



Wood Waste Assessment and Remediation in Puget Sound

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Acknowledgements

This document is intended to provide an overview of the subtle but significant difference between the affects of naturally occurring large woody debris and wood waste on habitat quality. An assessment protocol is proposed as a tool to determine when the presence and decomposition of wood waste is impacting habitat quality such that remediation is merited. The intended audience is restoration proponents which include landowners, non-governmental site managers, and other parties interested in nearshore restoration. This document is not meant to serve as a substitute for the Model Toxic Control Act (MTCA, Chapter 173-340 WAC), The Sediment Management Standards (SMS, Chapter 173-2004 WAC), or any other applicable laws or standards.

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1 Introduction

Recently there has been an increase in focus on the role of wood waste derived from historic milling operations in degrading habitat quality in nearshore environments throughout the Puget Sound. Biological assessments are used by the Washington State Department of Ecology (Ecology) as the definitive test to determine whether sediments are contaminated and regulated under the Sediment Management Standards (SMS) (Chapter 173-204 WAC). Using bioassays the by-products of wood waste decomposition at potential restoration sites can be determined to be a deleterious substance under SMS, however wood waste can impact habitat quality even if regulatory standards have not been exceeded. This document is meant to serve as a guidance document for the restoration proponent who is evaluating a wood waste site for potential restoration prior to its designation as a cleanup site under SMS.

This guidance document is presented in two sections: wood waste in the nearshore and assessment and restoration of wood waste. The intent of these sections is to provide the reader with the background to understand how wood waste is potentially detrimental to habitat quality, how to evaluate the extent of an impacted area, and what remedial options exist.

2 Wood Waste in the Nearshore

2.1 Wood Debris Sources

This initial section will provide working definitions for wood waste and identify how wood waste differs from naturally occurring large woody debris (LWD). Wood waste can be generally defined as any wood by-product of the wood processing industry. Table 1 provides a description of some forms of wood waste; however for the purpose of this paper the term wood waste will refer to fine particulate wood waste (i.e. chips, sawdust, and bark). These forms of wood waste have a much higher likelihood of impacting habitat quality, and will be discussed in detail.

Wood is primarily made up of cellulose, hemicellulose, and lignin (lignocellulose collectively) (Colberg 1988). This is similar for all forms of wood, including those listed in Table 1. While the molecular structure of wood waste and LWD may be similar their impact on nearshore habitat quality may vary widely based on the form and habitat function of LWD as compared to wood waste in nearshore environments. In order to understand this distinction an exploration of the function and decomposition of naturally occurring LWD deposits as it compares to wood waste is required.

There are many sources of LWD from upland forests and shorelines. Historically the natural erosion and migration of rivers, streams and shorelines provided much greater volumes of LWD to the greater Puget

Sound than are observed today (Maser and Sedell 1994). LWD recruitment¹ still occurs, but logging practices, flood control projects, and shoreline modifications have substantially reduced the amount of LWD present in the waters of the Puget Sound. LWD provides a wide variety of habitat enhancing functions which are not possible in its absence.

The habitat functions of LWD can be placed into three broad categories: shoreline protection, habitat creation, and food source. Historically the volume of LWD present in the nearshore was significantly greater than today, frequently accumulating to depths greater than 10 feet on many beaches throughout the greater Puget Sound (Maser et al. 1994). At this depth LWD serves as a significant structural component of the shoreline, decreasing the erosive energy of both waves and wind.

LWD can also create habitat for numerous other marine and terrestrial organisms and plants (Gonor et al. 1988). Within the marsh and estuary LWD introduces habitat complexity by creating depressions as a result of abrading and compacting the sediment it can also alter deposition and erosion patterns. These depressions provide habitat niches at a variety of tidal heights, increasing plant, animal, and invertebrate species diversity (Maser et al. 1994). Some of these species include burrowing rodents (Gonor et al. 1988), foraging birds such as Great Blue Herons (Eissinger 2007), and predatory birds (Bald Eagles, Kingfishers, and Cormorants). All of these species seek out nearshore LWD as their preferred resting and hunting habitat (Gonor et al. 1988; Maser et al. 1994).

LWD also serves as a primary food source for several wood boring invertebrates. The boring action of these organisms provides additional food and habitat to other marine and benthic invertebrates. The nearshore waters of the Pacific Northwest are dominated by two wood boring invertebrates: gribbles, a group of wood boring arthropods and shipworms, a group of wood boring mollusks (Ricketts et al. 1985).

Gribbles

Gribbles though small (3- 6 mm) play a large role in the processing of LWD in the nearshore environment. In our region there are two main gribble species present: the Northern gribble (*Limnoria lignorum*) and the Southern gribble (*Limnoria tripunctata*) (Maser et al. 1994). The

Northern gribble is native to this region while the Southern gribble is an introduced species in this region (Ricketts et al. 1985).

Both gribble species are between three and six mm in length and colonize the surface layers of submerged wood in very dense colonies of up to 10 individuals per

¹ LWD recruitment is the settlement of LWD on a beach, shoreline, structure, or debris jam.

Table 1 - Wood waste types, sources, and potential impacts.

Wood Waste Type	Potential Source	Definition ^a	Potential Impact
Sawdust	Sawmills	Waste by-product of timber milling process. Generally >10 mm ²	- Physical barrier - H₂S, methane, or ammonia production - Leachate production (rapidly depleted)
Wood Chips	Wood Chipping and transport facilities	Generally 6-10 cm ²	- Physical barrier - H₂S, methane, or ammonia production - Leachate production
Bark	Log booming, Log storage, and sawmills	All the material located beyond the cambium layer.	- Leachate production - Physical barrier - H₂S, methane, or ammonia production
Cut Logs	Log booming, transport, and storage	Cut timbers of various lengths free of roots and limbs	- Leachate production (slow release rate) - Compaction of sediment - Bark production - Navigational hazard - Can mimic functions of Natural wood
Wood Pulp	Paper Mills	Waste material consisting of wood fibers extracted in the pulp production process	- Physical barrier - H₂S, methane, or ammonia production

^a Concise universal definitions do not exist for various wood waste types. Working definitions are provided here for the use in this document.

square cm or higher. Because gribbles require an oxygenated burrow they are limited to the outer 3 cm of LWD even with active irrigation (Ricketts et al. 1985). Gribbles feed directly on wood and are able to use approximately 45 percent of the consumed material, voiding the remaining material as fine particulate fecal matter (Gonor et al. 1988). The fecal matter is slightly negatively buoyant which means it will sink, but is readily re-suspended and distributed by wave energy or tidal currents. This fecal matter is a valuable source of energy to the detrital food web. The high density and consumption by gribbles can reduce the circumference of LWD by as much as one inch per year (Maser et al. 1994).



Shipworms

Shipworms are the second set of wood boring organisms in this region. This group also has two species in our

region, the endemic *Bankia setacea* and the introduced *Teredo navalis* (Ricketts et al. 1985; Kozloff 2000). Both are mollusks and have slender tube like bodies with modified shells for rasping and burrowing on one end, and tube like siphons on the other. Shipworms live inside the wood in tubes that increase in diameter as they grow using their siphons to provide oxygen and nutrients from the water column (Maser et al. 1994). These siphons allow the shipworm to penetrate and consume the wood in the center of the log with little evidence of their presence on the surface. Both species of shipworm consume the wood they remove, and are capable of utilizing approximately 58 percent of the material (Gonor et al. 1988; Maser et al. 1994). The unused is expelled as fine particulate fecal matter similar to that of gribbles. Shipworms are substantially larger than gribbles, they can reach up to 3 cm in diameter and their bodies can be up to 2 meters in length (0.5 m in the case of *Teredo navalis*). In San Francisco Bay it was noted that shipworms (*T. navalis*) were able to weaken a new piling to the point of failure in as little as six months (Ricketts et al. 1985).

Both gribbles and shipworms are capable of converting large woody debris into a form easily transportable via currents and tides. This wood derived fecal material is in a form that is easily distributed and is a valuable source of energy to the detrital community which is the base of highly productive estuary and marine environments

(Gonor et al. 1988). The organisms that rely on this detrital material create a vital link to higher trophic levels such as forage fish, juvenile salmon and various species of birds (Fresh 2006; Eissinger 2007; Pentilla 2007).

Much of the productivity associated with the decomposition of LWD is dependent on the subtle but significant efforts of gribbles and shipworms. Wood waste in the form of sawdust and bark associated with industrial activity does not meet the habitat requirements of either gribbles or shipworms. Because wood waste is not an adequate substrate to support burrowing required by shipworms and gribbles they are not able to use wood waste as a food source or habitat. LWD consumed by wood boring organisms enters the detrital food chain in a form that is available to the benthic community and is easily transportable. Wood waste cannot be similarly processed and therefore can accumulate very rapidly in the sediment of the nearshore zone leading to an increase in the organic composition of the sediment. Elevated sediment organic composition increases oxygen demand and in the absence of adequate pore water exchange can lead to anoxic sediment conditions. Under anoxic conditions the degradation of the wood waste is dominated by sulfate reduction, and is discussed in section 1.2.

In summary, wood waste differs from LWD in several key manners. First, it does not provide the same shoreline protection and habitat complexity to the nearshore. Second, wood waste does not provide a substrate for colonization by gribbles and shipworms. As a result, large amounts of wood waste can accumulate which cannot be consumed by gribbles or shipworms. The persistence of this wood waste alters both the physical and chemical properties of affected sediments.

2.2 Impacts of Wood Waste on Habitat Quality and Structure

Wood waste is a unique form of organic enrichment in the nearshore environment. Elevated quantities of wood waste have been shown to negatively affect benthic and epi-benthic flora and fauna. These negative affects fall into three main categories: physical alteration of the sediment characteristics, acute toxicity through the production of leachate, and longer term toxicity associated with the byproducts of the anaerobic decomposition of wood waste.

Physical Effects

The presence of wood waste on the sediment surface can alter the physical characteristics of the sediment in several ways. Wood waste associated with milling activity can form dense layers with altered porosity and form a barrier to natural surface water/sediment porewater exchange. Many obligate benthic species depend on an adequately flushed sediment column for nutrients and oxygen. The presence of a barrier to pore

water transfer would alter sediment conditions which could impact the composition and distribution of the benthic invertebrate population (Conlan and Ellis 1979; Jackson 1986).

Depending on the thickness and composition of the wood waste, it can also function as a barrier to the movement of various species including bivalves (Conlan et al. 1979) and forage fish. Many marine species have life histories that rely on an appropriate sediment type for spawning or settlement of eggs and larvae. The presence of wood waste can inhibit burrowing by mature invertebrates, as well as prevent the settlement of juvenile or larval invertebrates (Jackson 1986).

The presence of wood waste could also limit kelp (*Macrocystis pyrifera* and *Nereocystis luetkeana*) distribution. Kelp requires a rocky substrate to establish a holdfast to anchor the plant. The presence of wood waste could cover any rocky substrate habitat, preventing the establishment of kelp beds and limiting its distribution.

Leachate Production

Leachate is a term used here to describe water that has come into contact with wood waste, absorbing various chemical compounds in the process (Samis et al. 1999). The concentration and composition of the leached compounds is dependent on the age and type of wood waste and volume of water it is exposed to. Wood waste materials have greater surface area in contact with the water column, producing more concentrated leachate, but generally for a short period of time. Logs on the other hand, can continue to produce leachate as long as there is unsaturated wood exposed to water (Samis et al. 1999). As logs become saturated their ability to produce leachate is reduced. As this occurs the logs become less buoyant and sink. Sunken logs generally produce lower concentrations of leachate (Samis et al. 1999).

Leachate is of particular concern because it has been shown to be toxic to a wide array of benthic invertebrates and fish species (Pease 1974; Peters et al. 1976; Buchanan et al. 1976; Samis et al. 1999). Concentration, composition, and toxicity levels of leachate can vary widely between tree species. Various studies have determined the toxicity levels for Douglas Fir (Schaumburg 1970), Western Red Cedar (Peters et al. 1976), Western Hemlock (Buchanan et al. 1976), Sitka Spruce (Buchanan et al. 1976), and Yellow Cedar (Pease 1974). Appendix A provides a generic list of the toxicity of several tree species and leachate compounds.

Many factors including tree species, chemical compound, concentration of leachate, and developmental stage of the bioassay organism influenced the outcome of the bioassays presented in Appendix A. For example Peters et al. (1976) found that tropolones (a compound found in Western Red Cedar leachate) was more toxic to coho fry than other life stages (smolts and alevins), and

that tropolones could inhibit fertilization they did not appear to impact hatching success.

All toxicity measurements for the fish and invertebrate bioassays in Appendix A were for water column concentrations of leachate. There is no mention of sediment or pore water accumulation of leachate is made in any of the studies. Most studies quantified toxicity levels for leachate, but did not identify it as a major toxicity concern in actively flushed marine waters. Flushing activity would not be expected in the pore water of the sediment, allowing leachate to potentially accumulate in sediment adjacent to wood waste deposition.

Sulfide Production

Leachate has the potential to degrade habitat quality in the nearshore. However much of the impact from leachate may be reduced through the flushing action of daily tidal movement. The potential for toxicity and habitat quality reduction remains as a result of the anaerobic decomposition of wood waste via sulfate reduction, the by-product of which is the production of sulfide.

Marine sediment is generally very low in organic content (Phillips 1984; Libes 1992). Organic material in the marine environment decomposes via different mechanisms than in the terrestrial environment. Research indicates that in marine environments bacteria, not fungi, are responsible for the majority of the decomposition of organic material including wood waste (Jorgensen 1982; Fenchel 1988) leading to the development of anoxic conditions.

A reduction-oxidation (redox) reaction is the transfer of an electron from a reductant (or electron donor) to an oxidant (or electron acceptor) (Holum 1998). Oxygen is the preferred electron acceptor, but is rapidly depleted within coastal marine sediments, generally within the first few millimeters (Jorgensen 1982; Phillips 1984; Holmer et al. 2005).

As oxygen is depleted within the sediment or water column, alternate electron acceptors can be used by anaerobes to decompose organic material. These

electron acceptors are preferentially used according to their specific free energy available and their potential for oxidation (Burdige 2006).

Table 2 provides a list of preferentially utilized electron acceptors in order of the amount of free energy available from each reaction, and the approximate redox potential where each electron acceptor is dominant.

Higher energy yielding electron acceptors would be preferentially used but are generally relatively limited and rapidly depleted in the marine environment. In contrast sulfate is readily available in marine waters and dominates anaerobic decomposition in coastal marine systems (Jorgensen 1982; Burdige 2006).

At lower pressures and temperatures sulfate reduction requires catalyzation by a facultative or obligate anaerobe; in the coastal marine environment the genus *Desulfovibrio* appears to be the most dominant of the seven known sulfate reducing bacteria genera (Jorgensen 1982; Zehnder and Stumm 1988; Burdige 2006). Sulfate reducing bacteria use biologically available organic material as its electron source or reductant and sulfate as the electron acceptor or oxidant. A by-product of sulfate reduction is the production of sulfide (HS^-), generally in the form of hydrogen sulfide (H_2S). The speciation of the reduced forms of sulfide is dependent on numerous physical and chemical parameters such as temperature, pH, salinity and availability of reactive iron and other minerals (Millero 1986; Fuller 1994).

H_2S is a chemically reactive substance known to impact the distribution of eelgrass (*Zostera marina*) (Pedersen et al. 2004), and act as a toxicant to many invertebrates, reducing the diversity of the benthic invertebrate community (Goodman et al. 1995; Wang and Chapman 1999; Hyland et al. 2005). The benthic and epi-benthic communities are particularly sensitive to hydrogen sulfide exposure. Invertebrates form the foundation of a broad food chain that includes a wide array of salmonids, other fish species, birds, and many others species. As sulfide levels increase there would be a fundamental shift in the structure or species present in favor of those more highly adapted to elevated sulfide levels (Rosenberg et al. 2001). The full effects of this shift have not been fully demonstrated.

Beyond the effect of sulfides on the benthic invertebrate community, sulfides levels directly impact the distribution of aquatic vegetation, particularly eelgrass (*Zostera marina*). Eelgrass meadows form the base of a highly productive ecosystem that is vital in providing habitat and nutrients to species within the meadow and beyond (Gillanders 2006). The structure and primary production provided by eelgrass meadows serve as vital spawning and forage habitat for Pacific Herring and Dungeness crab, as well as various other fish and invertebrate species (Gillanders 2006; Pentilla 2007). Juvenile salmonids are also known to rely on eelgrass beds for foraging and protection at various life history

Table 2 - Potential electron acceptors in marine sediments. Adapted from Billen (1982) and Burdige (2006)

Electron Acceptor	Thermodynamic energy available (J mol C^{-1})	Approximate Redox Potential (E_H)
O_2 Oxygen	-471	+800
NO_3^- Nitrate	-444	+700
Mn^{4+} Manganese	-397	+550
Fe^{+3} Iron	-131	+25
SO_4^{2-} Sulfate	-76	-200
CO_2 Carbon dioxide	No data	-350

stages (Fresh 2006). Eelgrass meadows serve a vital function in nearshore ecosystems by providing habitat structure and primary production which supports a wide array of species both directly and indirectly (Gillanders 2006).

Increased sulfide levels have been shown to influence or limit the distribution and health of eelgrass (Pedersen et al. 2004; Elliott et al. 2006). As a result of anaerobic decomposition wood waste can inhibit the growth and survival of eelgrass, a highly ecologically significant species. The loss of eelgrass habitat has far reaching implications on habitat quality for invertebrates, fish, birds, and marine mammals.

Affects of pH on Sulfide Production

Recent research has shown that increased atmospheric CO² levels are resulting in increased acidification and reduction in pH of the world's oceans (Feely et al. 2008). The implications of ocean acidification are not fully known, however it is known that sulfate reducing bacteria are adapted to a broad range of habitat types including basic and acidic environments (Muyzer and Stams 2008). Ocean pH is currently between 8 and 8.2; many sulfate reducing bacteria have optimum productivity levels at a lower or more acidic pH than this (Badziong and Thauer 1978). Therefore it is possible that one impact of ocean acidification could be a net increase in sulfate reduction leading to an increase in sulfide production and further reduction of habitat quality at wood waste impacted sediments.

The identification and assessment of wood waste impacted sites across Puget Sound could provide an opportunity to restore habitat function to many sites that have been fundamentally altered by the introduction of wood waste and is an important component of broader efforts to restore the Puget Sound. While it is clear that the impacts of wood waste are site specific, it is possible to determine when wood waste is degrading habitat quality and merits restoration or removal. An assessment protocol is presented in the next section as a method of evaluating sites impacted by wood waste and guiding restoration efforts.

3 Assessment and Restoration

3.1 Assessment of Wood Waste Sites

A significant hindrance to the progression of wood waste restoration in the region is the lack of an effective mechanism to identify and prioritize whether restoration is appropriate. While there are differences between sites it is possible to develop a template of approach that identifies what habitat functions have been limited and highlights a course of action. While cost is not the driving factor in the development of a methodology, it should be considered in tandem with anticipated benefits. It would be inappropriate to ignore the fact that sampling

and assessment efforts are costly, sometimes even prohibitively so. This section outlines an assessment protocol that will assist in determining if wood waste is impairing a habitat, and provide direction on how to develop a restoration plan for these sites.

This section is not meant to provide a substitute for the remedial investigation/feasibility study framework prescribed by Ecology under MTCA (Chapter 173-340 WAC). Rather this section is meant to provide the necessary tools to a restoration proponent to determine when restoration is merited at a site when regulatory standards have not been exceeded. The reader is directed to Model Toxics Control Act Statute and Regulation (RCW 10.105D, WAC 173-340) for further clarification of requirements under MTCA.

When assessing wood waste impacted sites there are several steps required to determine whether a site is likely to have impaired habitat quality, and is therefore a candidate for restoration. These main steps presented in this section are: historical assessment, site characterization, and laboratory assessment. Appendix C presents a flow chart displaying these steps and possible outcomes, while **Table 3** provides a description of the various steps.

Throughout this tiered assessment each step could trigger additional analysis to clarify if wood waste is impacting habitat quality, or it could determine that a particular area is not impacted and remove it from consideration.



Historical Assessment

The historical assessment is similar in intent and structure to an environmental assessment for terrestrial sites. The intent of this initial historical assessment is twofold. The first is to determine if there is potential for chemical contamination on the site, and second to determine the scale of historic operations along with potential sources and locations of wood waste. The assessment of wood waste contamination is undertaken

Table 3 – Description of assessment stages. Application of the assessment protocol leads to a determination if habitat quality is impaired as a result of wood waste.

Protocol Stage	Objectives	Methods and data sources	Product
Historical Assessment	• Determine the type and length of operation. • Define boundaries of potential impact area. • Identify and potential chemical contamination risks. • Identify pre-impact habitat type.	Review of historical records: • Photographs • Fire insurance maps • Written and oral histories • Production records	A rough map outlining the area potentially impacted by wood waste and historic habitat features if available.
Site Characterization	• Define the distribution and volume of wood waste impacted sediment. • Determine current habitat conditions.	Field sampling: • Define the sediment profile using an appropriate technique, see table 5. • Measure habitat quality parameters as defined by the appropriate habitat type for the site.	A more accurate map of the impacted area displaying the wood waste distribution and the volume of impacted sediment.
Laboratory Assessments	• Define the level where wood waste is impacting habitat quality.	Laboratory analysis: • Total sediment organic composition • Total pore water sulfides • Ammonia • Biological Assessments	A defined area where wood waste is impacting habitat quality.

via substantially different pathways than that of chemical contamination due to the status of wood waste under SMS. If the historical assessment identifies a potential for contamination, then it is necessary to incorporate sampling for SMS chemicals of concern (COCs) either into the laboratory assessment stage of this assessment protocol, or as an independent sampling event. If SMS criteria are exceeded then it is necessary to report the findings to the Washington State Department of Ecology Toxics Cleanup Program. Additional information on reporting requirement and the voluntary cleanup program are available in the MTCA cleanup regulation (Chapter 173-340 WAC) contained in Ecology publication number 94-06.

Both steps of the historical assessment are information gathering exercises and do not entail physical sampling. Most of this information is gathered from historic records, interviews, and photographs and is meant to guide the development of a sampling plan. There are many sources and types of information available, but certain types of information including photographs, site maps, production records, and written or oral histories are essential to an effective historical assessment. The type and volume of information available for each site will vary widely based on amount of information available for each site. This information is then used to develop a draft map of the impacted area, outlining the potentially impacted area. This outline will serve as the outer boundary for additional sampling and analysis

needed to define the area of impact. A thorough and complete review of historical record will result in a more accurate mapping of the potential impact area and is likely to reduce the area requiring verification via surveys thus expediting the process and reducing costs.

Site Characterization

Having exhausted all recorded information and developed an outline of the impacted area, ground verification via sampling is required. The objective of this stage is to further refine or verify the map of the impacted area developed for the first stage. The information gathered during this stage will be used to determine the number, location, and type of samples required to be taken for laboratory analysis in the next stage. This stage is comprised of a visual assessment of the sediment column to verify the presence or absence of

wood waste along the vertical and horizontal axis. To increase effectiveness and reduce costs it is essential to use an appropriate sampling method that is able to reach native sediment below the depth of likely wood waste accumulation. For example if the historical analysis revealed that wood waste producing activities were conducted at a site for 60 years then a grab sample, which only penetrates 10 to 20 cm, may not be an appropriate survey technique. On the other hand in the same situation if there were records of ongoing dredging, removing sediment and wood waste accumulations, then a grab sample or sediment profile imaging may be

effective. For larger sites, or sites with less detailed historical data it may be appropriate to begin with widely spaced samples to determine the areas of increased deposition, and then refine the scale and increase the number of samples to delineate the boundary of the existing wood waste. Alternately, if detailed historical information is available, or for small sites, it may be appropriate to start with a sampling effort directed at known locations with increased number of samples. Table 5 provides a list of potential survey methods and when they may be appropriate.

A second task to be completed during the reconnaissance and site survey stage is to collect information on the current physical conditions. The factors assessed will vary with each site, and may include, water temperature, salinity, light availability, prevailing current patterns, etc. An understanding of the current habitat conditions coupled with knowledge of the natural history of the location will clarify what habitat features are limited at the site and should be enhanced.

The product of this stage of analysis is a detailed map delineating the impacted area and highlighting the current physical characteristics of the site. As with every stage following its completion it is possible to reduce the size of the project site, or remove some areas from consideration, based on the mapped distribution of wood waste impacted sediments. In the event that substantial amounts of wood waste are observed it may be appropriate to provide a written notice to Ecology to satisfy reporting requirements prescribed under MTCA.

Laboratory Assessment

The laboratory assessment stage is the most complex in terms of implementation and interpretation of all of the stages. As the understanding of the impacts of wood waste improves, along with improved analytical techniques it is likely that these methods will change.

This stage involves correlating the level of wood waste in the sediment with sediment degradation. The impacts associated with wood waste deposition are dependent on many site specific criteria such as type, age, and density of wood waste, as well as local sediment chemistry. The task is greatly simplified however through approaching this from a restoration standpoint.

As was demonstrated in section one wood waste does not have a natural counterpart, and can elevate the organic composition of the sediment and ultimately the production of sulfide. While there are many habitat types, such as estuaries, that have naturally elevated organic composition, wood waste is not equivalent to organic material derived from the detrital food chain. Wood waste is a non-natural component of the sediment and the focus should be on its removal. Substantial time, effort and cost can be saved through this approach by reducing sampling and laboratory analysis.

Several analytical methods can be used to define when wood deposition or concentrations are deleterious and may aid in determining what constitutes degraded sediment conditions. Table 4 provides a list of laboratory analyses and levels at which they may be impacting habitat quality. There are no set levels for these sediment conventional measurements established under SMS or other regulatory authority. When evaluating these sediment conventionals it is important to incorporate information from the historical assessment regarding likely habitat conditions present prior to industrial activity. Natural levels for these sediment conventional measurements vary widely between habitat types. Estuaries and deltas generally have substantially higher sediment organic content, and therefore potentially higher TVS, pore water sulfide, and ammonia levels than other habitat types. The potential levels of concern should therefore be viewed as guidance and amended to according to the expected habitat type for each site.

Biological Assessments

The chemicals produced by the decomposition of wood waste may fall under the SMS definition of “other toxic, radioactive, biological or deleterious substances” (Chapter 173-204-200(17) WAC). Other toxic, radioactive, biological or deleterious substances do not have regulated cleanup levels, as a result biological assessments are used to determine sediment toxicity. Ecology has published the Sediment Sampling and Analysis Plan Appendix (Publication No. 03-09-043) as a guide to performing the required bioassays (two acute and one chronic toxicity). In the event of a bioassay failure MTCA requires that Ecology be notified by the property owner or operator. Please consult MTCA (Chapter 173-340 WAC) to be certain you are in compliance with reporting requirements, including applicable time limits.

Table 4 - Laboratory analysis methods to resolve boundary of wood waste impacted sediments.

Method	Potential Level of Concern ¹
Total Volatile Solids (TVS)	6% ³
Pore Water Sulfide ²	1-50 mg/L ⁴
Ammonia	20mg/L ⁵

¹ Benthic species have various tolerance levels for toxins. Species specific thresholds should be determined for each species of concern.

² Pore water sulfide is suggested over bulk sulfide analysis. The speciation of reduced sulfides is highly dependent on pH, temperature, and local sediment chemistry. Not all reduced sulfide species are of concern. Both methods measure acid volatile sulfides, which measures not only levels of toxic hydrogen sulfide, but also mackinawite, greigite, HS⁻, and others. Pore water generally provides a more accurate measure of H₂S and is therefore preferred.

³ Koch 2001

⁴ Wang and Chapman 1999

⁵ Dillon et al. 1993

Because bioassays can be costly and difficult to interpret, it is recommended that for restoration and enhancement projects, all efforts be made to determine the extent of the impacted area using historical assessments, site characterization, and laboratory assessment rather than relying on bioassays as the final determination.

However, if bioassays are required, or are anticipated to be required for additional permit or regulatory requirements, the Sediment Sampling and Analysis Plan Appendix (Toxics Cleanup Program 2008) and the Dredged Material Management Program Users Manual (Dredged Material Management Office 2008) provide detailed information on bioassay requirements and procedures.

Regardless of what laboratory assessment procedures are used the final product of this step would be a determination of the area impacted by wood waste. This determination will be used to develop a remedial investigation and guide the development and selection of a remediation option. Section 3 outlines some of the potential remediation and removal options available.

Remediation Options

This section provides a general description of the major categories of wood waste remediation technologies and the process of remedy selection. The Department of

Ecology is developing practical guidance providing a brief overview of remediation technologies and their use at wood waste cleanup sites. For this section we rely on the assumption that wood waste has degraded a subject property to the extent that cleanup standards are exceeded and a remedy must be applied. However a site manager or restoration proponent may chose to implement a remedial action for the sole purpose of habitat enhancement, even though regulatory standards are not exceeded.

The following major categories of remedial technology have been, or may be, used at wood waste sites:

1. Monitored Natural Recovery
2. Enhanced Natural Recovery
3. Capping
4. Dredging

A complex cleanup site could employ any mixture of the above methods. Remedial technologies rely on the following mechanisms: decomposition, isolation and removal.

MTCA allows cleanup sites to proceed under one of three levels of oversight: independent, voluntary cleanup program (VCP), or full regulatory oversight. An independent cleanup may make sense for simple, uncontroversial actions conducted by the owner on their

Table 5 - Potential sampling methods available for reconnaissance and site survey methods.

Survey Method	Resolution Depth of Sample	Considerations	Production Rates ³	Estimated Cost ^{1,2}
Sediment Profile Imaging (SPI)	15-20 cm	Capable of estimating grain size and redox potential discontinuity.	30-50 images/day	Medium
Hand Core	1-3+ m	There are a wide variety of hand cores available. They require little equipment mobilization and can be operated from a vessel or in the water. This method is low cost, but cannot produce large volumes of sediment. This system is well suited for small shallow sites.	10-30 cores/ day	Low
Piston Core	24+ m 4-5 m for clear cores	Retrieves a relatively undisturbed core. Clear cores can be used to visually assess sediment matrix. Pore water can be derived from cores. There are many variations of the piston core.	7-15 cores/ day	Low/ Medium
Vibracore	24 + m	Vibracore technology is widely available, and is capable of penetrating consolidated sediments that piston cores fail to penetrate. Generally the cores must be destroyed to be opened. This system could increase the number of cores collected in a single day.	7-10 cores/ day	Medium/ High
Video Core	3 m	Similar depth capacity as clear piston cores. New technology allows visual analysis of in-situ sediment matrix. Could be very rapid assessment method.	30-40 locations/ day	Low/ Medium
Grab Sample	10-20 cm	Many variations of grab sampler exist. Can derive pore water or sediment for laboratory analysis from this sample. Difficult to assess stratigraphy of sediment.	10-12 grabs/ day	Low
Underwater Video Survey	Surface	Rapid method of assessing surface composition and benthic community. Does not resolve sediment matrix.	1500-3000 m/day	Low/ Medium
Dive Transects	Surface/ 15cm	Provide broad overview of sediment surface. Not effective for sub surface sediment observations.	700 m/day	Medium/ High

¹ All costs are estimates and will vary widely based on site location and needs.

² Low \$3,000-5,000/day; Medium \$5,000-7,000/day; High \$7,000-10,000+/day

³ All production rates are estimates, actual rates will depend on site specific conditions such as depth, sediment type, and location.

own property. DNR recommends that in all other cases, especially when a site is located on state owned aquatic lands (SOAL), that independent cleanups not be pursued. The important distinction between the levels of oversight is that independent cleanups do not incorporate input from Ecology regarding the adequacy of the remedy. Ecology oversight reduces environmental liability risk for the site managers and property owners. Please refer to the introductory pages of Ecology publication 94-06 for more information. If a restoration proponent is pursuing remediation or habitat enhancement at a site where regulatory standards have not been exceeded it may be appropriate to proceed using the guidance for an independent cleanup once Ecology has been informed.

The Sediment Sampling and Analysis Plan Appendix (Toxics Cleanup Program 2008) provides guidance on sampling and reporting requirements for sediment investigations under SMS. First, a remedial investigation (RI), as described in Section 2.1 is completed to fully characterize the nature and extent of contamination. The data that is collected is then used to develop a feasibility study (FS). The FS carefully weighs the costs and benefits of a range of remedial options. On state owned aquatic land, DNR advocates a full range of options be considered, from no action to full removal.

At minimum, the selected remedy must be protective of human health and the environment. The FS also considers protectiveness, permanence, cost, long and short-term effectiveness, technical and administrative implementability, and public concerns as necessary decision factors. Cost may be considered when selecting a remedy. Usually for VCP, all the information is combined into an RI/FS report which is then submitted for agency and public review.

Monitored Natural Recovery

This approach relies on naturally occurring attenuating processes, such as: bioturbation, sedimentation, erosion, and biological decomposition. At each site these mechanisms must be studied and modeled to show that natural recovery will occur within an acceptable time frame. Regulatory agencies typically require that cleanup levels be reached within 10 years. If evidence does not predict natural recovery in 10 years, then regulatory agencies will usually require a more active remedial approach.

Natural recovery is appropriate for sites where wood waste coverage is discontinuous and cleanup objectives are only slightly exceeded. It becomes a more attractive option where sites are very large and more active approaches such as dredging are cost prohibitive. It also may be favored by resource agencies and tribes if disturbing the sediment could impact resources such as shell fish beds.

A monitoring program is required to show that natural recovery is occurring as predicted. Sampling regimes can vary from yearly to once every 3 years.

Enhanced Natural Recovery (ENR)

This method augments natural recovery with the placement of a six inch sand layer. The sand layer is not designed to isolate the wood waste and as such, should not be confused with a sand cap, discussed below. The enhancement layer provides a clean substrate to kick start benthic recovery, inducing recruitment of organisms more typical of the local habitat. It is anticipated that over the long term, bioturbation will mix the sand layer with the underlying wood waste layer. This will dilute the concentration of wood waste and accelerate aerobic decomposition.

Similar to natural recovery, a 10 year or less recovery time frame must be predicted by the site model and proven through long term monitoring. At sites with continuous coverage and thick accumulations, designers will probably not be able to justify ENR. Cleanup, as defined under regulatory standards, is only achieved when monitoring shows that the site has fully recovered to site cleanup goals.

Capping

Capping is the least preferred remedial technology for wood waste sites with thick accumulations of wood waste. A determination of what is too thick of an accumulation must be determined by remedial designers at each site. The long term efficacy of capping high percentage wood waste sediment has not been fully demonstrated. Potential problems include anaerobic off-gassing, leaching of soluble byproducts, and differential settling. It may be necessary to remove most of the overlying layer of wood waste before capping is approved.

A cap is a layer of material, such as sand, placed on top of contaminated sediment which has been engineered to physically and chemically isolate the underlying contaminated sediment. Caps are designed so that the rate of desorption of contaminants in porewater that passes through the cap does not exceed applicable water quality criteria at or near the surface. The cap prevents the contaminated sediment from coming into direct contact with marine organisms.

Caps are uniquely engineered for the conditions of each site and the set of contaminants that must be isolated. Although typically thought of as permanent, some caps may have a limited design life based on the partition coefficients and concentrations of the contaminants. Activities, such as prop wash, earthquakes, and changes in local hydrodynamics, may reduce the long term effectiveness of the cap.

Guidance from the Corps of Engineers (Palermo et al. 1996) is typically cited by designers for cap design. The

cap designer must provide an engineering basis for the cap specifications, which are unique at each site. The most often used cap thickness in Puget Sound is three feet, employing medium to fine sand.

Caps are usually placed by dispersing sand from a vessel at a controlled rate while the vessel transects the area to be capped. Cap placement in shallow areas such as tide flats may require land based methods such as excavators or pneumatic systems. A pneumatic cap placement system was used for the sensitive mud flats located at the head of Middle Waterway in Commencement Bay, Washington. Capping material is delivered through a tube that is handled without heavy equipment, preserving the natural contours.

Short and long-term monitoring is required after cap placement to demonstrate conformance with cap specifications and long term effectiveness. Cap thickness is verified by before and after bathymetry surveys and post-placement cores. Monitoring for five to ten years is usually performed to verify that the cap design is isolating wood waste as designed.

Dredging

Dredging of wood waste is the most effective and permanent option, but also the most expensive. It is usually performed from a barge platform using a cable operated bucket varying in size from three to five cubic yards. Clam shell dredging rates are typically 300-500 cubic yards per hour but vary widely based on site specific conditions. Alternate bucket types may be appropriate based on site conditions. The presence of debris such as old pilings and cables is common and could slow production rates and increase costs. Ideally, these conditions will have been identified during the RI and incorporated into the production rates in the dredging contract.

Vertical accuracy (e.g. depth of cut) is limited to about one foot. Dredging of wood waste thicknesses less than one foot will result in entrainment of underlying sediment and added cost beyond that of the wood waste volume. Backfilling may be required if dredging below natural surrounding contours.

Dredging requires a corps permit and Ecology water quality certification. Permits will limit dredging to certain times of the year to protect migrating fish. Dredging must be performed within the “fish window”. Water quality must be monitored during dredging to ensure that turbidity does not exceed permit limits.

After dredging, some residual material will remain. This results from wood waste and sediment being disturbed and suspend temporarily in the water column and then settling to the bottom after the dredging pass is complete. Several inches of finer wood waste may accumulate as residual material. This is unavoidable. Options are to perform a second dredging pass after the material has

settled, place an enhancement sand layer over the top, or leave it to naturally recover.

Disposal of wood waste is a significant cost element of dredging. Disposal options include: open water disposal at a dredged material management program (DMMP) site, beneficial use if clean, and upland disposal.

Open water disposal at a DMMP site is limited to sediment with less than 25 percent wood waste by weight and 50 percent by volume, unless confirmatory bioassays are conducted. If the sediment is otherwise clean the wood waste may be beneficially reused. This might require desalination through methods such as sparging. Landfill disposal is an option. If the sediment is contaminated it may need to be disposed of at a Subtitle D² upland disposal facility. Chemical testing must be performed to the satisfaction of the receiving facility.

More unusual disposal options such as confined aquatic disposal (CAD) are not covered here. Please see appropriate Ecology guidance documents for more detail.

In Situ Treatment

In situ treatment means treating the wood waste without moving it first. There is no known effective technology for in situ treatment of wood waste in marine environments.

3.2 Case Study: Port Gamble Interim Action

The Port Gamble Interim Remedial Action was contracted by DNR and successfully removed 16,500 cubic yards (cy) of dredged material containing abundant wood waste from Port Gamble Bay near the former Pope & Talbot (P&T) mill site. Project dredging and sand cover placement was completed in January and February 2007. Wood waste was transferred to a contained upland basin for sparging with fresh water to remove salt prior to beneficial reuse of the dredged material for landscaping purposes. Sparging and upland disposal were performed by another party and is not included in costs noted below. The dredged material consisted predominantly of sawdust-like material and heterogeneous, dark sediment and wood waste with a relatively minor amount of large wood debris.

During dredging, the interface between wood waste and native sediment was deeper and more transitional in many areas than anticipated based on available site investigation data. In some cases, the interface with the harder, native sediments was up to several feet deeper than expected. Additional site characterization in the form of cores, probes, and other physical data would have provided additional design data and decreased dredging uncertainty.

² Subtitle D facilities are state managed hazardous waste facilities.

Costs for the Port Gamble Interim Remedial Action include construction costs and technical assistance to DNR for construction management support, water quality sampling, and related items. The total construction cost for the Interim Remedial Action was \$760,100. Contract cost increases were largely due to additional dredging costs and compensation for removal of *in situ* wooden pilings.

Inclusive of mobilization, contractor submittals, labor, and equipment/direct costs, the unit cost of materials dredged and offloaded was about \$30 per cubic yard. This unit cost is relatively expensive compared to other sediment cleanup projects and reflects the influence of site conditions and logistical challenges discussed above. It should be noted that the summarized construction total cost does not include disposal, design, permitting, pre-construction and post-construction surveys, and monitoring costs. DNR, Ecology, and other agency coordination costs are also excluded.

Cover placement was completed by the contractor on a fixed fee basis for \$66,500. About 1,500 CY were placed over 1.2 acres in two 6 inch layers, for a total of about one foot thickness.

Limitations and Special Considerations

Since every wood waste site will have new and unanticipated challenges, retaining remedial design engineers and marine contractors who have experience with wood waste cleanup sites is highly recommended. DNR cannot recommend specific companies due to a potential conflict of interest. However, there is a relatively short list of completed wood waste cleanup sites in the region and associated contractors who have worked on them.

4 Data Gaps

This document is intended to provide guidance to parties interested in restoring sites impacted by wood waste. In addressing wood waste from this perspective it is viewed as a non-natural substance based on physical and chemical impacts on sediment quality. Several tools are suggested in section 2 as possible mechanisms for determining when wood waste is detrimental, but all of these tools require an assessment of local habitat conditions and best professional judgment to determine if habitat quality is degraded. In general the ability to make a determination on sediment quality would be greatly improved by an increased understanding of all aspects of wood waste as a material that can alter habitat conditions and degrade habitat quality. This task is complicated by the fact that the decomposition of wood waste and naturally occurring organic matter in the sediment occur via very similar pathways. Additional research is required to define the subtle but significant differences between the decomposition of wood waste and naturally occurring organic material. Within this

broader question there are several specific areas of study identified here that would greatly improve the current knowledge of wood waste and the ability to manage restoration and remediation projects.

Much of the understanding of wood waste decomposition is based on research on anaerobic decomposition of organic material. As a result very little is known about the rates and mechanisms of the decomposition of individual components of wood waste such as cellulose, hemicellulose, and lignin. Additional understanding of these processes is required in order to improve our understanding of what amount of wood waste constitutes a degraded state under specific conditions. In addition an improved understanding of the mechanisms of decomposition will inform our understanding and selection of remediation options. This research could validate the use of open water disposal as an option, or identify alternate methods such as enhanced natural recovery based on facilitating natural in-situ decomposition.

A second area that would benefit from additional research is the topic of leachate production. While some research has been conducted in this area (Schaumburg 1970; Pease 1974; Buchanan et al. 1976; Peters et al. 1976); these experiments would benefit from replication using improved analysis methods to assess the composition and toxicity of leachate components from various tree species. Current research has not identified this as an area of primary concern over the long term, but an increased understanding would result in a better ability to assess and manage sites with ongoing exposure to wood waste production sources.

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Appendix A – Bioassay results for several tree species

LC50 is the lethal concentration for 50% of the tested organisms. EC50 is the concentration at which 50% of the tested organisms experience altered behavior.

Tree Species	Chemical Compound	Test	Concentration	Species & life stage	Reference
Hemlock	Not Listed	96h Freshwater	75mg/L<LC50<90mg/L	Pink salmon fry	Pease 1974
Hemlock	Not Listed	96h Saltwater	LC50>200mg/L	Pink salmon fry	Pease 1974
Hemlock Bark	Not Listed	96h Saltwater	EC50 490mg/L LC50>1000mg/L	Larval Pink shrimp	Buchanan et al. 1980
Hemlock Bark	Not Listed	96h Saltwater	LC50>1000mg/L	Adult Pink shrimp	Buchanan et al. 1981
Hemlock Bark	Not Listed	96h Saltwater	EC50>1000mg/L LC50>1000mg/L	Larval Dungeness crab	Buchanan et al. 1982
Hemlock Bark	Not Listed	96h Saltwater	LC50 56mg/L	Pink salmon fry	Buchanan et al. 1983
Sitka Spruce	Not Listed	96h Freshwater	25mg/L<LC50<40mg/L	Pink salmon fry	Pease 1974
Sitka Spruce	Not Listed	96h Saltwater	LC50>200mg/L	Pink salmon fry	Pease 1974
Sitka Spruce Bark	Not Listed	96h Saltwater	EC50 155mg/L LC50 415mg/L	Larval Pink shrimp	Buchanan et al. 1976
Sitka Spruce Bark	Not Listed	96h Saltwater	LC50 205mg/L	Adult Pink shrimp	Buchanan et al. 1977
Sitka Spruce Bark	Not Listed	96h Saltwater	EC50 225mg/L LC50 530mg/L	Larval Dungeness crab	Buchanan et al. 1978
Sitka Spruce Bark	Not Listed	96h Saltwater	LC50 100-120mg/L	Pink salmon fry	Buchanan et al. 1979
Western Red Cedar	Not Listed	96h Freshwater	35mg/L< LC50<45mg/L	Pink salmon fry	Pease 1974
Western Red Cedar	Not Listed	96h Saltwater	LC50>200mg/L	Pink salmon fry	Pease 1974
Western Red Cedar	Lignans	120h Freshwater	LC50 60-64mg/L	Coho fry	Peters et al. 1976
Western Red Cedar	Lignans	120h Freshwater	LC50 33mg/L	Coho alevins	Peters et al. 1976
Western Red Cedar	Lignans	120h Freshwater	LC50 80mg/L	Mayfly nymphs	Peters et al. 1977
Western Red Cedar	Tropolones	96h Freshwater	LC50 0.31-0.33mg/L	Coho fry	Peters et al. 1978
Western Red Cedar	Tropolones	96h Freshwater	LC50 0.34mg/L	Coho juveniles	Peters et al. 1979
Western Red Cedar	Tropolones	96h Freshwater	Fertilization inhibited 0.7mg/L	Coho eggs/milt	Peters et al. 1980
Western Red Cedar	Tropolones	96h Freshwater	LC50 >2.5mg/L	Coho eyed eggs	Peters et al. 1981
Western Red Cedar	Tropolones	96h Freshwater	LC50 1.05mg/L	Coho alevins	Peters et al. 1982
Western Red Cedar	Tropolones	96h Freshwater	LC50 0.39mg/L	Prickly sculpin	Peters et al. 1983
Western Red Cedar	Tropolones	96h Freshwater	LC50 0.21mg/L	Steelhead trout	Peters et al. 1984
Western Red Cedar	Tropolones	96h Freshwater	LC50 4.4mg/L	Mayfly nymphs	Peters et al. 1985
Western Red Cedar	Tropolones	96h Freshwater	LC50 7.3mg/L	Caddisfly larvae	Peters et al. 1986
Yellow Cedar	Not Listed	96h Freshwater	LC50>50 mg/L	Pink salmon fry	Pease 1974
Yellow Cedar	Not Listed	96h Saltwater	150mg/L <LC50<200mg/L	Pink salmon fry	Pease 1974

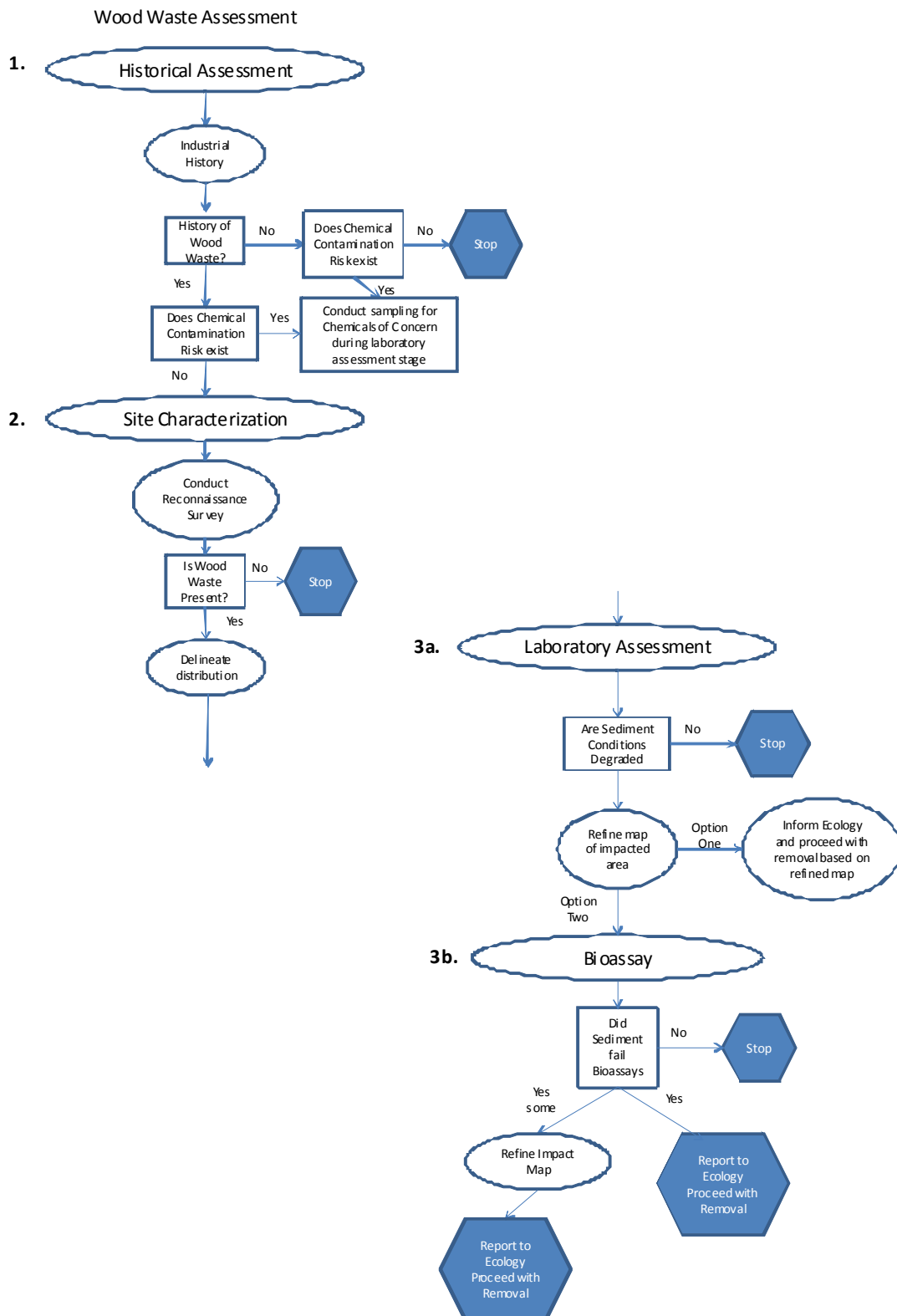
Appendix B – Permitting Requirements

Understanding the permitting requirements for each potential wood waste project can be a formidable barrier. The individual permits required for each action will vary based on site specific factors. In addition to the list detailing the likely permitting requirements for any wood waste removal project, there are several other resources available. The Washington State Governor’s [Office of Regulatory Assistance](#)³ and the Department of Ecology’s [Environmental Permit Handbook](#) provide a great deal of information to assist in understanding and navigating the permitting process. Regardless of what permits are required it is essential to allow for sufficient time to obtain all the required permits. Each permit has its own timeline, but a general timeframe of 6 months to 1 year should be expected to complete and obtain all required permits.

Authorizing Agency	Permit	Description	Information
Washington Department of Natural Resources	Use authorization or Right of Entry	Required for any activity on state owned aquatic lands	Contact appropriate DNR land manager or Aquatics region office for information. www.dnr.wa.gov 360 902-1100
Washington Department of Fish and Wildlife	Hydraulic Project Approval (included in the JARPA)	Required for any work that uses, diverts, obstructs, or changes the natural flow or bed of any of the salt or fresh waters of state.	http://wdfw.wa.gov/hab/hpa_criteria.htm
Advisory Council on Historic Preservation or Washington State Department of Archaeology and Historic Preservation	Section 106 or Archaeology excavation permit	Required for all sites where activity may impact cultural or tribal resources. Section 106 is required if any federal funds or permits are required.	Section 106: http://www.achp.gov/106summary.html#intro DAHP: http://www.dahp.wa.gov/pages/Archaeology/ArchaeologyOverview.htm
State or Local Government	SEPA (State Environmental Policy Act)	Required in conjunction with any state or local permitting.	http://www.ecy.wa.gov/programs/sea/sepa/e-review.html
Washington Department of Ecology	401 Water Quality Certification (included in the JARPA)	Required when 404 permit is required, and when conducting any activity that may result in discharge of dredge material into waters or wetlands.	http://www.epermitting.wa.gov/site/alias_resourcecenter/jarpa/9983/jarpa.aspx
Washington Department of Ecology	Coastal Zone Management Certification	Required if the project is located within one of Washington’s 15 coastal counties to ensure project is consistent with the coastal zone management program.	http://apps.ecy.wa.gov/permithandbook/permitdetail.asp?id=46
Federal Agency	NEPA (National Environmental Policy Act)	Required for all Federal permits. Requirements vary for each federal agency.	
U.S. Army Corps of Engineers	Section 10 Rivers and Harbors Act (included in the JARPA)	Required for all work in navigable waterways of the United States.	http://www.epermitting.wa.gov/site/alias_resourcecenter/jarpa/9983/jarpa.aspx
Local Government	Shoreline Substantial Development Permit (included in the JARPA)	Required for any activity which may impact the shoreline.	Contact local shoreline management agency
Federal, State, and Local agencies	JARPA (Joint Aquatic Resource Permit Application)	Joint permit application for most federal, state and local permits.	http://epermitting.org/site/alias_resourcecenter/jarpa_introduction/10042/introduction.aspx

³ The Office of Regulatory Assistance project questionnaire is very helpful in determining an individual projects permitting requirements. <http://www.ora.wa.gov/resources/questionnaire.asp>

Appendix C – Wood Waste Assessment Decision Tree



Appendix D – Locating Timber Operations and Wood Debris Locations

This report was provided November 25, 2008, concurrent with development of restoration guidance.

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1 Introduction

This scoping report is made to determine the feasibility of locating wood debris sites in Puget Sound, in part to identify feasible restoration sites in Puget Sound. After a review of the sources of information, the preliminary development of a geodatabase, which uses a geographic information system (GIS) to spatially index source information about potential wood sites based on general geographic locations of potential wood waste sources we have found that such an effort is feasible. In order to populate the database, and to digitize polygons to represent wood debris sites by operation type, a budget of 1 FTE over the period of one year should be adequate. But, as with most databases and GIS products, this effort should not be perceived as a project, but as a program—in order to maintain and update the database. It is estimated that on an annual basis such an effort would entail less than a .2 FTE per year, and could be performed as part of a positions overall duties. Given the nature of past GIS projects, and the ad hoc manner of their existence, it is recommended that such a programmatic effort be considered at the outset.

This effort will require an extensive information gathering phase using historic records and other documentary sources that will be used to locate and describe potential wood waste sites. This information will be input into a geodatabase that will spatially index this information best on the general locations of wood waste facilities and potential deposition sites.

The timber industry has evolved its processes and practices in harvesting the forests of Washington State based on the ownership of the land, the occupation of waterways, and the timber products that have been produced by mills. Prior to 1854, large sawmills were established in what was to become Washington Territory to make lumber out of vast stands of timber in Puget Sound. The first large sawmills were the Port Ludlow, Port Gamble, Blakely Harbor and Port Madison.

Local saw mills in general relied on logs sold to the mills from the clearing of private and federal land. Regional saw mills relied to a greater extent on timber produced on mill-owned lands or under long term contracts for federal, state or tribal timber lands. These logs were transported to the mill over great distances, and were located initially to transport the mill's products by ship to external markets such as California. For example, the Port Blakely Mill Company on Southern Bainbridge Island, harvested trees in Mason and Thurston Counties, conveyed those trees to Skookum Inlet on a log railroad, dumped those logs into that inlet at Kamilche and New Kamilche, conveyed them to Blakely Harbor by log raft, log boomed those logs in the harbor. Blakely Harbor provided a safe harbor for ocean going vessels. As another example, the Bloedel-Donovan Company located in Bellingham, acquired large stands of timber in Clallam County south of Sekiu, transported the harvested logs to Sekiu by rail, dumped the logs and created log rafts, transported the log rafts from Sekiu, through the Straits of Juan de Fuca and the San Juan Islands to Bellingham, where the logs were boomed on private tidelands.

With the development of railroads, lumber mills were able to move inland and locate closer to their timber. Railroads provided a means to convey the lumber to nearby ports, as well as to markets located in the interior of the United States. The mills along railroad lines could be located on the interior, often adjacent to lakes that acted as mill ponds.

A report on the timber industry identified numerous mill locations (From Sedell, et al: 1991, citing Cox 1974):

Note that each one of the mills is located on Puget Sound's shore, at harbors that could be used by ships for ocean trade.

Pulp and paper mills commenced operation in the 1920s, and were located primarily at major ports connected to railroads. These mills relied on company owned forest lands, or timber lands harvested with long term contracts.

Wood treatment plants were often co-located near railroads and developing seaports since much of their products were used in Port development and railroad construction.

Each mill had to secure its timber supply, and also provide transportation facilities to get that timber to the mill. Each aspect of the operation, including felling, transport, and milling, would produce its own type of wood waste: log dumping and booming would produce bark and large wood debris; lumber mills would produce sawdust and log ends; pulp and paper mills would produce sulfite liquor waste and fibrous wood debris; plywood mills would produce resins and wood chip waste; and wood treatment facilities would produce creosote and other treatment chemicals—often associated with log booming. Each of these production facilities may have disposed of their waste either by dumping behind bulkheads in nearshore areas, by burning in a “teepee burner”, or in a hog fuel burner to produce energy. The burning of salt water infused wood has been shown to produce dioxin.

In order to identify and catalogue wood waste sites, several documentary sources have been identified and a simple database with three linked tables is proposed to determine not only the location, but the type of operation that generated the wood waste at each location, and document the sources of information for each site. The sites with the most complete documentation would be the urban embayments such as Olympia, Tacoma, Seattle, Everett, Bellingham, Anacortes, and Port Angeles to include state harbor areas plats, detailed DNR index sheets, federal navigation channel condition maps, railroad station maps navigation charts, and Sanborn Maps. These are documentary source rich areas. But records do exist to identify activities for non-urban areas as well: DNR Index Sheets, DNR booming company plats, federal navigation charts, Metsker Maps, and other sources of information. Secondary sources may often have to be reviewed, especially for non-urban areas and localized mill activities. The amount of documentary source detail required for each wood waste polygon would be professionally determined.

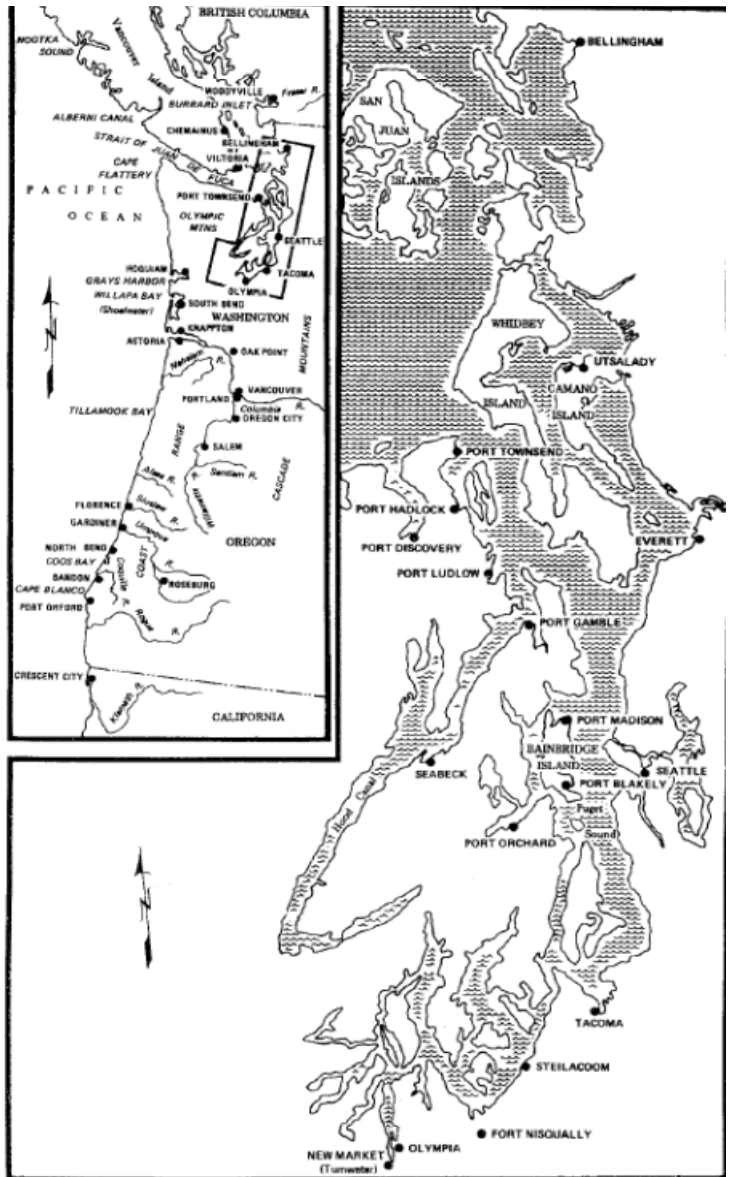
2 Wood Waste Database

A suggested database structure for this project would include three linked tables: polygon, location, and source. Each table would be linked to each other through the Polygon field, and each polygon table would have a list of source document codes.

Polygon table:

Polygon ID:
Polygon Name:

Reference field for wood waste polygon or facility operation point.
Name of operation



Source Code:	List of codes that relate to records in the source table.
Geographical location:	Name of embayment, etc.
GIS Position:	Lat/long (if available from source material)
Ownership:	State or Private
Land Classification:	Harbor area, 1 st class tideland, 2 nd class tideland, 1 st class shorelands, 2 nd class shorelands, beds of navigable waters, waterways.
Deed:	Vol/Page of DNR Aquatic Land Register of Aquatic Land Deeds.
DNR Use Authorization:	DNR use authorization prefix and sequential number
Regulatory Permits:	Identify regulatory permits for operation--if known.

Source Table:

Source List:	Booming Company Plats: CoName/Waterbody
	US Coast-Geodetic Survey: Chart Number/Date
	DNR Harbor Area Plats: DNR Map Code
	DNR Index Sheets: DNR Map Code
	DNR Financial Data Reports: DNR FR
	US Corps of Engineers: Corps Map Code
	Railroad Right of Way Maps: Code/date
	Sanborn Fire Insurance Maps:Date/City/Sheet
	Secondary Sources: Title

Sources Description:

Booming Company Plats: In 1890 the Washington State Legislature authorized corporations organized “for the purpose of catching, booming, sorting, rafting and holding logs, lumber or other timber products” to have the powers “to acquire, hold, use and transfer all such real and personal property or estate, by lease or purchase, as shall be necessary for carrying on the business of said corporation.” The legislature established these boom companies as public corporations and authorized them “to construct, maintain and use all necessary sheer or receiving booms, dolphins, piers, piles or other structure” in any of the waters of this state or the dividing waters. The 1890 legislature also required that these corporations file with the Secretary of State “a plat or survey of so much of the shore lines of the waters of the state and lands contiguous thereto as are proposed to be appropriated for said purpose by said corporation.” These plats are now stored at the State Archives, and an inventory of those plats are included as Attachment A.

U.S. Coast and Geodetic Survey Charts: (http://historicalcharts.noaa.gov/historicals/historical_zoom.asp). The navigation charts of the U.S. Coast and Geodetic Survey often show obstructions such as log booms, pilings and may be useful in defining the geographical limits of the log booms.

DNR Harbor Area Plat Maps: For a period of years, these plat maps would show the location of manufacturing industries. These plat maps have been scanned and are available from DNR.

DNR Index Sheets: DNR Index Sheets act as a geographic register of all aquatic land transactions—including sales, leases, permits, licenses, withdrawals. One of the historical activities noted on the sheets is log booming. If a geographic area is a known timber industry operation on private tidelands, they will show when the aquatic lands were sold. If the aquatic lands were leased, it will show the DNR Aquatic Land Jacket file number. These Sheets have been scanned and are available through DNR.

DNR Lease Jackets: Each booming lease identified in the index sheets, and in DNR databases, may be reviewed for more information related to the wood waste activity.

DNR Lease Exhibits: Many Historical Exhibits have been scanned based on use authorization number, other exhibits may be found in the DNR Lease Jackets.

DNR Financial Database Reports: Fields within this database would often indicate whether a lease was a booming lease, and reports of booming leases may be made from this database. Reports may be requested from DNR. Attached is an example of such reports:

U.S. Corps of Engineers Congressional Authorization and Chief of Engineers Annual Report Maps:
Published maps available from the Corps

U.S. Corps of Engineer Condition Maps: Corps Condition Maps show the condition of federally designated and maintained channels. These maps show the ownership of land abutting the federal channel.

Railroad Right of Way/Station Maps: These maps are helpful in identifying log dump areas, as well as other log and timber manufacturing operations.

Sanborn Fire Insurance Maps: These maps show timber manufacturing sites in detail, diagram plant facilities (including hog fuel/waste burner locations), over time.

Secondary resources: Often books, articles and reports exist that provide historical information about the location and scale of a particular operation. These sources are especially important in giving a time frame for the operation, as well as the nature of the operation, such as the operator, etc.

Source Table fields:

Source Code:	Reference Code for each source. Each source may refer to multiple polygons.
Source Image	Image of polygon on source document image
Type of Source	Secondary Source (SS); Navigational Chart (NC); Corps Map (CM); DNR harbor plat (DHP); DNR index sheet (DIS); Booming Company Plat (BCP); Railroad Right of Way Maps (RRM); Sanborn Maps (SM)
Author:	Author whether personal or corporate.
Title:	Full title of Source.
Source Cite	Chart Number, Map Number, Plat Number—date-title/name.
Source date	Year document was published

Operation and Location Table:

Operation	log dump, log booming, lumber mill, pulp mill, pulp and paper mill, plywood mill, wood treatment facility, wood waste landfill
Operation Name:	Facility name, if known
Operation Date:	Year operation is identified by source
Hog Fuel or Teepee Burner	Yes/No-(Existance)
Burner Location	Lat/Long
Begin date:	Date operation began, if known
End Op date:	Date operation ended, if known

Example of GIS Product:



Figure 1 an example of spatially indexed wood waste sites in Bellingham Bay. The green polygons represent general locations of where wood waste is potentially occurring, based on historic research and professional judgment. The yellow points represent the physical location of the facilities. Queries about the characteristics of these sites, source information, etc. can be made on individual polygons and points using a GIS.

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