic environments are:

C2 -- Lumber, Timbers, Bridge Ties and Mine Ties, Pressure Treatment
C3 -- Piles
C14 -- Wood for Highway Construction
C18 -- Material in Marine Construction

BEST MANAGEMENT PRACTICES

The BMPs for ACZA/ACA are to ensure that fixation occurs prior to the material leaving the treating facility. In order to assure fixation, the following BMPs shall be followed:

TREATMENT PROCEDURES

- Treat using chemicals specified by AWPA Standard P5 for Waterborne Preservatives.
- Follow good housekeeping practices to minimize sawdust and other surface residues on the wood products prior to treatment.
- After treatment by either the Bethel (full cell) process or the Lowry (modified empty cell) process, a final vacuum of 22" shall be applied for a minimum of two hours. The retort should be heated to between 180˚F and 210˚F during the vacuum process. Note: If the Lowry (modified empty cell) process can be used to obtain the specified product retention, it is the preferred process for products to be used in aquatic environments.
- After removal from the retort, the materials shall remain on the drip pad until all drippage has ceased.

POST TREATING PROCEDURES

Prior to shipment material for aquatic applications shall be processed under one or a combination of the following procedures:

• Minimum Plant Holding Time — Products (with treating stickers in place for sawn and plywood products) shall be held in a storage area with free air circulation for a minimum of three weeks at ambient temperatures equal to or exceeding 60˚F. If the ambient temperature is less than 60˚F, kiln drying or another source of artificial heat shall be used to achieve the 60˚F requirement.

• Post Treatment Kiln Drying — Products shall be kiln dried to a maximum oven dry basis moisture content of 30% in the specified treated zone employing a kiln cycle of 120˚F to 160˚F dry bulb temperature. ASTM Method D442-84, using increment boring, shall be used to determine that the moisture content requirement has been met.

• In-Retort Ammonia Removal Plus Plant Holding Time **--** Plants equipped to follow this procedure will find it a highly effective method for ensuring fixation. After the final vacuum period, with heat, the retort door shall be opened and ambient air drawn through the treated wood charge from the door to the rear of the retort to a scrubber at a rate of 250 cfm, minimum, for a period of three hours. The treated wood product is then handled in the same manner as under “minimum plant holding time” described above except the minimum holding time is one week at ambient temperatures of 60˚ or more rather than three weeks.

MAXIMUM CHEMICAL LOADING

Treating shall be conducted in such a manner as to seek to minimize the amount of chemical placed into the wood while assuring conformance with the AWPA retention and penetration requirements.

VISUAL INSPECTION

The ACZA/ACA treated product shall be visually inspected prior to leaving the treatment plant to insure that no excessive residual materials or preservative deposits exist.

TECHNICAL NOTES

Because of its ability to treat Douglas Fir (as well as other species), ACZA/ACA is most prevalent on the west coast for use in piling and aquatic applications.

“Fixation” is the term applied to the chemical reaction in which the active ingredients within the waterborne treating solution become fixed within the wood cells resulting in leach resistance and durability of the product. Failure to have achieved fixation at time of installation increases the potential for the treating chemicals to leach into the aquatic environment.

The key to the treating process for ACZA and ACA is the ammonia which facilitates carrying the active ingredients into the cell structure of the wood during the treatment process. When the ammonia is evaporated out of the product, the remaining ingredients become fixed and opportunity for leaching is minimized. If too much ammonia remains in the product when it is placed into an aquatic environment then chemicals can be released into the surrounding environment. The BMP procedures are designed to accelerate the removal of the ammonia and minimize the opportunity for chemical leaching.

MAXIMUM CHEMICAL LOADING -- Earlier efforts to set precise maximum chemical loading levels have proven technologically unachievable due to the inherent variability found in wood including cell structure and amount of sap versus heartwood. Industry remains focused on conducting the necessary research to reduce required chemical levels in the AWPA standards consistent with maintaining the needed protection provided by treating.

BEST MANAGEMENT PRACTICES

for

ACQ

USES AND SPECIFICATIONS

ACQ (Alkaline Copper Quat) is accepted for a full range of salt and fresh water applications in the American Wood-Preservers' Association (AWPA) Book of Standards. The specific commodity standards that should be used to specify the preparation and use of various ACQ treated products used in and above aquatic environments are:

C2 -- Lumber, Timbers, Bridge Ties and Mine Ties, Pressure Treatment
C14 -- Wood for Highway Construction
C18 -- Material in Marine Construction

Specifiers and installers should follow the guidance in the ACQ treated wood Material Safety Data Sheets (MSDS) and hazard labels as required by OSHA. Consumer Information Sheets are not required for ACQ.

BEST MANAGEMENT PRACTICES

The BMPs for ACQ are to assure that fixation occurs prior to installation of the material. In order to assure fixation, the following BMPs shall be followed:

TREATMENT PROCEDURES

• ACQ treating solutions should be used in accordance with AWPA Standard P5 and C2.

• Follow good housekeeping practices to minimize sawdust and other surface residues on the wood products prior to treatment.

• Treat according to AWPA Standard C-1

POST TREATMENT PROCEDURES

Apply appropriate post treatment procedures to achieve fixation. Achieving fixation using one of the following technologies is a function of time, temperature and humidity and must be adjusted based on the characteristics of the material and the process.

- Air Seasoning
- Kiln Drying

MAXIMUM CHEMICAL LOADING

Treating shall be conducted in such a manner as to seek minimize the amount of chemical placed into the wood while assuring conformance with the AWPA retention and penetration requirements.

VISUAL INSPECTION

The ACQ treated product shall be inspected visually prior to leaving the treatment plant to insure that no excessive residual materials or preservative deposits exist.

TECHNICAL NOTES

ACQ is considered an excellent treatment for many western softwoods including Hem-Fir and Douglas Fir because of its ability to achieve standard penetration and retention of preservative in these difficult to treat species.

ACQ is not recommended for saltwater immersion applications.

MAXIMUM CHEMICAL LOADING -- Earlier efforts to set precise maximum chemical loading levels have proven technologically unachievable due to the inherent variability found in wood including cell structure and amount of sap versus heartwood. Industry remains focused on conducting the necessary research to reduce required chemical levels in the AWPA standards consistent with maintaining the needed protection provided by treating.

BEST MANAGEMENT PRACTICES
for
DUAL TREATED MARINE PILING

USES AND SPECIFICATIONS

Due to the extreme hazard from marine organisms in some waters, dual treated piling is often specified (C18). In dual treating, the piling is first treated with a waterborne preservative (CCA, ACZA or ACA) after which the piling is treated a second time with Creosote.

BEST MANAGEMENT PRACTICES

The BMPs for dual treating require that individual BMPs for each preservative be specified for the treatment unless the same objectives can be obtained through a combined practice. Dual treatment on the Pacific coast is generally only required or preferred in coastal areas south of San Francisco, California.

BEST MANAGEMENT PRACTICES

for

COPPER NAPHTHENATE

USES AND SPECIFICATIONS

Copper Naphthenate treated wood has limited uses in aquatic applications and is used more in above water applications. It is accepted for freshwater applications in the American Wood-Preservers' Association (AWPA) Book of Standards. Copper Naphthenate is not a restricted use pesticide and is commonly used for field treating holes and field fabrication cuts in treated wood applications. The specific commodity standards that should be used to specify the preparation and use of various Copper Naphthenate treated products used above freshwater aquatic environments are:

C2 -- Lumber, Timbers, Bridge Ties and Mine Ties, Pressure Treatment
C3 -- Piles
C14 -- Wood for Highway Construction

Specifiers and installers should follow the guidance in the Copper Naphthenate treated wood Material Safety Data Sheets (MSDS) and hazard labels as required by OSHA. Consumer Information Sheets are not required for Copper Naphthenate.

BEST MANAGEMENT PRACTICES

The BMPs for Copper Naphthenate are to assure a clean product and minimize the potential for chemicals to enter the aquatic environment.

In order to minimize the amount of Copper Naphthenate material available to migrate into the environment, the following guidelines shall be used when treating material for use in marine applications:

TREATMENT PROCEDURES

• Treat using Copper Naphthenate which meets AWPA P8, Section 2. The solvent used shall meet the requirements of AWPA Standard P9, Hydrocarbon Solvent, Type A or Type C, depending on the product being treated and the specifications.

• Solution Filtration — The Copper Naphthenate solution in use shall be filtered or otherwise kept clean regularly to remove solids which may otherwise be deposited on the wood during treating.

• Follow good housekeeping practices to minimize sawdust and other surface residues on the wood products prior to treatment.

POST TREATMENT PROCEDURES - OIL CARRIER

For Copper Naphthenate treated products with an oil carrier to be used in an aquatic environment, use one or both of the following BMPs:

• Expansion Bath — This process increases the temperature of the preservative solution surrounding the wood for the purpose of recovering excess preservative and improving surface cleanliness of the product.

Use a minimum expansion bath of one hour. The maximum temperature of the expansion bath shall be 220˚F or 230˚F depending on the specific commodity standard limitations.

The expansion bath shall be followed by a vacuum period using a minimum of 22" for a minimum of two hours.

• Final Steaming — Following the pressure period and once the Copper Naphthenate has been pumped back to the storage tank, a vacuum shall be applied for a one hour minimum at not less than 22" of vacuum to recover excess preservative. Following the vacuum period, the wood shall be subjected to steaming for a two-hour time period for lumber and timbers and three hours for piling per the limitations of the AWPA Commodity Standards. The minimum temperature during steaming shall be 200˚F and the maximum shall be 240˚F to 245˚F depending on the species being treated. After steaming, apply a final vacuum for a minimum of four hours at 22" of vacuum.

POST TREATMENT PROCEDURES - “LIGHT” SOLVENT CARRIER

For Copper Naphthenate treated products with a light solvent carrier, such as AWPA Standard P9, Type “C” solvent for aquatic environment applications, use the following BMP:

• A final vacuum shall be used for a minimum of 1 hour at a minimum of 22" vacuum.

MAXIMUM CHEMICAL LOADING

Treating shall be conducted in such a manner as to seek to minimize the amount of chemical placed into the wood while assuring conformance with the AWPA retention and penetration requirements.

VISUAL INSPECTION

Prior to shipment and/or installation in aquatic environments, visually inspect the treated wood product and reject any pieces with excessive surface residue. Note, however, that an oil carrier may be detected in a surface wipe of a properly treated and acceptable product. Avoid excessive solids or grease-like deposits which can be scraped off the surface. Also, reject material where liquid preservative “bleeds” from the product.

FIELD TREATING GUIDELINES

Copper Naphthenate based solutions are commonly used in field treating of holes, cuts or injuries which occur to the treated product. The objective of field treatment is to assure complete product treatment.

The following guidelines should be followed in field treating aquatic projects:

- Follow the procedures outlined in AWPA Standard M4, Standard for the Care of Preservative-Treated Wood Products.
- When field treating by brushing, spraying, dipping or soaking do so in such a manner that the preservative does not drip or spill into the aquatic environment or onto the soil.
- Whenever possible, apply field treatments prior to assembling the structure over the body of water.
- Conduct the application of the preservative so that any overspray or drippage of preservative can be recovered or retained.

TECHNICAL NOTES

MAXIMUM CHEMICAL LOADING -- Earlier efforts to set precise maximum chemical loading levels have proven technologically unachievable due to the inherent variability found in wood including cell structure and amount of sap versus heartwood. Industry remains focused on conducting the necessary research to reduce required chemical levels in the AWPA standards consistent with maintaining the needed protection provided by treating.

BEST MANAGEMENT PRACTICES

for

PENTACHLOROPHENOL (PENTA)

USES AND SPECIFICATIONS

Pentachlorophenol (Penta) is a preservative that has limited uses in aquatic environments, but has a number of above water applications. The specific commodity standards that should be used to specify the preparation and use of various Penta treated products used in freshwater, or above the splash zone in marine aquatic environments are:

C2 -- Lumber, Timbers, Bridge Ties and Mine Ties, Pressure Treatment
C3 -- Piles
C14 -- Wood for Highway Construction
C28 -- Laminated Beams

Specifiers and installers should follow the guidance in the Pentachlorophenol treated wood Material Safety Data Sheets (MSDS) and hazard labels as required by OSHA and use the product in conformance with the Consumer Information Sheet for Pentachlorophenol pressure treated wood.

BEST MANAGEMENT PRACTICES

The BMPs for Penta are to ensure responsible treatment and product use. Its use in marine projects should be limited to above the splash zone because Penta does not protect against marine organisms. In order to minimize the amount of Penta material available to migrate into the environment, use the following guidelines when treating material for use in marine applications:

TREATMENT PROCEDURES

Manage the treating plant's "in-use" Penta by continuous filtration or other available methods to maintain the solution with minimum particulate matter. Such processes will result in less surface deposits, minimizing the amount of material which may be released from in-service wood.

• Treating Recommendations — While there are various pressure and thermal treatment methods, a common wood treating process using Penta is called the "empty cell" process. The wood may be treated using the empty cell (Rueping or Lowry) process according to the applicable AWPA Standards, Sections C2, C3 and C4, including appropriate post treatment steps such as vacuums, expansion baths in oil, and post steaming to clean the wood surface.

• Follow good housekeeping practices to minimize sawdust and other surface residues on the wood products prior to treatment. If necessary, power wash to remove excess surface deposits.

• Conditioning — Remove the water prior to treatment. Reduce the wood's moisture content by one of several conditioning processes which includes air seasoning, kiln drying, in-cylinder steaming and subsequent vacuum, or heating under a vacuum in the presence of the treating solution followed by a vacuum (Boultonizing).

• Preservative Impregnation — With the dried wood in the treating cylinder, apply initial air pressure. The initial air amount is dictated by the dryness of the wood, the species of wood being treated, plant equipment capabilities and the target retention level. Initial pressures in the range of atmospheric to 50 psi are common.

After achieving the desired initial air pressure, pump the treating solution into the treating cylinder, and maintain the air pressure while filling the cylinder. Supply additional treating solution into to the cylinder until attaining a calculated gross injection.

POST TREATMENT PROCEDURES

Following injection, relieve pressure and remove excess solution from the cylinder followed by a vacuum application to encourage removal of excess preservative and pressurized air from the wood cells.

• Surface treatment — Incorporate one of the following procedures into the treating process to minimize the amount of residual treating which may occur on the treated product surface. Techniques may vary depending upon the product type and wood species.

- • Steaming — After applying the vacuum to the treating cylinder for a period of time, apply final steaming to remove excess preservative solution from the surface of the wood.
- • Expansion Bath — When final steaming is not utilized the treater may use an expansion bath. Perform this expansion bath in accordance with AWPA Specification 2.23 of C1.

Following the above procedures should result in a clean and dry treated wood product.

MAXIMUM CHEMICAL LOADING

Treating shall be conducted in such a manner as to seek to minimize the amount of chemical placed into the wood while assuring conformance with the AWPA retention and penetration requirements.

VISUAL INSPECTION

Visually inspect the Penta product to insure no excessive residual materials or preservative deposits exist. If the material does not appear clean and dry, it shall be rejected. Once on the site and prior to installation, visually inspect the materials in accordance with the above directions. Reject materials which have developed areas of “bleeding” or those that do not meet the clean and dry appearance criteria. Good housekeeping is essential to avoid surface deposits and keep the product clean until shipment and installation.

TECHNICAL NOTES

Surface Sheen — When driving Penta treated wood, a visible sheen may develop on the water surface. This sheen contains a negligible quantity of Penta as there is generally less than 1% Penta in Penta treated wood. In nearly all instances this sheen will cease in less than 24 hours through bio and photodegradation. Available data indicates that this sheen does not represent any harm to aquatic life nor will it enter the food chain. It is basically an aesthetic concern which decreases rapidly following installation.

MAXIMUM CHEMICAL LOADING -- Earlier efforts to set precise maximum chemical loading levels have proven technologically unachievable due to the inherent variability found in wood including cell structure and amount of sap versus heartwood. Industry remains focused on conducting the necessary research to reduce required chemical levels in the AWPA standards consistent with maintaining the needed protection provide by treating.

BEST MANAGEMENT PRACTICES
for
QUALITY CONTROL & PRODUCT ASSURANCE

BMPs — A SHARED RESPONSIBILITY

While the wood treating industry supports and encourages the use of the BMPs for aquatic applications of its products, it is a free enterprise industry and compliance cannot simply be assured. The significant increased cost of the BMPs create an incentive for some producers to avoid the extra efforts. **It is the government agency regulators and project specifiers who have the ability to ensure BMPs implementation. Until a more standardized system is developed (see discussion below), BMP use can be immediately implemented by:**

- **Regulators, in approving projects, and designers, in specifying materials should require that "the treated wood products used in this project shall be produced in accordance with the most current version of the Best Management Practices for Treated Wood in Western Aquatic Environments, as per the Western Wood Preservers Institute and Canadian Institute of Treated Wood."**

- **The producer of the products should be required to provide a "written certification that BMPs were utilized including a description and appropriate documentation of the BMPs used."**

FUTURE QUALITY ASSURANCE & THIRD PARTY INSPECTION

In addition to continuing efforts to improve and refine the BMPs, the treated wood industry is in the process of developing a BMP quality assurance identification mark linked with a third party inspection system. The inspection would provide oversight to ensure that the plants are properly and consistently utilizing the BMPs and that the products meet the BMP required results. It is WWPI's goal to implement such a system in 1997.

BEST MANAGEMENT PRACTICES

ENVIRONMENTAL CONSIDERATIONS FOR USING BMP TREATED WOOD IN AQUATIC PROJECTS

Preservatives protect wood by inhibiting fungal and borer attack. The effectiveness of these treatments is achieved by forcing naturally occurring metals (copper, chromium, zinc, arsenic) or polycyclic aromatic hydrocarbons (PAH) into the wood under pressure. In properly treated wood, preservatives are stable and minimal amounts are lost. However, the biological risks associated with these releases have caused concern within some government regulatory agencies. In response to these concerns, the Institutes have commissioned extensive literature reviews and environmental risk analyses associated with the major preservative treated wood products utilized in aquatic environments. Through these ongoing efforts, over 7000 pages of information regarding these risks have been reviewed and analyzed. This research effort resulted in the production of detailed risk assessment documents and computer risk assessment models for creosote, CCA and AZCA which discuss and quantitatively predict the environmental levels of preservatives associated with treated wood products. In addition to these currently available tools (see summary discussions below), a similar analysis and model is nearing completion for ACQ. These tools, available through the Institutes, are intended to allow the regulator or specifier to assess the potential environmental impact of using treated wood products where site specific information justifies such analysis. Such intense review and modeling is not considered appropriate for preservatives normally limited to above water uses such as Penta, and Copper Naphthenate.

ENVIRONMENTAL RISKS ASSOCIATED WITH CREOSOTE

The compounds of concern in creosote are called polycyclic aromatic hydrocarbons (PAH). These compounds are naturally produced and have been ubiquitous on earth since carbon was first fixed in organic compounds. Annual inputs of PAH to aquatic environments, from all sources, is estimated at half a billion pounds worldwide. Much of this input is from natural sources such as forest fires. However, inputs from cities and industry can result in the localized accumulation of PAH, in sediments, to levels that are toxic to aquatic organisms.

Polycyclic aromatic hydrocarbons are hydrophobic and rarely occur in the water column at levels that are toxic to aquatic organisms. In healthy sediments, with adequate oxygen, naturally occurring microbes metabolize PAH. However, where sediments are devoid of oxygen, these compounds can accumulate to levels that cause acute and chronic toxicity in a variety of fish and invertebrates.

The use of creosote treated piling in fast flowing water with sandy or gravely substrates generally poses no risk. However, the use of large amounts of creosote treated wood in very poorly flushed waterbodies, especially those with muddy sediments that lack oxygen, can result in the accumulation of toxic levels of PAH. To help identify these high risk areas, WWPI has sponsored the creation of computer models which predict the accumulation of PAH in sediments as a function of several important parameters. Testing the creosote model under two worst case studies in Canada demonstrated its ability to very accurately predict sediment levels of PAH.

These models suggest that maximum concentrations of PAH occur within a few inches of a piling. Further, these models can be used to determine the minimum current speeds required, as a function of the amount of oxygen in the sediments, to help protect our aquatic resources against toxic levels of PAH. Table 1 can be used to predict conditions where individual site assessments are warranted.

This table is based on a sediment Total Organic Carbon (TOC) content of one percent. Different levels of TOC will result in different requirements. In open marine or freshwater environments, maximum currents are generally greater than 8 to 10 centimeters per second. The RPD is the Reduction Oxidation Potential Discontinuity. This is the depth at which the sediment color turns from gray-green to black. It is measured in centimeters below the sediment surface.

Minimum current speeds required to protect aquatic life are significantly less in constantly flowing water. The use of moderate amounts of creosote treated wood (fewer than five piling in a row parallel with the currents) is not likely to effect aquatic resources where the current speed is greater than 10 cm/sec. Where sediments are well oxygenated (RPD > 3 cm), current speeds as slow as 3 cm/sec are adequate to protect aquatic life.

TABLE 1

Minimum current speeds necessary to prevent unacceptable levels of PAH from accumulating in marine sediments with varying levels of oxygen (measured by the depth of the Redox Potential Discontinuity in centimeters).

Depth of the RPD	Minimum Currents Required*
0.0 cm	31.0 cm/sec
0.1 cm	14.5 cm/sec
1.0 cm	8.0 cm/sec
2.0 cm	4.0 cm/sec
>3.0 cm	3.0 cm/sec

*These currents should be measured three hours before, or after, slack tide on a tidal exchange to mean low water (18.6 year average of all low tides).

For a more detailed examination of these issues, please refer to the Creosote Risk Assessment documents and the CREORISK model. Both of these documents are available through the Institutes.

The following briefly summarizes environmental concerns regarding the use of creosote:

1. Water column levels of PAH associated with creosote treated wood do not pose significant risks in open bodies of water.

2. An in-depth analysis of creosote use in association with drinking water fully supports the EPA Consumer Information Sheet which allows the incidental use of creosote treated wood in drinking water supplies.

3. When large creosote projects are contemplated in poorly circulated water bodies where sediments contain low oxygen levels, a site specific risk assessment should be undertaken.

ENVIRONMENTAL RISKS ASSOCIATED WITH CCA -TREATED WOOD

The waterborne preservative CCA relies on copper and arsenic to protect wood. These naturally occurring metals are fixed in the wood fibers by the presence of chromium. However, small amounts do leach from preserved wood during the early stages of immersion. The CCA risk assessment clearly shows that copper is the metal of concern in aquatic environments. While copper is not a human toxicant (the water pipes in our homes are made of copper), it can be toxic at levels as low as six parts per billion to the embryos of sensitive bivalves and echinoderms. An exhaustive review of the published literature indicates that the EPA's fresh and marine water quality criteria for copper are adequate to protect all aquatic life.

Unlike the sediment concerns with PAHs found in creosote, dissolved copper in the water column presents the highest risk to aquatic organisms. Literature reviews and the predictions made by the CCARISK computer model suggest that if water column levels of copper are maintained below 2.9 parts per billion, then sediment levels of copper, chromium and arsenic will be well below thresholds associated with stress or disease.

The CCA piling risk assessment model indicates that water column copper levels associated with the use of a single CCA piling are approximately 25% of the EPA criteria when maximum currents are as slow as 0.5 cm/sec. Maximum currents this slow are rarely encountered in open aquatic marine environments. Projects located in constantly flowing rivers pose even less risk and steady state current speeds as slow as 0.1 cm/sec are sufficient to protect aquatic life. Therefore, in nearly all open environments, we can predict that CCA treated piling will have little, or no, impact on aquatic resources.

Bulkheads treated with CCA pose a different problem and the models predict that the EPA marine quality copper standard can be exceeded when maximum tidal currents are less than 4.0 cm/sec. Maximum currents this slow can be encountered in residential canals and other poorly circulated bodies of water. We recommend site specific risk assessments when bulkheads are proposed in any poorly circulated body of water. However, when maximum current speeds are greater than 5.0 cm/sec, or in open water bodies with significant wave action, CCA treated bulkheads will not lose enough copper to exceed EPA water quality criteria, even during the first few days after installation.

Leaching data from a variety of sources accumulated over the last 28 years indicates that copper losses from CCA treated wood are time dependent and that losses are very small after 90 days. Recently completed leaching studies on piling that had been previously immersed in sea water for 16 months have confirmed previous predictions that long term copper losses are approximately 4% of the initial losses upon which environmental risks are based.

Where large surface area projects are proposed at poorly circulated sites, the project should be constructed during that time of year when sensitive bivalve and echinoderm larvae are not present (usually in late fall and winter). In addition, these are generally seasons of increased water circulation due to wind and wave action.

ENVIRONMENTAL RISKS ASSOCIATED WITH ACZA -TREATED WOOD

Ammoniacal Copper Zinc Arsenate (ACZA) is an improved preservative that replaces half of the arsenic in ACA with zinc. This preservative is suitable for treating difficult woods such as Douglas fir. The naturally occurring arsenic, copper and zinc metals used in ACZA are fixed to the wood fibers following evaporation of an ammonia carrier. However, small amounts of metal do leach from preserved wood during the early stages of immersion. The ACZA risk assessment clearly shows that copper is the metal of concern in aquatic environments. While copper is not a human toxicant (the water pipes in our homes are made of copper), it can be toxic at levels as low as six parts per billion to the embryos of sensitive bivalves and echinoderms. An exhaustive review of the published literature indicates that the EPAís fresh and marine water quality criteria for copper are adequate to protect all aquatic life.

Unlike the sediment concerns with PAHs found in creosote, dissolved copper presents the highest risk to aquatic organisms. Literature reviews and the predictions made by the ACZARISK computer model suggest that if water column levels of copper are maintained below EPA water quality copper criteria, then sediment levels of copper, zinc and arsenic will be well below thresholds associated with stress or disease.

Slightly more copper is lost from ACZA treated wood during the first week to 10 days than is lost from CCA treated piling. However, metal losses decline more quickly in ACZA treated wood, and reach very low values in less than two weeks. The ACZA model predicts that minimum current speeds (measured three hours before or after slack tide on an exchange to mean low water) of 1.0 cm/sec are sufficient to insure that copper losses from a single ACZA treated piling do not elevate marine water copper concentrations by an amount equal to the EPA marine water quality criteria (2.9 ppb). In constantly running water, such as rivers, a minimum current speed of 0.5 cm/sec is required to meet EPA fresh water quality criteria (assuming background copper levels are at 1.5 ppb. Very few rivers and streams have current speeds this slow. Even backwater estuaries typically have current speeds greater than three or four centimeters per second. The 1.5 ppb background copper level is typical of western rivers such as the Columbia River.

Bulkheads treated with ACZA pose a different problem and the models predict that EPA water quality standards can be exceeded during the first few days following installation when steady state current speeds are less than 18.5 cm/sec in fresh water and when maximum tidal currents are less than 13 cm/sec in marine environments. These are typical current speeds in open rivers and marine environments. However, currents slower than these can be encountered in quiet riverine backwaters and protected marine embayments. We recommend a site specific risk assessment whenever an ACZA bulkhead is proposed for use in the water.

Leaching data indicates that metal losses from ACZA treated wood are time dependent, and that losses are very small after one or two weeks. When large surface area ACZA projects are proposed at poorly circulated sites, the project should be constructed during that time of year when sensitive aquatic species, including migrating salmon, are not present (usually in winter). In addition, these are generally seasons of increased water circulation due to wind and wave action.

SUMMARY

It is the view of the Western Wood Preservers institute and the Canadian institute of Treated Wood that, based on the best available scientific information, the combination of the AWPA treating standards and BMPs for Creosote, CCA, ACZA, ACA, ACQ, Copper Naphthenate and Pentachlorophenol will produce products that provide excellent environmental performance in most open aquatic environments. Projects calling for large volumes of treated wood immersed in (i.e., below the splash zone) poorly circulating bodies of water should be evaluated on an individual basis utilizing risk assessment procedures. The Institutes will assist treated wood users in determining when a risk assessment is needed and in providing documentation to assist in the completion of a risk assessment, when required.

NOTE: USA AND CANADIAN VERSIONS

Both a USA and Canadian version of this document have been prepared. However, the differences are minimal, reflecting only the slight differences in the appropriate product standards between those of the American Wood Preservers Association and the Canadian Standards Association.

DISCLAIMER

If you have questions, need additional copies of this document, or guidance on specifying treated wood in aquatic environments, please contact:

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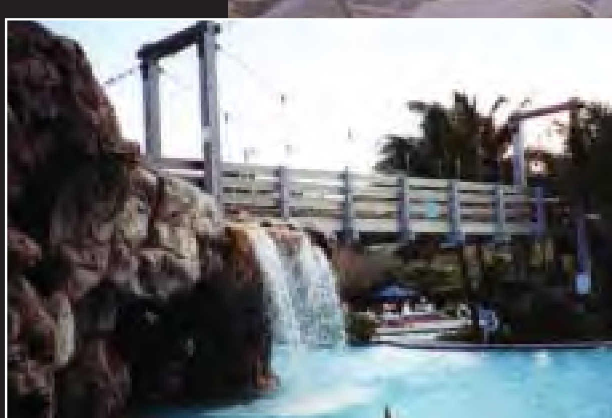
Printed in the USA on Recycled Paper

Volume II
Section IV
WWPI Documents

3. **Treated Wood in Aquatic Environments.** Semi-technical document. Has section on selection of preservative with retention recommendations. Also has WWPI risk matrix.

Treated Wood in Aquatic Environments

TIMBERPILINGCOUNCIL
FOUNDATION & MARINE PILING



A Specification and Environmental Guide to Selecting, Installing and Managing Wood Preservation Systems in Aquatic and Wetland Environments

Your Internet Companion Additional materials and references are provided throughout this document and are all available via the Internet at www.WWPInstitute.org, www.spta.org, www.timberpilingcouncil.org

- **If you are** *viewing this document online*, **you need only double click on the reference indicated by blue or green print and a number** (1).
- **If you are** *working from a hard copy* **and want to check the referenced materials: Go to one of the sites, select "Treated Wood in Aquatic Environments" and then select "Guide Companion." Simply click on the number** (1), (2) **etc. of the text reference and it will take you to the document and/or specific reference area.**

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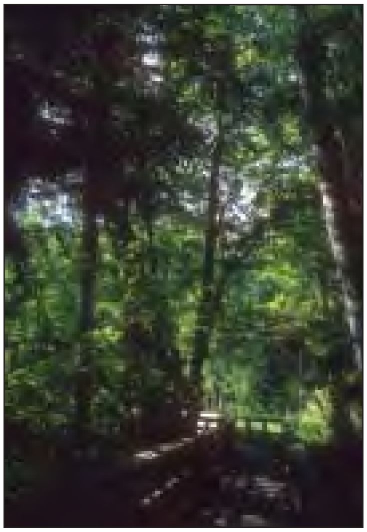


Terminology

To take full advantage of this guide, it will be important to understand critical terminology referred to throughout the publication. Following are definitions you'll need to know.

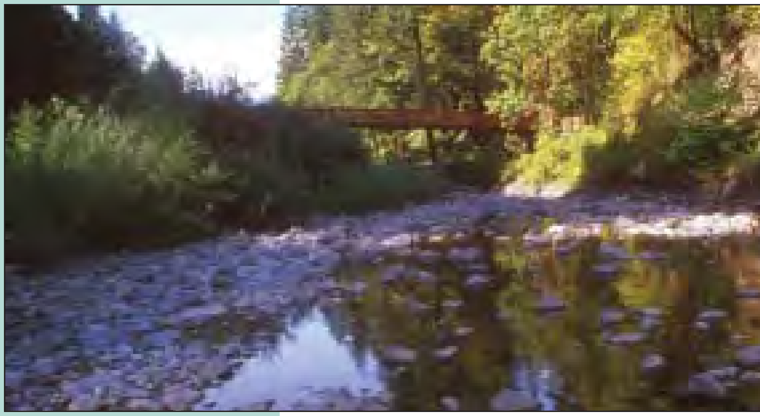
Standards The American Wood-Preservers' Association (AWPA) is the national standards-setting organization for treated wood in the U.S. and its counterpart in Canada is the Canadian Standards Association (CSA). The consensus standards of these two organizations establish what preservatives and chemical formulations are appropriate for common applications; set treating procedures; establish wood species requirements and testing procedures. The AWPA standards establish treatment requirements for wood products in Standard U1, "Use Category System: User Specification For Treated Wood." Section 2 of the standard will guide users to the appropriate Commodity Specifications in Section 6. These include the specifications for sawn products, posts, crossties and switchties, poles, round timber piling, wood composites, marine (salt water) applications, fire retardants and nonpressure applications.

Best Management Practices (BMPs) These are a set of environmental guidelines established by the Western Wood Preservers Institute and Wood Preservation Canada for products used in aquatic applications. They are formally known as the *Best Management Practices for the Use of Treated Wood in Aquatic Applications* (BMPs). Inspection services and a BMP Certification Mark program are available for BMP materials.

Consumer Information Sheets or Consumer Safety Information Sheets For wood treated with restricted-use preservatives, EPA has approved Consumer Information Sheets (CIS) and Consumer Safety Information Sheets (CSIS) to provide guidelines for safe and appropriate use of these materials. In addition, producers will provide Material Safety Data Sheets (MSDS) for the treated wood.

Incising Many species, such as western softwoods, do not accept pressure treating easily and must be *incised* to ensure adequate penetration to meet the treating standards. Incising is a process where small cuts are made on the wood surface in a regular pattern to enhance preservative penetration. Incising does *not* need to be specified since the requirements for each species are included in the AWPA C Standards. For aesthetic reasons, designers may choose species which do not require incising in the standards; others may forego incising on non-structural components of a project, recognizing the wood will not meet AWPA standards, although this practice is not recommended.

Penetration In general, only a shell of material around the perimeter of the wood is treated. *Penetration* is the measure of how deep the treatment extends into the wood. Required minimum penetration depths and percentage of sapwood treated are stipulated for each wood species, type of preservative and end use by AWPA standards. Project engineers and end users *do not* need to specify penetration depth, but instead merely the acceptable wood species, preservatives, AWPA Standard U1, and applicable Use Category.



Pressure Treatment The term *pressure treated wood products* generally refers to wood products that have been treated in a pressure cylinder, called a *retort*, in a highly controlled process using pressure to force the needed amount of preservative chemical into the wood. Depending upon the preservative system, the wood may be conditioned prior to treatment through drying or in the retort using steam and vacuum processes. Finally, the retort is filled with the treating solution in either a water- or oil-based carrier; then pressure is applied and held for a set amount of time. At the end of the treating cycle, the cylinder is drained and excess preservative is drawn off with vacuum before the wood is removed to the drip pad area, where it is held until free of preservative drippage. Sample borings are taken and tested to be sure the material *penetration* and *retention* standards have been met.

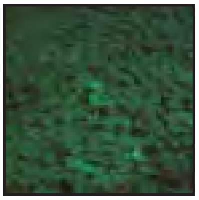
Quality Assurance Structural materials produced by the industry are subject to plant quality control procedures and third-party inspection to assure compliance with the AWPA standards. Building codes require that all treated wood used in structural applications must be inspected by an American Lumber Standard Committee (ALSC) accredited third-party agency.

Quality Assurance Information (7)

Registered Preservatives Wood-treating chemicals are pesticides and as such go through rigorous periodic review by the Environmental Protection Agency, Health Canada's Pesticide Management Regulatory Authority (PMRA), and/or state agencies. These detailed scientific health and environmental studies establish if the chemical will be registered as a wood preservative, and if so, what conditions apply. They may be classed, as most are, as restricted-use pesticides that can only be used by certified applicators in approved treating plants and only for certain uses. Alternatively, they may be classified as a general use pesticide and available for treatment of wood used for non-industrial applications as well as for field treating of drill holes or abrasions in treated materials.

Retention Retention is a measure of the amount of treatment chemical present in the portion of wood called the assay zone. It is measured in *pcf* – pounds of preservative per cubic foot – or kg/m^3 of the assay zone. Retention is cited in the Standards both as pcf and in kilograms per cubic meter, but this document will use only pcf. In AWPA standard U1, minimum retention values are defined by reference to the applicable Use Category in each commodity specification. Although retention values are included in this document for your information, when specifying, reference the applicable Use Category to ensure the proper retention level.

Treated to Refusal Sometimes hard-to-treat materials are placed in the treating cylinder (retort) for a long period at a given pressure to force as much preservative into the wood as possible. Often such materials *do not* meet the penetration and/or retention requirements. *Treated to Refusal* material should *not* be accepted in lieu of material inspected and marked as meeting the specified retention.



Why Treated Wood?

Wood's structural, economic, environmental and aesthetic benefits make it the preferred building product in a wide variety of construction applications – including bridges, boardwalks, piers and structures in or near our waterways and wetlands.

Wood's one weakness is its susceptibility to attack by natural enemies - marine borers, insects, decay and fungus. For most species, this means its useful life in open environments can be measured in terms of only a few years. Over the past century a variety of wood preserving treatments have been developed that introduce a small controlled amount of protective preservative into wood cells. The life of treated wood products can now be measured in terms of decades, not years.

For well over a century, treated wood has played an essential role in the economic prosperity and quality of life in North America. From the ties that carry the trains; to the poles that carry communications and power; to bridges that cross our rivers; to docks and piers that support recreation and commerce; to boardwalks that allow school children to view the wonders of sensitive wetland habitats, treated wood has been the preferred, time-proven material.

The environmental awakening of our society in the second half of the twentieth century brought an appropriate and continuing review of treated wood. Wood-treating chemicals became regulated by the environmental agencies, which produced guidelines intended to protect human health and the environment.

It was not until the 1990s that the potential impacts of treated wood used in our most sensitive ecosystems – aquatic environments – was the focus of close scientific study. Various governmental agencies, universities and the wood treating industry have undertaken extensive efforts to understand the potential effects of treated wood in aquatic environments. This continuing work has produced a substantive base of scientific knowledge about the behavior of treated wood and the level of risk it represents when used in aquatic environments. A worldwide review failed to find a single case where appropriately produced and installed treated wood products resulted in a significant adverse environmental impact. Studies of treated wood in the most sensitive aquatic environments have shown that the risks associated with treated wood are small and easily manageable.

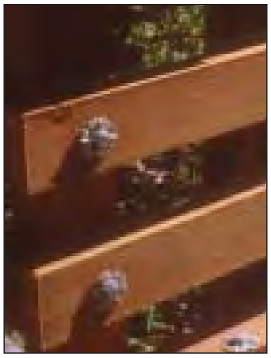
Protection of water quality and diversity of various life forms found in the lakes, streams, estuaries, bays and wetlands of North America is a responsibility shared by every private and corporate citizen. The treated wood industry is committed to actively supporting this important societal value. The purpose of this guide is to help you understand the facts and provide the tools and guidance to ensure that treated wood products are selected, specified and used in an environmentally appropriate manner.

Five Steps to Appropriate Use of Treated Wood in Aquatic Environments

This guide will help you understand the science and learn how to select and manage your use of treated wood to achieve the performance your project requires while minimizing the potential for any adverse environmental impacts. The process begins at project conception and tracks all steps through installation and maintenance.

The five basic steps are:

1. Selecting the Proper Preservative and Retention Level
2. Environmental Considerations and Evaluations
3. Specifying the Best Management Practices
4. Providing Quality Assurance and Certification
5. Appropriate Handling, Installation and Maintenance



Step 1: Selecting an Appropriate Preservative and End Use Category

(8) *U.S. Forest Products Lab*

To use treated wood appropriately, you need to fully understand your treatment options and how to select and specify material for different uses. A more extensive discussion of Wood Preservation can be found in the U.S. Forest Products Lab (FPL) Wood Handbook.

The initial step in specification for a particular application (piling, decking) is to determine the desired preservative for the project and select the appropriate End Use Category. These judgments should be made in conjunction with the environmental evaluation in Step 2.

Treatments Available for Use in Aquatic and Wetland Projects

While AWPA has identified 27 different preservative systems, only seven are commonly available and designated for freshwater and/or marine aquatic uses by AWPA standards and governmental registrations. These preservative systems can be divided into two general categories – Waterborne and Oil-type systems. The distinctions between them follow.

Waterborne Systems

(8A) *U.S. Forest Products Lab*

In waterborne systems, water is the carrier for the preservative chemicals. The chemicals react or precipitate into the wood substrate and become attached to wood cells, minimizing leaching. There are five main waterborne preservatives used in aquatic applications:
CCA – Chromated Copper Arsenate; **ACZA** – Ammoniacal Copper Zinc Arsenate;
ACQ – Alkaline Copper Quat; and **CA-B** – Copper Azole.

(9) *Preservative-specific Links*

Waterborne preservatives leave a dry, paintable surface and are commonly used in aquatic projects such as docks, boardwalks and bulkheads. For a detailed discussion of the preservative formulations in waterborne systems, refer to the U.S. Forest Products Lab Handbook or specific chemical manufacturer's web sites.

Oil-type Preservatives

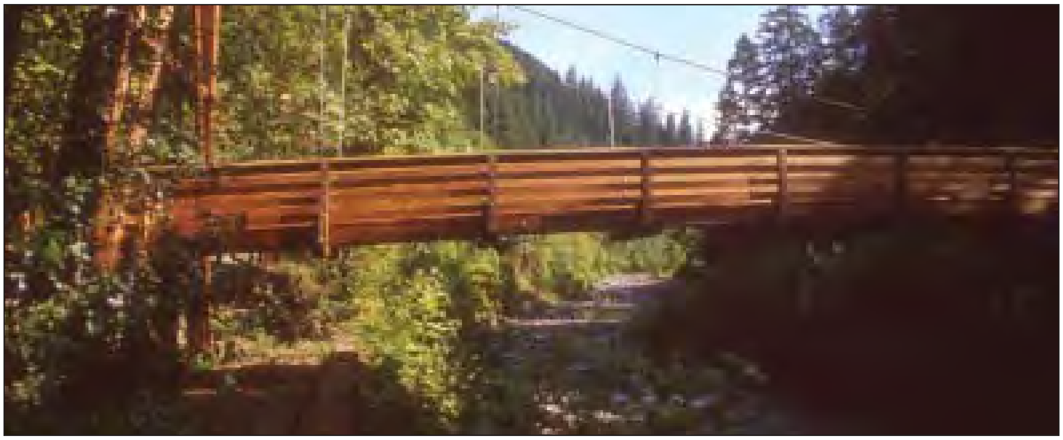
In oil-type systems the preservative is 100 percent active (creosote) or dissolved in an oil-based solvent. The mixture then fills or coats the wood cell walls during treatment. There are three oil-type preservatives that are used in aquatic or wetland applications: **Creosote, Pentachlorophenol** and **Copper Naphthenate**.

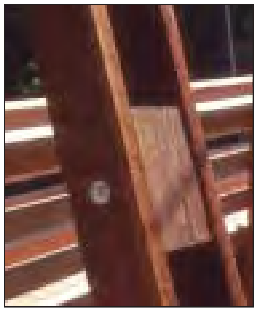
(6) *Consumer Information Sheets or Consumer Safety Information Sheets*

Oil-type preservatives are commonly used to treat round, solid-sawn and laminated products used in aquatic applications for piling, timbers, bulkheads, bridges and board walks. Because of their oil carrier and possible aroma, they are not acceptable for applications involving frequent or prolonged skin contact or interior uses unless the wood is sealed.

(8B) *U.S. Forest Products Lab*

The oil present in these preservative systems also acts as a water repellant and can help limit checking and splitting. You may select the type of carrier oil to meet specified uses – such as selecting light solvents where a clear untreated appearance is desired with Penta or Copper Naphthenate. For a detailed discussion of the preservative formulations for oil-type preservatives, refer to the U.S. Forest Products Handbook.





Selecting the Appropriate End Use Category

AWPA Standard U1, The Use Category System: User Specification for Treated Wood, is based on the end use hazard, similar to other international standards for w ood treatment. The Use Category System (UCS) is used to specify the w ood treatment based on the desired w ood species and the environment of the intended end use. There are six Use Categories which describe the exposure conditions that wood may be subject to in service. Use categories 3, 4 and 5 have multiple risk levels.

Use Category UC1 Wood and wood-based materials used in interior construction not in contact with the ground or foundations.

Use Category UC2 Wood and wood-based materials used for interior construction that are not in contact with ground, but may be subject to dampness. These products are continuously protected from the weather but may be exposed to occasional sources of moisture.

Use Category UC3A Wood and wood-based materials used for exterior construction that are coated and not in contact with the ground. Such products may be exposed to the full effects of weather, such as vertical exterior walls or other types of construction that allows water to quickly drain from the surface.

Use Category UC3B Wood and wood-based materials used in exterior construction and not in contact with the ground. Materials do not require a coating, but ma y be finished to achieve a desired aesthetic appearance. (Retentions above the minimum specified for materials in the use category ma y be required for products where the individual components are difficult to maintain, repair or replace and are critical to the performance and safety of the entire system).

Use Category UC4A Wood and wood-based materials used in contact with the ground, fresh water, or other situations favorable to deterioration.

Use Category UC4B Wood and wood-based material used in contact with the ground either in a severe environment, such as horticultural sites, in climates with a high potential for deterioration, in critically important components such as utility poles, building poles and permanent w ood foundations, and wood used in salt water splash zones.

Use Category UC4C Wood and wood-based material used in contact with the ground either in a severe environment, or climates demonstrated to have extremely high potential for deterioration, in critical structural components such as land and fresh water piling and foundation piling, and utility poles located in a semi-tropical or tropical environment.

Use Category UC5A Wood and wood-based materials exposed to salt and brackish water generally to the north of New Jersey on the East Coast and north of San Francisco on the West Coast to the extent that the marine borers can attack them.

Use Category UC5B Wood and wood-based materials exposed to salt and brackish water between New Jersey and Georgia on the East Coast and south of San Francisco on the West Coast to the extent that the marine borers can attack them.

Use Category UC5C Wood and wood-based materials exposed to salt and brackish water south of Georgia and along the Gulf Coasts in the Eastern U.S. as well as Ha waii and Puerto Rice, to the extent that the marine borers can attack them.

Which Preservative to Use?

Given the proper standard, many factors enter into your decision on which specific preservative meets your needs best. You will likely weigh the economics, type of project, wood species, aesthetics and availability as well as being sensitive to environmental concerns. These decisions are a matter of personal preference, organization policy, professional knowledge and the specific environment in which your project will be placed. To help you make your selection, you may want to investigate the links to manufacturers' preservative information.

WWPI Abbreviated Guide (2)

Use Category System (3)

Preservative-specific Links (9)

Guide to Retentions for Treated Wood End Uses

USE	AWPA STANDARD Use Category System	OIL-TYPE PRESERVATIVES Minimum Retentions – Pounds Per Cubic Foot[1] Copper Naphthenate	Creosote	Pentachlorophenol
BEAMS & TIMBERS, glue laminated before or after treatment				
Interior, dry	1	0.04	8.0	0.30
Interior, damp	2	0.04	8.0	0.30
Exterior, above ground	3B	0.04	8.0	0.30
Exterior, ground contact	4A	0.06	10.0	0.60
Highway construction	4B, 4C	0.080 – 0.15* *after gluing	9.0 – 12.0	0.45 – 0.60
HIGHWAY MATERIAL				
Lumber and timbers for bridges, structural members, bridge decking, cribbing and culverts	4B	0.075	10.0	0.50
Structural lumber, beams and timbers:				
– In saltwater use and subject to marine borer attack	5A, 5B, 5C	Not Listed	25.0	Not Listed
– Piles, foundation, land and fresh water use	4C	0.10 – 0.14	12.0 – 17.0	0.60 – 0.85
– Piling in saltwater use and subject to marine borer attack	5A, 5B, 5C	Not Listed	16.0 – 20.0	Not Listed
– Posts: Round, half-round, quarter-round (General const. – fence posts, sign posts, handrails)	4A	0.055	6.0 – 8.0	0.40
– Posts: Round, half-round, quarter-round (Guardrails, spacer blocks, critical structural members	4B	0.069	10.0	0.50
– Posts: Sawn (General const. – fence posts, sign posts, handrails	4A	0.06	10.0	0.40
– Posts: Sawn (Guardrails, spacer blocks, critical structural members	4B	0.075	10.0	0.50
LUMBER AND TIMBERS				
Above ground	3B	0.04	8.0	0.40
Ground contact and freshwater use	4A	0.06	10.0	0.50
MARINE LUMBER AND TIMBERS				
Members above ground and out of water but subject to saltwater splash	4B, 4C	0.06, 0.075	10.0, 12.0	0.50, 0.60
In brackish or saltwater use and subject to marine borer attack	5A, 5B, 5C	Not Listed	25.0	Not Listed
PILES				
Foundation, land and freshwater use (round)	4C	0.10 – 0.14	12.0 – 17.0	0.65 – 0.85
Marine (round) in salt or brackish and subject to marine borer attack	5A, 5B, 5C	Not Listed	16.0 – 20.0	Not Listed
Marine, dual treatment (round) for maximum protection	5B, 5C	Not Listed	20.0	Not Listed
Sawn timber piles	4B, 4 C	.075	10.0 – 12.0	0.50
PLYWOOD				
Sub-floor, damp, above ground	2	0.04	8.0	0.40
Exterior, above ground	3B	Not Listed	8.0	0.40
Soil contact	4A	Not Listed	10.0	0.50
Marine	5A, 5B, 5C	Not Listed	25.0	Not Listed

NOTE: *This is a summary document only; for complete information, see AWPA Book of Standards.*

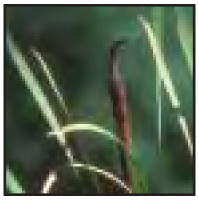
[1] Retentions vary because of differences in wood species or project location.
[2] Alkaline Copper Quat
[3] Ammoniacal Copper Zinc Arsenate
[4] Copper Azole
[5] Salt water splash only; sawn members must be 2″x 8″ or 3″x 6″ in nominal dimension or larger.
[6] Chromated Copper Arsenate
[7] It is generally recognized that Douglas fir is extremely difficult to treat with CCA to required penetration and retention.

Guide to Retentions for Treated Wood End Uses

USE	WATERBORNE PRESERVATIVES Minimum Retentions – Pounds Per Cubic Foot[1]			
	ACQ[2]	ACZA[3]	CA-B[4]	CCA[6,7]
BEAMS & TIMBERS, glue laminated before or after treatment				
Interior, dry	0.25	0.25 – 0.30	Not Listed	0.25*
Interior, damp	0.25	0.25 – 0.30	Not Listed	0.25*
Exterior, above ground	0.25	0.25 – 0.30	Not Listed	0.25*
Exterior, ground contact	0.40	0.40 – 0.60	Not Listed	0.40*
Highway construction	Not Listed	0.40 – 0.60*	Not Listed	0.40*
		*before gluing		*before gluing
HIGHWAY MATERIAL				
Lumber and timbers for bridges, structural members, bridge decking, cribbing and culverts	0.60	0.60	0.31	0.60
Structural lumber, beams and timbers:				
– In saltwater use and subject to marine borer attack	Not Listed	2.50	Not Listed	2.50
– Piles, foundation, land and fresh water use	Not Listed	0.80 – 1.0	Not Listed	0.80 – 1.0
– Piling in saltwater use and subject to marine borer attack	Not Listed	1.50 – 2.50	Not Listed	1.50 – 2.50
– Posts: Round, half-round, quarter-round (General const. – fence posts, sign posts, handrails)	0.40	0.40	0.21	0.40
– Posts: Round, half-round, quarter-round (Guardrails, spacer blocks, critical structural members	0.50	0.50	0.31	0.50
– Posts: Sawn (General const. – fence posts, sign posts, handrails	0.40	0.40	0.21	0.40
– Posts: Sawn (Guardrails, spacer blocks, critical structural members	0.50	0.50	0.31	0.50
LUMBER AND TIMBERS				
Above ground	0.25	0.25	0.10	Not Listed
Ground contact and freshwater use	0.40	0.40	0.21	Not Listed
MARINE LUMBER AND TIMBERS				
Members above ground and out of water but subject to saltwater splash	0.60	0.60	0.31	0.60[5]
In brackish or saltwater use and subject to marine borer attack	Not Listed	2.50	Not Listed	2.50
PILES				
Foundation, land and freshwater use (round)	0.80	0.80 – 1.0	Not Listed	0.80 – 1.0
Marine (round) in salt or brackish and subject to marine borer attack	Not Listed	1.50 – 2.50	Not Listed	1.50 – 2.50
Marine, dual treatment (round) for maximum protection	Not Listed	1.0	Not Listed	1.0
Sawn timber piles	0.60	0.60 – 0.80	Not Listed	0.60 – 0.80
PLYWOOD				
Sub-floor, damp, above ground	0.25	0.25	0.11	0.25
Exterior, above ground	0.25	0.25	0.11	0.25
Soil contact	0.40	0.40	0.21	0.40
Marine	Not Listed	2.50	Not Listed	2.50

NOTE: *This is a summary document only; for complete information, see AWPA Book of Standards.*

1 Retentions vary because of differences in wood species or project location.
2 Alkaline Copper Quat
3 Ammoniacal Copper Zinc Arsenate
4 Copper Azole
5 Salt water splash only; sawn members must be 2″x 8″ or 3″x 6″ in nominal dimension or larger.
6 Chromated Copper Arsenate
7 It is generally recognized that Douglas fir is extremely difficult to treat with CCA to required penetration and retention.



STEP 2: Environmental Considerations and Evaluations

Understanding Risk and Treated Wood

To protect wood from attack by insects and decay, materials must be treated with controlled amounts of preservatives. Like most chemicals (natural or man-made), they can be "toxic" to life forms at high enough concentrations. To manage the risk, society has turned to the Federal Environmental Protection Agency (US EPA) and other state or provincial agencies to conduct expansive scientific reviews of wood-treating preservatives to evaluate the risks to human health and the environment versus the benefits.

This process determines which treating preservatives will not be allowed, which will be allowed under strict application restriction and which will be allowed for more general use. The results are expansive regulations governing the handling and application of preservatives in the treating process and guidelines for the use of the products. Ongoing US EPA and Canadian registration processes are the first level of Risk Management.

The purpose of this document is to provide guidance to a second level of Risk Management for treated wood that is to be used in the most sensitive environments – waterways and wetlands.

After identifying a preferred preservative, you need to review your project for its potential environmental impacts. In rare instances, this review will cause you to change the preservative you have selected.

Environmental Concerns with Treated Wood

Nearly all materials, man-made or natural, placed in an aquatic environment will introduce chemicals which, if present in large enough concentration, will either immediately or over time pose a potential threat to plant and animal life forms dependent upon that environment.

A certain quantity of the chemicals used to preserve wood will leach or migrate from treated wood structures built in aquatic and wetland areas into the water column and surrounding sediments. The question is how much and when will the preservatives move into the environment and under what circumstances might they represent a significant risk. Section B of this report concentrates on the science behind this question. The following summarizes the issues.

Chemicals of Potential Environmental Concern

For all practical purposes only three compounds used in common preservative systems could potentially cause concern in aquatic environments. Understanding these chemicals will help assure that the products you specify and handle will avoid risk to the aquatic and wetland environments.

Copper

Copper is a commonly used component in several wood preservatives. Many preservatives classified "general use" by the EPA rely on copper as the principal component for biocidal activity. For waterborne systems and for oil-based copper naphthenate, the chemical of concern is copper. Fishes and aquatic organisms are much less tolerant of copper than are people or other mammals. If the levels of copper from treated wood are appropriately managed for aquatic use, other chemicals used in waterborne preservative systems such as arsenic, zinc, chromium, tebucoazole and quaternary compounds simply are not present at levels of concern. Extensively reviewed and published information is available on the effects of copper in the environment and the biological importance of copper.

CCA Assessment (10)
ACZA Assessment (11)
ACQ Assessment (12)
Copper Information (13)
CA-B Assessment (14)

PAH

The toxic compounds in creosote are called polycyclic aromatic hydrocarbons or PAH. These naturally occurring substances are also generated by forest fires, volcanoes, coal deposits and oil seeps. They are formed whenever there is combustion. Power generation, automobiles and asphalt paving are common sources of PAH associated with human activity. PAHs are not water soluble and are generally of little concern in the water column. However, they can accumulate in sediments to levels of 10 to 20 parts per million (ppm) that have been associated with cancer in fish.

PAHs are rarely found at concentrations that are acutely toxic to aquatic organisms except in association with historic industrial activities. Because they have been part of our environment long before mankind, they are metabolized by most organisms. In fact, bacteria efficiently break them down in healthy environments where there is sufficient oxygen, and they decompose more slowly in the absence of light or in anaerobic environments.

Creosote Assessment (15)

Pentachlorophenol

Pentachlorophenol (Penta) from treated wood may be dissolved in the water column and sorbed to matter in bottom sediments. Penta readily degrades in the environment by chemical, microbiological, and photochemical processes. Penta-treated materials used in aquatic applications are limited to above-water structures and freshwater pole or piling structures. If present in large enough quantities, penta may be toxic to fish and other aquatic life. Accumulation in fish and other animals is not a concern for penta.

Penta Assessment (16)

Where Are Preservatives a Concern?

The safety of treated wood products is confirmed by their long history of use without a single documented instance in which treated wood products have jeopardized natural environments. However, wood preservatives do leach or migrate from pressure treated wood at very low rates. Previous research has accurately defined these loss rates allowing industry to produce guidelines and risk assessment models that insure the continued safe use of these products. For example, Figure 1 on page 12 describes the loss of copper from CCA-C treated wood. Risk assessments are based on the first few days of immersion because that is when preservative loss rates are highest. These rates decline very quickly over time and are generally undetectable in the water after the first few weeks.

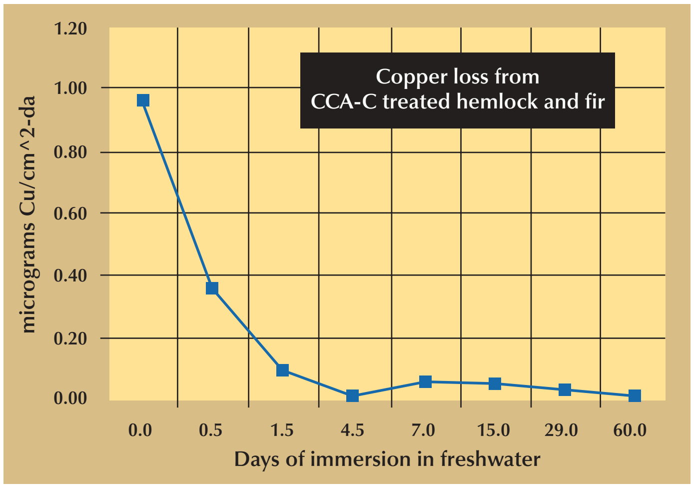


Figure 1

(17) *WWPI Risk Assessment Models*

Because of the very low amounts of chemical that will move into the environment, the appropriate use of treated wood will not represent an adverse risk except in cases where the sites were previously contaminated from other sources, or in very sensitive environments with almost no water current where very large projects are planned.

Environmental Evaluation and Risk Assessment

Knowledge of preservative loss rates from properly treated wood, when coupled with site-specific environmental data (such as water current speeds and background levels of metals and organics), allow the industry to use relatively simple computer models to predict the environmental response to any project you might design. These models have been peer-reviewed, repeatedly field-tested and proven to protect the environment. They are used by the U.S. Forest Service, U.S. Park Service, Environment Canada and Canadian Department of Fisheries & Oceans as well as a host of local and state regulatory bodies.

Examples of Typical Models

Example 1: The models have also been used to define categories of projects that should require no risk assessment and those where additional assessment should be carried out during the preliminary design phase. As an example, Tables A and B below describe the number of CCA-C, ACZA, ACQ-B, CA-B or Copper Naphthenate piling or timber that can be placed in a row paralleling freshwater currents without jeopardizing the environment. The tables were constructed assuming a receiving water pH of 6.5, hardness of 75 mg $CaCO_3$/L, and a background copper concentration of 1.5 µg Cu/L. These values are typical of many rivers and lakes in the country.

Most large lakes have current speeds greater than 2.0 cm/sec and river speeds greater than 10 cm/sec. Most projects being permitted today involve fewer that four piling placed in a row parallel to the currents (i.e. along the shore) and all four of the preservatives listed in the table are acceptable in most applications.

Table A: Guide for number of CCA-C, ACZA or Copper Naphthenate piling (see UCS 4C) that can be placed in a row paralleling freshwater currents without jeopardizing the environment.

Preservative	Day 0.5 loss rate micrograms Cu/cm²	Maximum Current Speed (cm/sec)							
		0.5	1.0	1.5	2.0	3.0	5.0	7.5	10.0
CCA-C	3.98	66	132	198	264	397	661	992	1322
ACZA	39.60	7	13	20	27	40	66	100	133
CuN	17.37	15	30	45	61	91	151	227	303

Table B: Guide for number of ACQ-B or CA-B timbers (see UCS 4A) that can be placed in a row paralleling freshwater currents without jeopardizing the environment.

Preservative	Day 0.5 loss rate micrograms Cu/cm²	Maximum Current Speed (cm/sec)							
		0.5	1.0	1.5	2.0	3.0	5.0	7.5	10.0
ACQ-B	44.10	6	12	18	24	36	60	90	119
CA-B	40.30	7	13	20	26	39	65	98	131

Example 2: Creosote-treated projects are typically located in marine environments and their evaluation is somewhat more complex. The figure below describes projects where creosote-treated wood should not be used without a risk assessment (red); where it is not likely to have an effect but caution suggests an individual risk assessment should be completed (yellow); and where creosote-treated projects are not likely to affect the environment and require no additional assessment (blue or green). The values in each cell are the maximum predicted sediment concentrations of PAH.

Creosote is broken down by microbes in sediments and microbes need oxygen to start that process. Therefore, the suitability of creosote in an environment depends in part on the availability of oxygen – as measured by the depth of the reduction-oxidation potential discontinuity (RPD) in this chart. The RPD in healthy environments is generally greater than 3 cm and typical maximum current speeds present in most projects will be > 3 to 5 cm/sec. In sum: the typical small creosote-treated piling project is not likely to affect healthy marine environments.

Table C: Creosote Guide for determining need for Risk Assessment (RA).
Red: RA recommended; Yellow: RA advised; Green or Blue: no RA needed

	Depth of Reduction-Oxidation Potential Discontinuity (cm)						
Maximum current speed (cm/sec)	0.0	0.5	1.0	1.5	2.0	3.0	4.0
0.5	262.96	120.25	66.79	43.83	33.05	25.50	24.57
1	131.48	60.13	33.40	21.91	16.52	12.75	12.29
2	65.74	30.06	16.70	10.96	8.26	6.37	6.14
3	43.83	20.04	11.13	7.30	5.51	4.25	4.10
4	32.87	15.03	8.35	5.48	4.13	3.19	3.07
5	26.30	12.03	6.68	4.38	3.30	2.55	2.46
6	21.91	10.02	5.57	3.65	2.75	2.12	2.05
7	18.78	8.59	4.77	3.13	2.36	1.82	1.76
8	16.43	7.52	4.17	2.74	2.07	1.59	1.54
9	14.61	6.68	3.71	2.43	1.84	1.42	1.37
10	13.15	6.01	3.34	2.19	1.65	1.27	1.23
11	11.95	5.47	3.04	1.99	1.50	1.16	1.12
12	10.96	5.01	2.78	1.83	1.38	1.06	1.02
13	10.11	4.63	2.57	1.69	1.27	0.98	0.95
14	9.39	4.29	2.39	1.57	1.18	0.91	0.88
15	8.77	4.01	2.23	1.46	1.10	0.85	0.82

When Is a Full Risk Assessment Needed?

A Starting Point

To be conservative, an individual Risk Assessment is recommended in the general cases that follow.

You can access on-line the actual guidelines that apply and the Microsoft EXCEL™ computer models that allow you to conduct your Risk Assessment. It should be emphasized that the criteria below are very conservative and it is likely that fewer than five percent of all typical projects will actually require a complete Risk Assessment.

WWPI Risk Assessment Models (17)

- Projects involving greater than 100 piling
- Substantial projects having large treated wood surface areas such as bulkheads

- Projects in industrial areas where there may be high background levels of metals or polycyclic aromatic hydrocarbons
- Projects in close proximity (<50 feet) to other projects in volving more than 20 piling that are treated with a similar preservative (creosote, copper based, etc.)

The industry is proud of the improvements in production processes and its history of environmentally appropriate product performance. The use of these guidelines and risk assessments is intended to insure that this history of safe use continues into the future.

Aquatic Use and Selection Guides for In-water Applications

In addition to running the models just described, the following preservative-specific criteria should be considered to determine if a full Risk Assessment is called for in water projects:

(17) Risk Assessment Models

NOTE: For each preservative, select the model that fits your specific application.

Creosote (freshwater or marine)

- The sediments are black and smell of hydrogen sulfide
- Maximum current speeds are less than three cm/sec
- Project involves more than four piling placed in a row parallel to the currents

Pentachlorophenol (freshwater only)

- Maximum current speeds less than 2.5 cm/sec
- Project involves more than four piling placed in a row parallel to the currents

Copper Naphthenate (freshwater)

- Maximum current speeds less than 1.0 cm/sec
- Project involves more than six piling paralleling the currents

Waterborne treatments (freshwater)

- Maximum current speeds less than 1.0 cm/sec or:

  CCA-C. Project involves more than 100 piling parallel to the currents
  ACZA. Project involves more than 25 piling parallel to the currents
  CA-B. Project involves more than two timbers parallel to the currents
  ACQ-B. Project involves more than two timbers parallel to the currents
  The pH of the receiving water is less than 5.5

Waterborne treatments (marine environments)

- Maximum current speeds less than 1.5 cm/sec or:

  CCA-C. Project involves more than four piling parallel to the currents
  ACZA. Project involves more than two piling parallel to the currents

Over-water Considerations

While the greatest potential environmental exposure is with in-water use of treated material where direct contact and higher retention levels exist, the large volume of wood used in above-water structures and decking also merits risk consideration and sound chemical management. Splash and rain runoff represent potential paths for treating chemicals to move from treated wood into the environment. Experience has shown that where environmental concerns have been raised, any adverse impacts found were caused by improper specification, treating or installation.

CONCLUSION *It should be emphasized that these recommendations are very conservative from an environmental point of view. Pressure treated wood has a long history of safe use in aquatic environments with no published report describing a significant loss of biological integrity associated with its proper use. Adverse impacts, where they have occurred, have been linked to significant concentrations of the preservative chemicals at old treating facilities and not with use of the treated product. The industry is proud of the improvements in production processes and its track record of environmentally appropriate product performance. The use of these guidelines and risk assessments is intended to insure that this history of safe use continues into the future.*

STEP 3: Specifying the Best Management Practices

The treating industry believes the potential for any adverse environmental impact is reduced when certain conditions are met:

- Materials are specified with the minimum retention needed for their application
- Best Management Practices (BMPs) are mandated with certification of inspection
- Proper field guidelines are followed

Best Management Practices

Protecting the lakes, streams, bays, estuaries and wetlands of North America is a responsibility shared by every citizen. The pressure treated wood products industry is committed to ensuring that its products are manufactured and installed in a manner which minimizes any potential for adverse impacts to these waters. To achieve this objective, the industry developed and encourages the use of the **Best Management Practices** or **BMPs**. BMPs are *in addition to the AWPA standards* and contain guidelines specific to each preservative system related to the treating process. These include technical guidance on the handling and use of the treating preservative, wood preparation and treating procedures, post treatment processes and inspection. The BMPs are designed to:

Complete BMP Document (4)

- Minimize the amount of preservative placed into the wood while assuring conformance with AWPA standards
- Maximize fixation or stabilization in waterborne systems
- Minimize surface residues and bleeding from oil-type, preservative-treated products.

The specification for treated wood products used in aquatic and wetland applications should contain language to the effect: *These products are to be produced in accordance with the Best Management Practices for Treated Wood in Aquatic Environments issued by the Western Wood Preservers Institute, Wood Preservation Canada, and The Timber Piling Council.* Using such a reference, you will not need to list the specific requirements of the BMPs.

STEP 4: Providing Quality Assurance and Certification

Treating Quality and BMP Assurance

Sound project management will provide for quality control to assure that the treatment and BMP specifications have been met. Third-party independent inspection procedures are in place to meet these needs.

Treating Quality

7 *Quality Assurance Information*

To assure products meet the specified AWPA standards, the presence of a quality mark or letter of certification from a third-party inspection agency should be required in the specification. Building codes require all treated wood used in structural applications must be inspected by an American Lumber Standard Committee (ALSC) accredited third-party agency. The presence of the CheckMark logo on structural materials notifies the user that the inspection agency and materials were under the ALSC Treated Wood Enforcement program to assure compliance with AWPA standards.

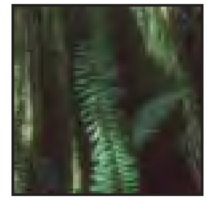
BMP Assurance

18 *BMP Quality Assurance*

Specifications for material intended for use in aquatic or wetland applications should require that the material be produced in accordance with the BMPs. Conformance should be certified by third-party inspection documented by written certification or the presence of the BMP Certification Mark. Check on-line for details.

Work with the Treater

It is strongly recommended that, once a supplier has been selected, the specifying organization and/or contractor contact the wood treating company directly to review the project, specifications and material expectations. Direct contact with the treating firm should be made even if the material is being purchased through a third-party wholesale firm. Experience has shown that where treated materials have *not* met the purchaser's expectations it has been the result of a lack or breakdown in communications. In addition to going over the treating requirements, calling the treater affords you an opportunity to review lumber grades and framing requirements that may have been part of the specification.



STEP 5: Appropriate Handling, Installation and Maintenance

The most critical time in the life of a treated wood project – in terms of potential environmental impacts – is during and immediately following construction. Specification of BMP materials will provide assurance that materials at the job site meet fixation requirements (for waterborne preservatives) and are free of excessive surface preservative. This minimizes initial risks.

There are several additional actions that can be taken to ensure the project is completed in an environmentally safe manner:

- **Framing, sawing, cutting and drilling.** To the maximum degree possible, framing, sawing, cutting and drilling should be done before treatment. Most treaters are able to provide these services or the work can be done prior to the material going to the treating plant. This may require more engineering and product coordination, but it assures the best treated product, minimizes the need for field treating and yields the more efficient installation.
- **Field inspection.** The materials should be visually inspected when they arrive on site. Materials which display excessive bleeding (oil-type) or surface deposits should be rejected and the supplier contacted for replacement.
- **Re-treatment.** If the materials do not meet the retention or penetration specifications, caution should be taken before agreeing to re-treat. This is especially true with oil-type preservatives, since re-treatment can lead to excessive retentions and increased potential for environmental impact.
- **Fasteners.** Fasteners for preservative-treated wood shall be hot dipped galvanized in accordance with ASTM A-153, silicon bronze, copper or 304 or 316 stainless steel. Stainless steel fasteners should be used below grade in Permanent Wood Foundations and are recommended for use with treated wood in other corrosive exposures such as in or near salt water.
- **Field fabrication.** All sawing and drilling should be done away from the water when practical, taking steps to collect, contain and prevent dust and shavings from entering the water or soil. Dispose of all scraps and sawdust in an appropriate landfill.
- **Field treating.** All field cuts and drill holes should be field treated. Field treating (as well as applying sealers) should be done well away from the water if at all possible. If over-water treatment is necessary, steps should be taken (such as using tarps) to collect any surplus treatment for removal and disposal.
- **Absorbent booms.** When oil-type materials are first placed into the water a sheen may appear on the water. While generally environmentally benign, a visual concern exists until the sheen evaporates or dissipates. You should consider installing absorbent materials to contain the sheen, and booms should remain in place until the sheen ceases.
- **Demolition.** Removal of old or abandoned treated wood structures from the water can disturb sediments, creating a greater potential concern than if left alone. Alternative strategies such as cutting them off at the sediment line or leaving them as fish habitat should be considered.
- **Worker safety.** The treated wood material supplier will provide an EPA-approved Consumer Information Sheet (CIS) or Consumer Safety Information Sheet (CSIS) and a Material Safety Data Sheet (MSDS) for the treated material. Be sure employees are aware of the information in the CIS or CSIS and follow the guidelines.

Fastener Information (19)

Disposal of Treated Wood (20)

Field Treating (21)

For another perspective on using treated wood in sensitive environments, it is suggested you access: ***Guide for Minimizing the Effect of Preservative-Treated Wood on Sensitive Environments*** *published by the USDA Forest Products Laboratory.*

FPL Environmental Guide (22)

Consumer Information Sheets or Consumer Safety Information Sheets (6)

The Environmental Impact of Treated Wood – What Does the Science Say?

*by Dr. Kenneth M. Brooks
President, Aquatic Environmental Sciences*

Dr. Books heads up a leading biological laboratory located in Port Townsend, Wash. Under his guidance, extensive North American aquatic-oriented research in the areas of intensive fish and shellfish aquaculture and environmental response to pressure treated wood products is conducted. His work modeling and evaluating the environmental response to treated wood has been used by Environment Canada, the U.S. Forest Service and industry. Prior to forming the Aquatic Environmental Sciences Laboratory, Dr. Brooks, a doctor of Physics and Marine Biology, was a Navy researcher at Lawrence Livermore Laboratories. He worked extensively with conservation districts, the National Resource Conservation Service and state extension service; and served as chairman of both the Washington State Conservation Commission and Agriculture-Natural Resources Forum.

Over the last several decades, a great deal of research has been undertaken by scientists from around the world to understand the environment's response to pressure treated wood structures. Much of this work focused on the performance of pressure treated wood and on human health concerns. In addition, several laboratory studies were undertaken to understand the transport and fate of wood preservative chemicals that are slowly leached from wood projects in natural environments. Each Risk Assessment contains bibliographies for this literature.

When large blocks of treated wood were placed in small bowls of water, laboratory studies demonstrated adverse effects on a number of freshwater and marine animals. Missing from the literature were real world studies that measured and evaluated the impacts of large treated wood structures on natural biological communities. However, in recent years, a number of major field studies have been sponsored by the Canadian and U.S. governments to fill this knowledge gap. This Report focuses on the overall conclusions of this extensive research. You are encouraged to review the complete documents for a detailed discussion.

ACZA

ACQ-B

CCA-C

The Wildwood Study

In 1996 the U.S. Forest Service and Bureau of Land Management constructed a massive boardwalk system through wetlands created by a series of beaver dams in an abandoned channel of the Salmon River on the western slopes of Mount Hood in Oregon.

Wildwood Study (23)

The 1,800-foot long boardwalk was built to provide public access to this pristine, otherwise inaccessible environment. Different sections of the boardwalk were constructed with ACZA, ACQ-B or CCA-C preserved wood. Soils, wetland sediments, the water and invertebrates living around the structures were carefully sampled and analyzed before construction began and periodically afterward for one year. Conditions at varying distances from the structures were compared with those at a similar control structure built of untreated wood in an isolated part of the wetland. The results of this study were published by the U.S. Forest Service in 2000.

For background information on specific preservatives see:

CCA Assessment (10)

ACZA Assessment (11)

ACQ Assessment (12)

The Wildwood site was chosen for this evaluation because the project was large and the environment sensitive. The soft and very slow-moving water, fine-grained sediments and heavy rainfall, combined with the massive scale of the boardwalk, led the authors to conclude this was a worst-case study. If adverse effects were to be found in sensitive invertebrate communities, they would be found here.

Each of the structures behaved differently but their metal loss rates were consistent with laboratory leaching studies. The full report contains a detailed description of the metal concentrations observed in the water and sediments within 12 meters of each structure during the entire study. For waterborne systems, copper is the metal of concern because aquatic organisms, unlike humans, are much less tolerant of copper than they are of arsenic, zinc or chromium. If the levels of copper from treated wood were maintained at less than toxic thresholds, then other chemicals used in waterborne preservatives would simply not be present at concentrations causing concern. The following discussion will focus on the results for the CCA-C structure because this preservative is the most commonly used product in the U.S.

What is intuitive for most people is the biological response. Wildwood is a “buggy” place: 86,144 bugs, snails, clams and worms were collected and identified in the 424 samples collected by the researchers. One hundred fifty-one different kinds of animals were identified from sediments, vegetation and on artificial substrate collectors used to sample the “drift community.” Scientists have numerous ways of analyzing databases developed in these kinds of studies and many of those analytical techniques were used here. Figures 2 and 3 on page 20 show four common ways of assessing animal communities. For each metric in the figures, higher values are associated with healthier communities.

No adverse effects on the sensitive invertebrate community were evident in this study at the structures built using ACZA, ACQ-B or CCA-C-treated wood.

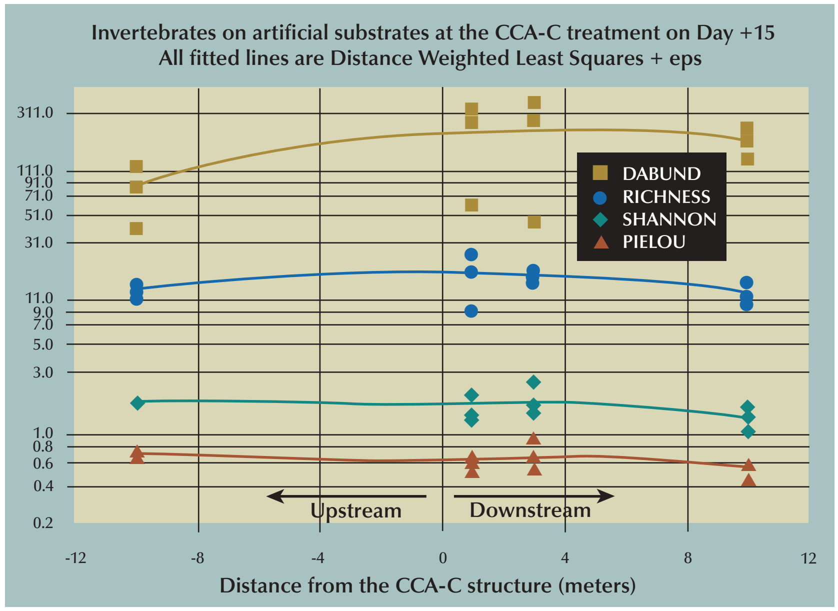


Figure 2

Figure 2 describes the response of invertebrates most exposed to the peak concentrations of dissolved copper observed two weeks after construction of the CCA-C viewing platform. Copper declined dramatically in all subsequent samples confirming that this first two-week period represented the worst case for this part of the insect community.

As many or more invertebrates were collected from the artificial substrates located immediately next to the treated wood (0 to 4 meters distance on chart) as were observed at the upstream control (–10 meters distance on chart). All of these indices (which measure the numbers and kinds of invertebrates and how well integrated they are in the community) showed no significant changes caused by the structure.

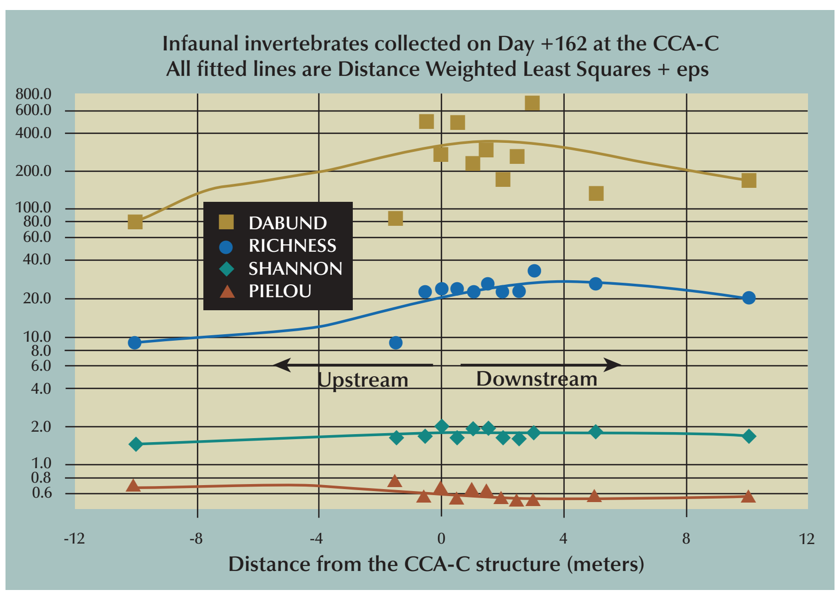


Figure 3

Figure 3 above describes the community of animals that live in the sediments (infauna) at the end of the study when sediment concentrations of all metals had reached their peak. Again, there is no indication that the CCA-C structure resulted in a compromise of these infauna, which are sessile (stationary) and had been exposed to the pressure treated wood structure for a year. The same results were obtained for the other two preservatives. It is impossible to prove a negative and therefore we cannot state that there could never be an adverse effect associated with these structures. *What we can say is that this worst case study did not reveal any adverse environmental effects and these results indicated that these preservatives can safely be used in sensitive wetland areas.*

New creosote-treated dolphin used to evaluate creosote in Sooke.

Sooke Basin Creosote Evaluation

At sufficiently high concentrations, polycyclic aromatic hydrocarbons (PAH), that make up 80 percent of creosote oil, can be acutely toxic. At moderate concentrations of 7.5 to 20 parts per million (ppm) in sediments, PAH have been associated with tumors in fish.

Polycyclic aromatic hydrocarbons are ubiquitous in our environment, including many natural sources such as volcanoes, forest fires, coal deposits, plants, peat bogs and oil seeps. Petroleum refining and distribution, asphalt paving, vehicle exhaust, coal, home fireplaces, power generating facilities, tires, BBQ's and a host of other human activities also contribute PAH to our environment.

Sooke Basin Study (24)

The natural sources have been present since before there were humans, and all living creatures have developed enzyme systems that break down these compounds. In fact, some strains of bacteria thrive on PAH as a food source and can very efficiently destroy even high concentrations. All PAH are eventually broken down to carbon dioxide and water, leaving no trace of their pre-existence. The fact is that no matter how hard we try, it is not possible or necessary to eliminate PAH from our environment. What we need to do is manage anthropogenic sources of PAH so they do not reach toxic levels and do not degrade valuable environments.

For background see:

Creosote Assessment (15)

In 1994, the Canadian Department of Fisheries and Oceans and Environment Canada initiated a long-term study to evaluate the environmental effects associated with creosote-treated wood used in marine environments. Because most creosote structures are located in harbors (where there are many confounding sources of PAH), this evaluation was conducted in an isolated portion of Sooke Basin, British Columbia, where low PAH background levels were observed and where there were minimal other sources.

The Sooke Basin site had very slow currents and fine-textured sediments supporting a healthy community of sessile invertebrates. Three dolphins were constructed with six class "A" piling in each structure. One of the dolphins was constructed of untreated wood, the second of eight-year-old piling pulled from a pier in Vancouver Harbor, and the third of new BMP piling that were over-treated to 27 pounds per cubic foot with marine-grade creosote. This over-treatment insured that the Sooke Basin Study would represent a worst-case evaluation.

The loss of PAH and their accumulation in sediments was modeled before constructing the dolphins. The environment around these dolphins was intensively monitored for four years, documenting the loss of PAH to the water and their accumulation in sediments. The biological response was evaluated in an exhaustive series of in-situ and laboratory bioassays coupled with thorough documentation of the invertebrate community living within 100 feet of each of the structures.

What Did This Study Find?

(25) *Creosote Model (Marine)*

- Creosote did migrate from the piling and accumulate in sediments downcurrent from the piling. As shown in Figure 4 below, the actual accumulation of PAH in sediments (red line) was less than that predicted in the model (blue line). These sediment concentrations also peaked earlier and declined faster than predicted. These models have been field-verified repeatedly over the last six years. In every case, they have proven conservative from the environment's point of view – that is, predictions of PAH accumulation were higher than what was actually observed.

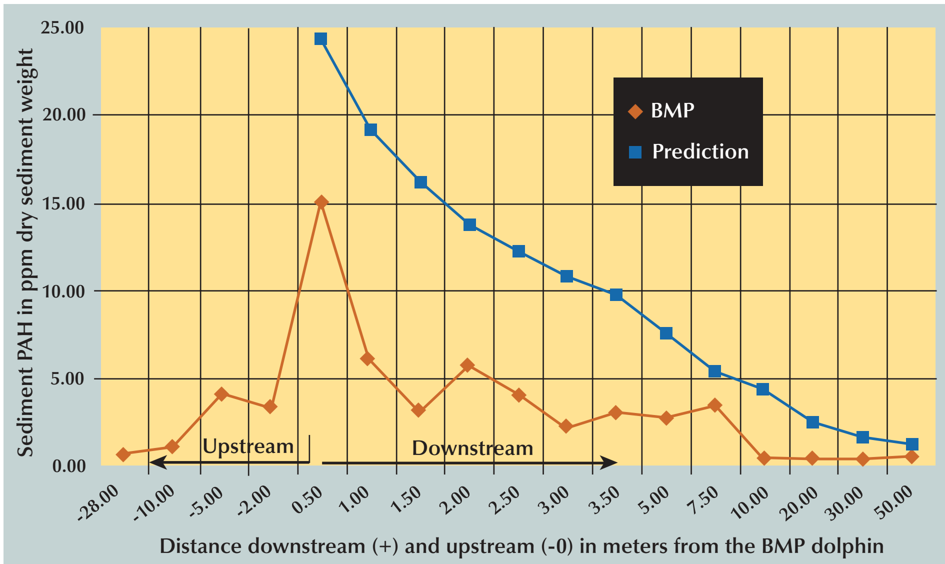
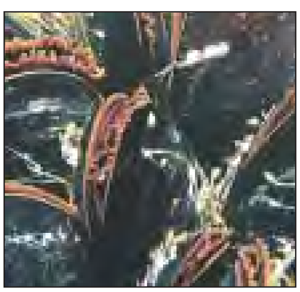


Figure 4

- Even at the peak of PAH accumulation, concentrations did not diminish the natural invertebrate community growing as close as one-half meter from the piling. However, evidence from the extensive suite of bioassays did indicate toxicity in sediments located within 0.65 meters of the dolphins. Mussels grown in cages within 15 cm of the piling did not accumulate significant amounts of PAH. Tissue concentrations peaked 14 days after construction at levels that were safe for human consumption. The same was true for mussels growing directly on the piling at the end of the study.

  As previously noted, concentrations of PAH in the sediments peaked earlier and declined more quickly than predicted by the models. The fact that there were lower-than-expected levels of PAH is an important environmental observation. Perhaps more important was the fact that the piling provided habitat for an astounding array of aquatic life with no significant or lasting adverse impact from the creosote treatment.

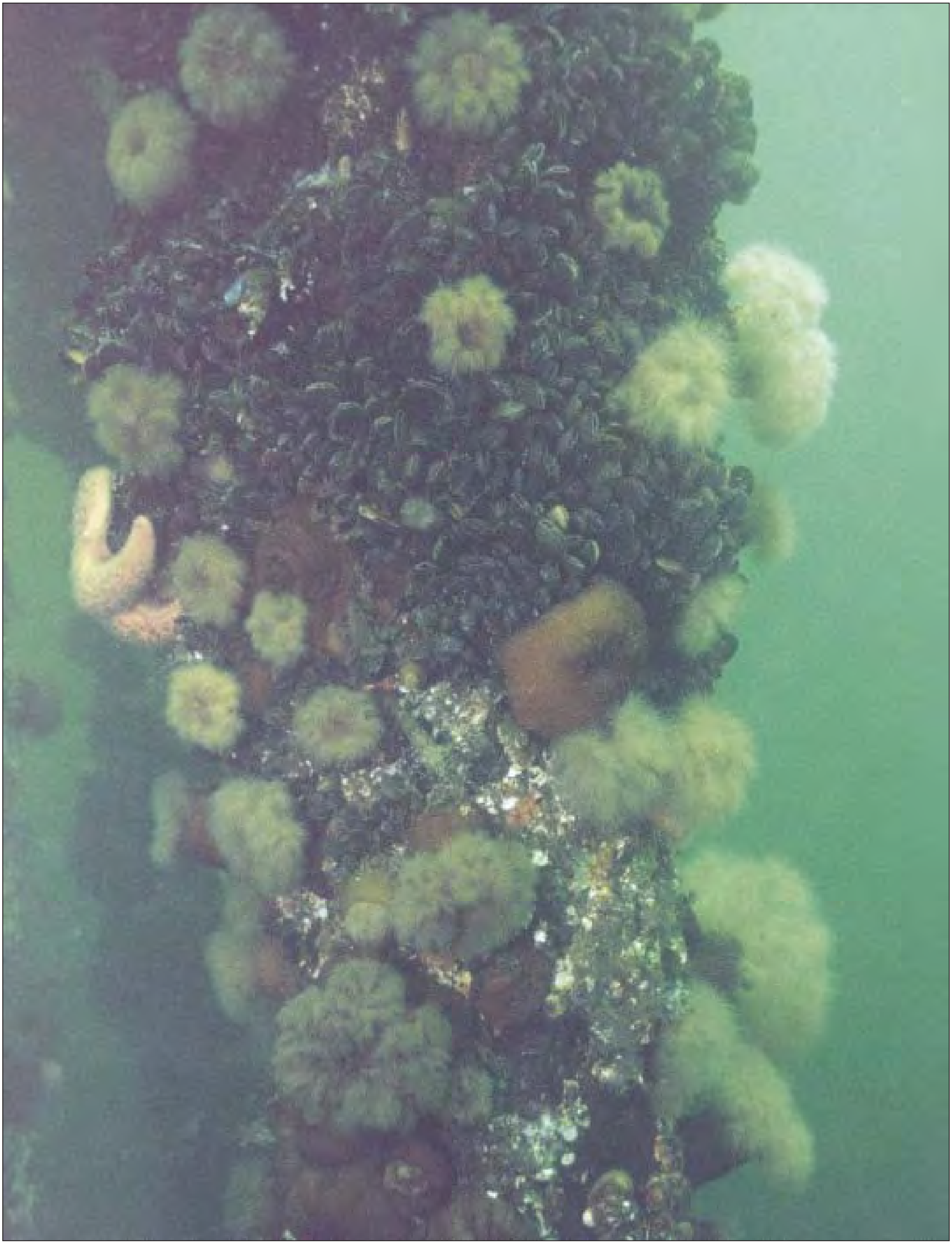


Blue mussels growing on creosote-treated piling

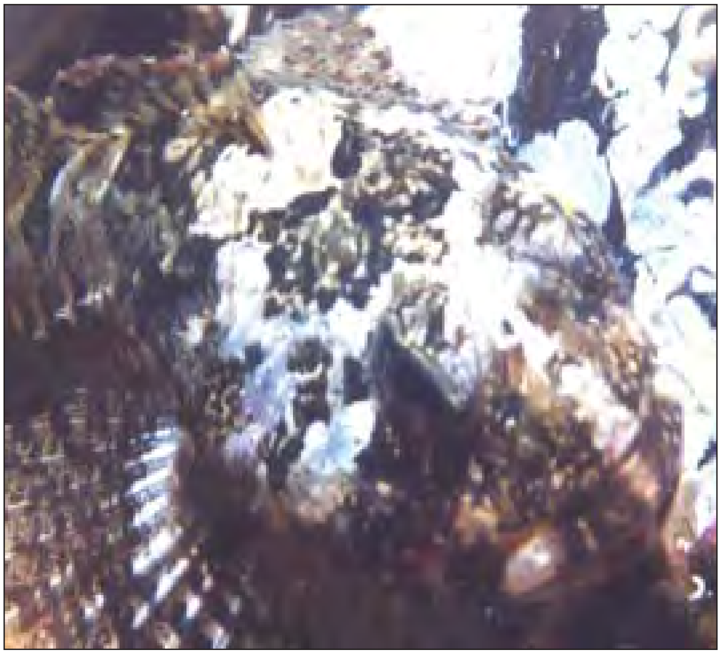
- Based on the evidence observed in Sooke Basin and on unpublished laboratory studies, the authors hypothesized that most of the creosote lost from the piling was transported as tiny droplets of oil – much of which likely originated from above the water line on hot summer days. As the piling aged, the air-exposed portion of the piling developed a hard covering of asphalt-like tar. This covering may have sealed the surface reducing further loss of creosote.

- The continually immersed portions of the creosote-treated piling were quickly overgrown with a rich and abundant community of fouling organisms. The full-page photograph on the next page shows one of the newly treated creosote piling at the end of the study. Dozens of species were identified including fish, shrimp, nudibranchs and tunicates such as *Cnemidocarpa finmarkiensis* shown at left. From an intuitive point of view, this luxuriant fouling community does not suggest that these piling were creating a toxic environment.

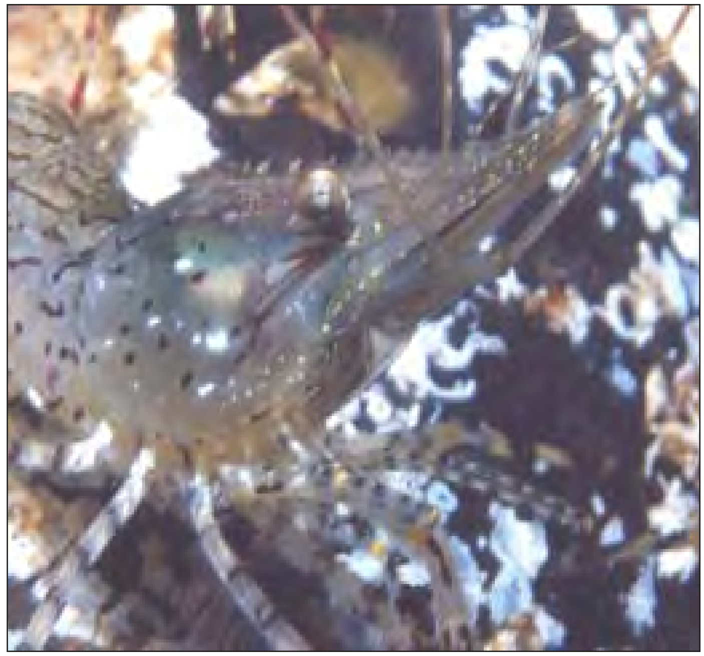
Tunicate growing on creosote treated piling



Invertebrate community growing on a new creosote-treated marine piling in Sooke Basin



Red Irish Lord



Coonstripe shrimp (Pandalus danae)

Many of these fouling organisms are considered highly sensitive to pollution and are used by regulatory agencies like the Environmental Protection Agency in setting water quality standards. The Red Irish Lord (*Hemilepidotus hemilepidotus*) shown above was resting on a clump of mussels attached to the piling, oblivious to the divers who were collecting samples.

Polycyclic aromatic hydrocarbons are hydrophobic – i.e. they don't like water. They bind to organic tissues that contain lipid. The mussels and other animals living on these piling generated a mat of lipid-rich organic detritus at the base of the fouling community. This detritus was being decomposed by bacteria. It is likely that it also intercepted much of the creosote oil still migrating from the treated wood. The microbial communities are expected to metabolize the creosote caught in this organic matrix. The point is that this luxuriant fouling community was likely reducing the migration of creosote to the sediments. Note that this appears to have been accomplished without the animals themselves becoming contaminated as evidenced by the lack of PAH in mussels.

Starfish (Pisaster ochraceus) foraging on the fouling community

Another possible hypothesis explaining the significant reduction in sediment PAH around the piling was also associated with the fouling community. The community was continually being devoured by predators like the Ochre Stars seen in the figure at left. This predation resulted in a raining down of enormous quantities of biological debris that collected around the base of the piling. This food attracted hundreds of Dungeness crab (*Cancer magister*), sea cucumbers (*Parastichopus californicus*) and a variety of anemones.

By the end of the study, all of this biological activity had exceeded the assimilative capacity of the sediments around the piling. They were anaerobic and contained very high levels of sulfide. The resulting sediment toxicity had nothing to do with the creosote treatment. In fact, these conditions were as bad or worse at the untreated control dolphin. Why? Because the untreated wood was quickly being consumed by marine borers (toredos, bankia and limnoria). Few fouling organisms were found on these piling because as soon as a community established itself, the wood failed and the organisms fell to the bottom where they were consumed by predators.

The untreated piling were deteriorating and did not support a vibrant fouling community

Dungeness crabs foraging on mussels dislodged by starfish around the new creosote-treated dolphin

It also appeared that the biological debris was diluting the sediment concentrations of PAH. All three of these factors were likely responsible for the unexpectedly quick decline in sediment PAH associated with the creosote-treated structures. Whatever the cause, the result was that the PAH lost from creosote appeared to have little long-term effect on the biology of the sediments – even within a few feet of the structures.

CREOSOTE SUMMARY *During the first year of the Sooke Basin study, creosote migrating from the piling did accumulate in sediments within 7.5 meters of the structures. The concentrations did not appear toxic to the local fauna because the infaunal community remained stable. However, toxicity was observed in laboratory bioassays of sediments located within two feet of the piling using sensitive species. The accumulation of PAH was overestimated by the model and the sediment concentrations declined more quickly than expected. At four years and presumably for the remainder of the 50- to 75-year life span of creosote-treated wood in this area, the major effect was caused not by the preservative, but by the flourishing community of animals that took up residence on the piling. By the end of the study, the creosote structures did not diminish marine life in this area – they enhanced it. Treated wood structures do typically attract large communities of organisms.*

The personal use pier shown here is constructed of creosote-treated piling with ACZA-treated walkways

Timber Bridge Study

(26) *Timber Bridge Study*

In 1997, the U.S. Forest Service initiated a study to examine the environmental response to the construction of timber bridges preserved with creosote, pentachlorophenol or CCA-C. Timber bridges are lightweight, long lasting and relatively inexpensive to build in rural areas carrying light to moderate traffic loads. The Timber Bridge study compared preservative concentrations in the water and in sediments under and downstream from two creosote-treated bridges in Indiana, two CCA-C-treated bridges in Florida and two pentachlorophenol-treated bridges on the West Coast. Invertebrate communities were carefully evaluated along with laboratory bioassays to determine the biological response to each bridge.

Measurably increased concentrations of metals, creosote or pentachlorophenol were not observed in the water under or downstream from any of these bridges. However, the active ingredients in each preservative were observed in sediments under each bridge – albeit at very low levels – and no decreases in the number of invertebrates or restrictions in the kinds of invertebrates were observed under or downstream from any bridge when compared with reference stations.

Pentachlorophenol-treated Timber Bridges

Dairy Creek Bridge

New York State has established a freshwater sediment quality criterion for pentachlorophenol. The maximum sediment pentachlorophenol concentration observed at the Satsop River bridge was 19 μg/kg (parts per billion or ppb), representing 4.5 percent of the New York State standard of 420 ppb. The maximum concentration observed at the Dairy Creek Bridge was 1.98 percent of the sediment standard. At these low concentrations, no adverse biological effects were anticipated at either bridge and none were observed.

Example of substrate in the Satsop River where salmon spawn

These two bridges were located over salmon-spawning rivers with sand-gravel and cobble substrates supporting a vibrant community of pollution-intolerant aquatic insects in the Orders Ephemeroptera (mayflies) and Trichoptera (caddis flies). The larvae of these Orders are generally associated with fast-moving oligotrophic streams and rivers. The biological response of this sensitive community is illustrated in the figure below. It describes sediment pentachlorophenol concentrations (µg/kg) in red; the proportion fine-grained sediments (sand, silt and clay) in blue; biological response described by the number of species (green); and the abundance of invertebrates (brown).

Note that the number of species and the total abundance of in vertebrates were much higher three feet downstream from the bridge's drip line where the proportion of fine sediments dropped from 70 to 80 percent to about 40 percent. Also note that invertebrate abundance peaked where the proportion of fines decreased to between fi ve and 12 percent. There were as many species and as many animals downstream from the bridge as there were at the upstream control. And there was essentially no correspondence between invertebrate community and the small amount of pentachlorophenol observed under the bridge and at the station located three feet downstream. Amphipod (*Hyalella azteca*) bioassays also found no evidence of toxicity in sediments from either of these pentachlorophenol-treated bridges. The invertebrate community was far more influenced by the substrate type than by the bridge.

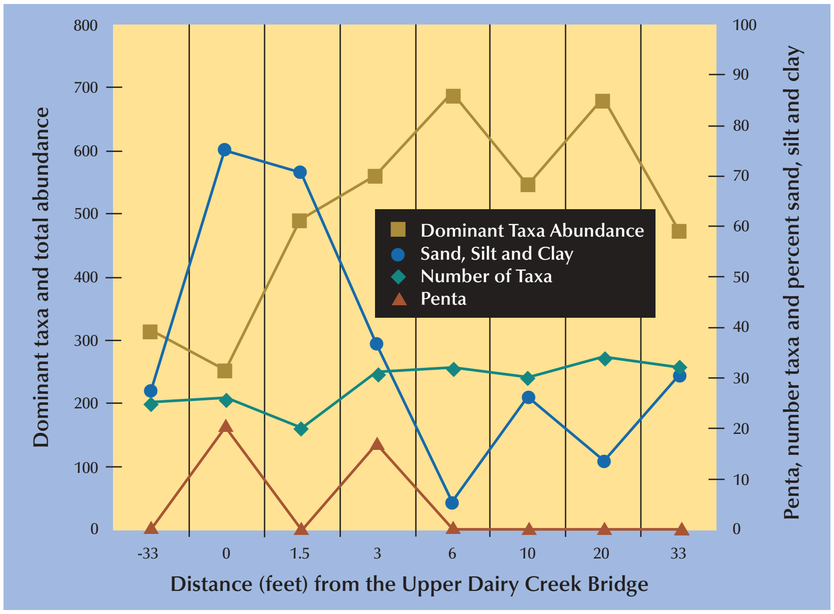


Figure 5

CCA-C-treated Timber Bridges

Horseshoe Bayou Bridge

Two bridges, each constructed entirely of CCA-C-treated wood, were evaluated in Sandestin, Florida. The Horseshoe Bayou Bridge, the largest, was designed to carry a 20-ton load. Its 160-foot span crossed a pristine marine estuary at the entrance to Horseshoe Bayou. Construction was just being completed when the survey was conducted. This timing was considered important to observing any increase in the concentration of dissolved metals during the period right after immersion when leaching is greatest from CCA-C-preserved wood.

As seen in Figure 6 below, copper and chrome concentrations were essentially the same along the sampling transect with no significant changes. Dissolved arsenic concentrations actually increased slightly with distance from the CCA-C-treated bridge.

It should be noted that all metals were below their respective water quality criteria of 3.1 μg copper/L, 36 μg arsenic/L and 50 μg chromium (VI)/L. As shown in Figure 7, increased sediment concentrations of all three metals were observed within 10 feet of the bridge.

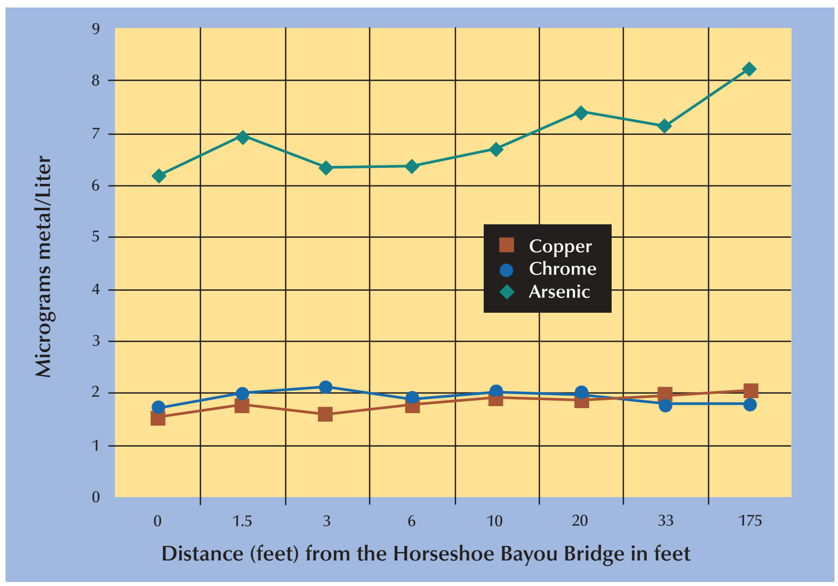


Figure 6

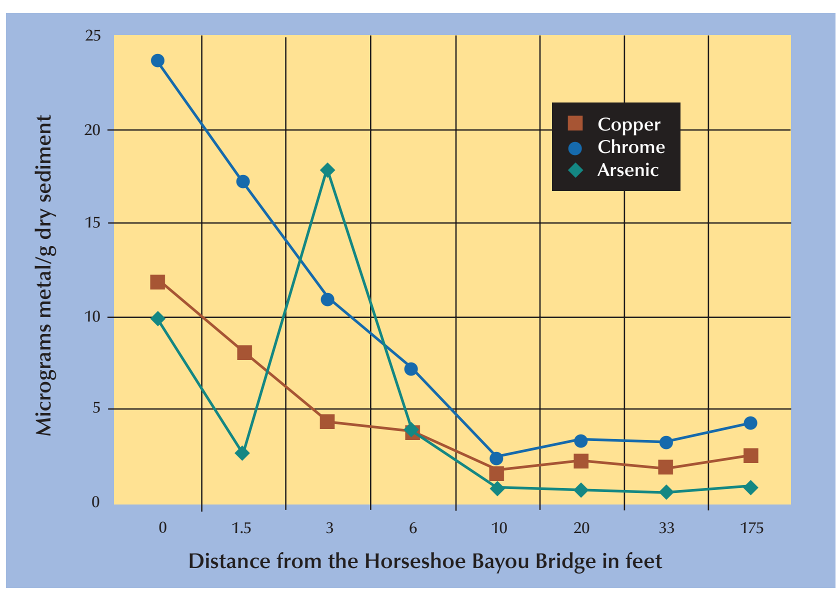


Figure 7

The reason for the increase illustrates an important point in the construction of treated-wood structures. As previously noted, this is a truly massive bridge. One thousand four hundred fifty-eight holes were drilled in the bridge to bolt together the heavy-duty treated-wood railing. Each hole was 3/4″ in diameter and approximately 14″ long. The drill shavings were not contained and they blew into the estuary where they could be seen on the bottom all around the bridge.

There are at least two reasons why the drill shavings, although an esthetic problem, did not result in measurable environmental damage. First, because the metals remained fixed in the wood shavings, they were expected to slowly leach out over time. Second, the resulting concentrations did not exceed commonly accepted sediment benchmarks of 63.4 µg copper/g; 16.2 µg chromium/g; or 24.4 µg arsenic/g dry sediment. This poor housekeeping practice resulted in what should be recognized as unnecessary environmental risk. There is no reason for those shavings to be there.

No adverse biological effects were anticipated at the low metal levels observed at Horseshoe Bayou and none were observed. As many or more species and numbers of animals were observed in sediments collected under and in the immediate vicinity of the bridge as were found at the reference station. Survival of *Menidia berylina* was excellent in all of the bioassays completed for this site, and no significant differences were observed when comparing stations close to the bridge with either the local reference station or laboratory controls.

The second bridge examined in San Destin was the 8-year-old Fountain Bridge, which crossed a freshwater marsh. This older bridge was examined to evaluate the accumulation of metals in sediments around the bridge and their effect on infauna. Increases in dissolved metals were not observed in the vicinity of the bridge in this essentially stagnant body of water.

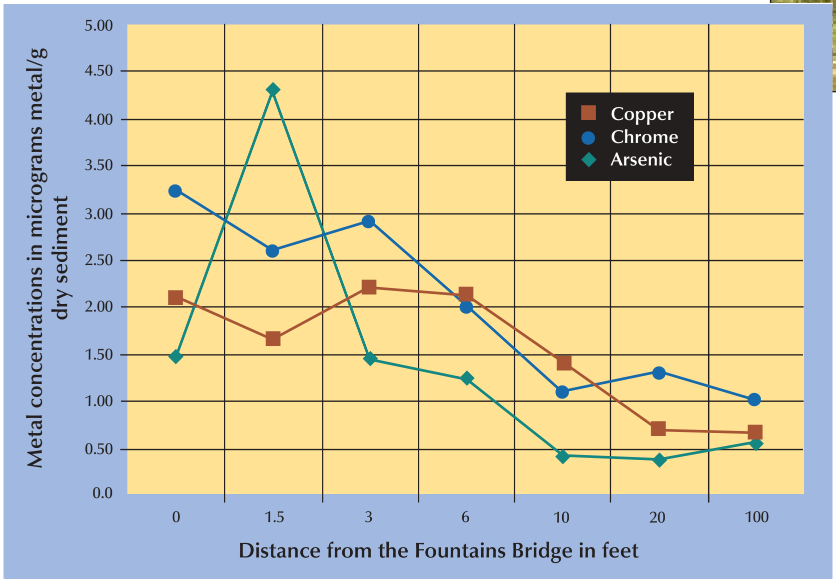


Figure 8

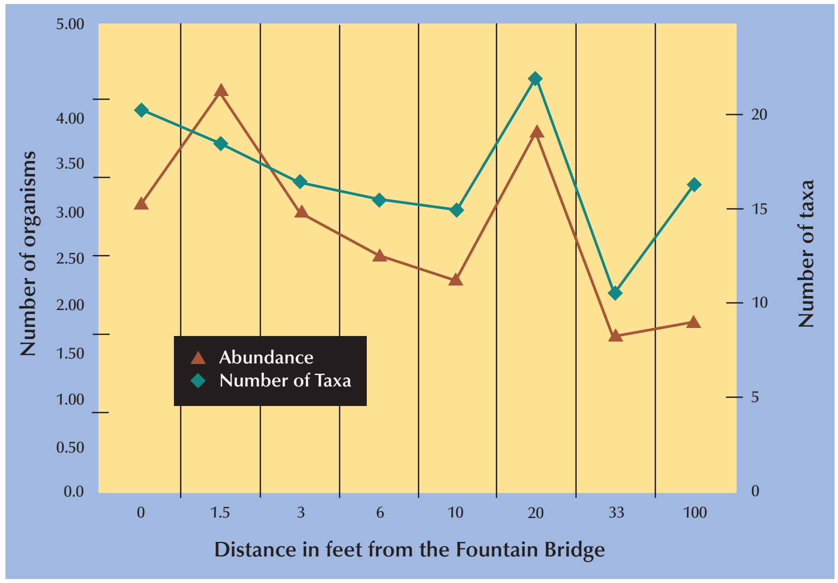


Figure 9

Figure 9 describes sediment concentrations of metals under and adjacent to the bridge. Sedimented metal concentrations were all very low (<4.25 µg/g). However, the bridge has left a definite signature in the muddy substrate that extends to a distance of between six and ten feet from the piling. Having said that, the maximum observed concentration of each metal was less than background concentrations in most parts of North America. No biological effects whatsoever could be expected at these concentrations and, as seen in Figure 9, none were observed. The abundance and diversity of invertebrates was as high under and immediately adjacent to the bridge as they were further away.

CCA-C SUMMARY *Metal losses from CCA-C-treated wood have been well known and predictable for at least 30 years. Losses from the bridges surveyed in this evaluation were so low as to be undetectable in the water. Metals did accumulate in sediments but to levels that were so low as to have no predicted or observed adverse biological effect. The CCA-C evaluation did point out the need to develop and use Construction Best Management Practices to insure that all waste is cleaned up and properly disposed of in a landfill. The drill shavings present in Horseshoe Bayou should not have been there: They represented unnecessary environmental risk and were an eyesore.*

Creosote-treated Timber Bridges in Cass County, Indiana

Creosote is the most common preservative used in the construction of timber bridges. Two creosote-treated bridges were evaluated on Pipe Creek in Indiana. Both bridges are substantial structures. They each sit on 20 Class A piling treated to a nominal retention of 17 pounds creosote per cubic foot (pcf) in the treated zone (outer 1.5″). Support beams, crossbeams, decking and guardrails were all similarly treated with creosote oil to a retention of 8 or 10 pcf in the treated zone.

Pipe Creek Bridge

Pipe Creek flows through corn country and carries a heavy load of sediment. Current speeds along the chosen sampling transects were very slow at <1.0 cm/sec. From an environmental point of view, both bridges behaved similarly. Slightly higher PAH concentrations were observed in sediments near the 2-year-old Bridge 146 than were found under the 8-year-old Bridge 148. The following discussion describes the results at new Bridge 146.

Creosote is a complex mixture of hundreds of compounds including many types of naturally occurring organic compounds called polycyclic aromatic hydrocarbons or PAH. Each of these PAH compounds degrade at different rates in the environment and they have different effects on biological organisms. This discussion will focus on the sum of the concentrations of all the PAH (TPAH) observed in Pipe Creek sediments. The parent report contains an evaluation of individual compounds and the results are not different from those presented here.

Sediment concentrations of polycyclic aromatic hydrocarbons (PAH) are described in Figure 10. This graph also includes sediment quality benchmarks described as the Threshold Effects Level (TEL), a value below which adverse biological effects are not generally observed under any condition, and the Probable Effects Level (PEL), a value above which increasingly severe biological effects should be anticipated in most environments. The mean of these values or MEL is also displayed. This mean is increasingly used as a reasonably protective benchmark for assessing environmental risk. Maximum sediment PAH concentrations between 1.5′ and 6.0′ downstream from the bridge exceeded the Threshold Effects Level for TPAH but not the Mean Effects Level. This suggests that adverse effects could be anticipated in a community of the most sensitive organisms.

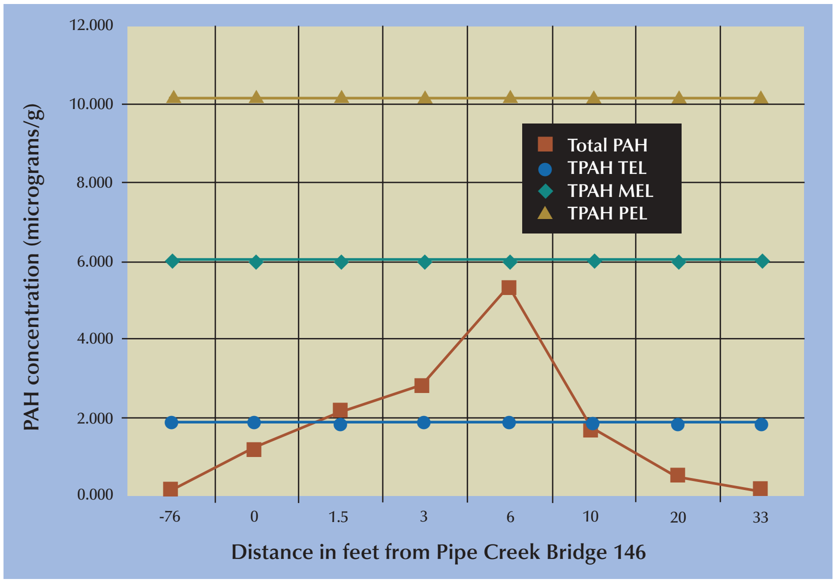


Figure 10

As previously discussed, Pipe Creek is a slow-moving stream flowing through cropland. It carried a significant bedload of sand, silt and clay. Like the Wildwood wetland, this is a naturally stressful environment and the invertebrate community was dominated by annelids (worms) and chironomids (midges). Both groups are generally robust and typically dominate other taxa in stressful environments. Therefore, it could be anticipated that the moderate levels of PAH observed in these sediments would not adversely affect this robust resident invertebrate community – and they did not.

Figure 11 compares the abundance (blue) and richness (green) of invertebrates observed in sediment samples from Pipe Creek Bridge 146 with the TPAH concentration in each sample. More species in greater abundance were observed with increasing TPAH concentrations. It might appear logical to conclude that the PAH were enhancing the invertebrate community. However, some other unmeasured factor in the environment was more likely responsible.

The point that should be made is that neither of these bridges lost enough PAH to affect the creek's invertebrate community. The results of this study were also consistent with those obtained in Sooke Basin. Lower sediment TPAH concentrations were observed at the older bridge and higher concentrations at the new bridge. Experience has shown that creosote- and pentachlorophenol-treated bridges are most likely to lose preservative during the first year following construction – particularly during extended periods of high ambient temperatures. Oil-type preservative losses decline significantly with time.

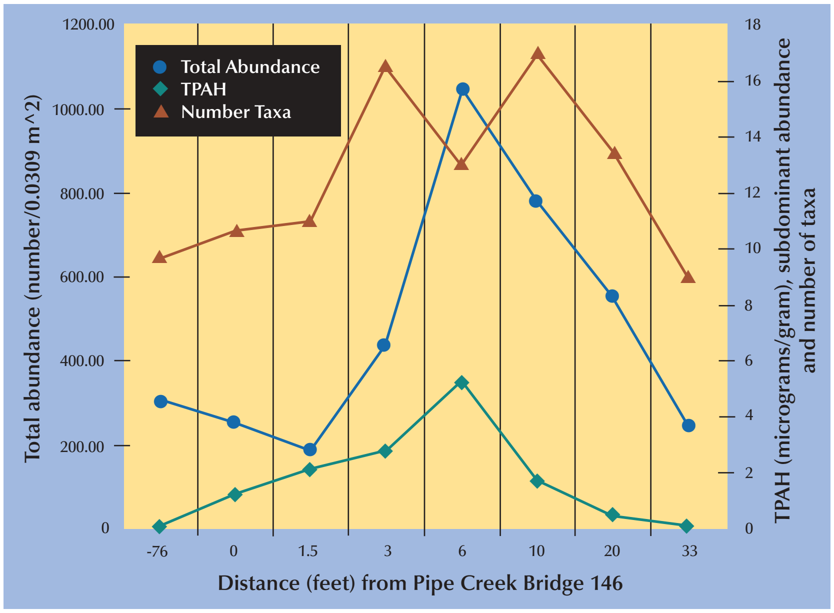


Figure 11

SUMMARY

A variety of types of treated wood have been used in aquatic environments for over half a century with no scientific reports documenting adverse environmental affects. These three studies have looked at a range of preservatives used to treat wood for constructing large structures in a range of sensitive marine and freshwater environments. Each of these studies was designed to conduct the assessments in worst-case conditions.

The following statements summarize the results of these three "real world" studies, describing the use of pressure treated wood in aquatic environments:

- Despite the production and use of billions of board feet of preserved wood, there are no published reports describing environmental damage associated with the use of these products in such structures.
- Small quantities of wood preservatives leached or migrated from all types of pressure treated wood. Using modern analytical techniques, small amounts of preservatives could be detected in the sediments but not in the water column around the treated-wood structures.
- The detailed studies discussed here were conducted to determine if treated-wood projects might be creating environmental damage on a scale so small as to have been previously ignored. No adverse effects were documented in association with the use of pentachlorophenol or the waterborne preservatives ACQ-B, CCA-C, CA-B or ACZA.
- Laboratory bioassays using very sensitive species indicated toxic effects in sediments collected within two feet of a large creosote-treated structure constructed in a worst-case marine environment. However, the resident infauna suffered no apparent harm.
- The longest-lasting effect of the installation of creosote-treated dolphins in Sooke Basin was a proliferation of life on and around the structures – creating a remarkable artificial reef.
- Models designed to assess the risks associated with very large treated-wood structures in sensitive environments have repeatedly been found to be conservative from the environment's point of view. These models can be used as a valuable tool in managing society's use of treated wood in aquatic environments.
- Most of the concern expressed by regulators regarding the use of pressure treated wood occurs during construction and/or demolition. Simple management practices can be used to eliminate the unnecessary risks sometimes created at the beginning and end of the 50- to 75-year life span of pressure treated wood structures. Best Management Practices (BMPs) are available to minimize preservative loss during the first year following construction of pentachlorophenol- or creosote-treated wood projects exposed to high ambient air temperatures.
- Based on the literature (including the detailed studies discussed here), there is no scientifically defensible reason to prohibit the use of treated wood in aquatic environments. Like many other human activities, treated wood simply needs to be managed.

(27) *Link to Science and Assessment*

(28) *BMP-related Information*

(29) *Using Treated Wood in Aquatic Environments*

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