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Needs Assessment and Scoping Study for Sinking Ships as Diving Sites in Puget Sound

By Steve Rubin, Eric Grossman, Lynne Koontz, Anthony Paulson, Natalie Sexton, and
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By Steve Rubin, Eric Grossman, Lynne Koontz, Anthony Paulson, Natalie Sexton, and Reg Reisenbichler

Executive Summary

There is growing interest in starting a program to sink one or more large, steel ships in Puget Sound to create underwater dive sites, thereby attracting divers to Washington State with attendant economic benefits. The State legislature reviewed this possibility during the 2006 session and directed several State agencies to undertake a preliminary scoping study of the feasibility. The Washington Department of Fish and Wildlife (lead State agency) in turn asked the U.S. Geological Survey to conduct the study.

The objectives of the scoping study are to design a feasibility study and estimate the cost to conduct such a study. Specifically, the scoping study assembles the questions that a feasibility study should address, develops approaches or tasks to address each question, and estimates the cost associated with each approach or task. The main objective for the feasibility study would be to provide sufficient information for the legislature to decide whether to go forward with actual ship sinking. Specifically, the objectives of the feasibility study would be to (1) estimate the costs (initial and ongoing) of sinking ships, (2) estimate the economic benefits that would be derived, (3) identify political and community stakeholders and gauge their support or opposition, and (4) develop detailed information about environmental (physical, water quality, biological) impacts.

Initial and ongoing costs of ship sinking include ship selection, acquisition, preparation, and deployment; site selection; permitting; liability coverage; developing necessary infrastructure; maintenance; and monitoring. Contaminant removal is a key element of ship preparation, and ease of contaminant removal is an important ship selection criterion. Contaminants are retained in Puget Sound due to basin morphology and current circulation patterns, and sediments and biota show elevated levels of contaminants. Major initiatives are underway to prevent contaminants from entering the Sound and to clean up those that are already present. For these reasons thorough contaminant removal is imperative. The Environmental Protection Agency and the Maritime Administration (MARAD) recently established best management practices (BMPs) for contaminant removal from ships destined for sinking. Whether these BMPs are sufficient for Puget Sound needs to be evaluated. There is also growing concern about polybrominated diphenyl esters (PBDEs) and other “emerging contaminants,” so called because their effects are less well known than those of older contaminants such as polychlorinated biphenyls (PCBs). BMPs have not yet been established for emerging contaminants. PCBs and PBDEs bio-accumulate and are found at high levels in southern resident killer whales which spend much of their time in Puget Sound and are listed as endangered under the Endangered Species Act. Contaminants are considered a major threat to this whale population. The feasibility study needs to estimate the inventory of contaminants on each of

the candidate vessel classes, which for emerging contaminants will likely require onboard sampling of ship materials, and determine the feasibility and cost of contaminant removal.

The largest navy ships (e.g., aircraft carriers) are hard to clean of contaminants which may make these ships poor choices. Furthermore, total cost (acquisition to sinking) is directly proportional to ship weight, making large ships expensive. Ships may be available from the U.S. Navy or MARAD; however, subsidies currently offered by these agencies for cleaning and transport cover only a small fraction of the costs. Two types and sizes of ships have been suggested as potentially good choices for Puget Sound. The first is Washington State ferries (~250 feet long; ~2,000 tons). They have an open structure that may allow for easy cleaning, were rebuilt recently which may have removed some contaminants, and have a known service history which should facilitate contaminant assessment. The second is medium sized destroyers as have been sunk in the Strait of Georgia (~350 feet; ~3,000 tons). However, the smallest destroyers currently available from the Navy or MARAD may be ~500 feet long (3000-6000 tons).

A number of factors must be considered in selecting a site. Physical characteristics must ensure ship stability and provide safe and desirable diving conditions. Navigation lanes and sensitive species and habitats must be avoided. We propose a two stage approach for locating suitable sites and confirming their suitability. First, use existing data to construct a Puget Sound-wide map to roughly identify areas that may be physically suitable and don't conflict with navigation or sensitive species or habitats. Note that existing data, with the possible exception of depth, lack sufficient resolution at the scale needed to ensure suitability for ship sinking. Second, conduct field surveys at five of the potentially suitable sites, selected to provide some geographic variability, to confirm whether sites identified from the Sound-wide map meet requirements of substrate type, seafloor structural integrity, water clarity, current speeds, and biological community.

Potential environmental impacts (other than contaminants which are addressed above) include scouring or deposition, increased turbidity, harm to sensitive or harvested species or to sensitive habitats or aquatic communities (e.g., eel grass beds), loss of the benthic community at the sinking site (i.e., under the ship), changes in ecological processes, promotion of invasive species, and cumulative effects of multiple ships. Ship colonizers might compete with or prey upon organisms in the area surrounding the ship or passing by the ship, thus altering the food web. Sunken ships may attract organisms away from hard substrate habitat in surrounding areas which would be especially problematic if attraction resulted in reduced survival, a circumstance that could result from increased harvest rates if harvest were allowed. A potential benefit of ship sinking might be promotion of sensitive species such as rockfish. It might be possible to design ship sinking to maximize any such benefit if it were identified as a secondary objective and did not conflict with creation of the dive site or the well being of other sensitive species.

Important considerations in evaluating support or opposition to ship sinking are the regulatory framework for sinking ships; the policies, structures, and incentives that will likely drive the decision process; the identity of stakeholders; and the perceptions, attitudes, and preferences of nearby communities as well as key stakeholders. This report proposes comparative studies of similar ship sinking programs in other areas, focus groups to qualitatively explore attitudes and perceptions of divers and other stakeholders, and surveys of divers and local community members to quantitatively assess attitudes and perceptions.

Because the costs associated with sinking ships to create dive attractions can be substantial, the economic benefits must be examined to determine if the project would be an advisable investment. To estimate anticipated economic benefits it is necessary to estimate the number of divers and average spending per diver currently (pre-deployment) and after deployment. Sampling of dive charter logbooks, and on-water sampling to determine the ratio of charter to non-charter divers, is proposed to estimate the current number of divers. Surveys of divers are proposed to estimate the number of future divers and the average spending per diver currently and in the future. The best (and most expensive) option is to survey divers nation-wide as well as in Washington. This may be the only way to estimate the post-deployment influx of non-residents into Washington. Surveys will also allow evaluation of how economic benefit varies among regions within Puget Sound. Once the gross economic benefit is determined (i.e., anticipated additional funds attributable to ship sinking), the net economic benefit can be determined by subtracting out anticipated project costs, including costs of new infrastructure.

We present three funding options for the feasibility study: “full” with consideration of two ship types (ferries and destroyers), “minimal for two ship types”, and “minimal for ferries only”. The ferries-only option is included to provide a cheaper alternative and because ferries may offer greater ease of cleaning than destroyers. Both minimal options rely mostly on existing data whereas the full option includes significant development of new data for tasks associated with siting, evaluation of community support or opposition, and estimation of economic benefits. The purpose for these new data is to validate, refine, or provide critical information for making predictions and conclusions. The full option will provide the most reliable assessment of feasibility across Puget Sound. The minimal options include field sampling at only one site rather than at five sites, which seems most appropriate if that one site has been selected as the desired location for sinking a ship, subject to final field verification. The estimated total cost of the feasibility study is $2.8 million for the full level, $1.4 million for the minimal level with two ship types, and $1.2 million for the minimal level with ferries only, assuming an overhead rate of 100%. Overhead rates vary among potential contractors from less than 50% to well over 100%.

Other funding levels are possible. We described the tasks that we think should be included in a feasibility study, along with a cost estimate for each task and information on how we derived the estimate. From this information the reader may wish to adjust, eliminate, or even add tasks, or to adjust cost estimates to create other alternatives for study intensity or cost.

The feasibility study could be conducted in stages. Contaminant issues might be evaluated first because of their overriding importance. Only if thorough cleaning were found to be feasible for ships of interest would other components of the study proceed. Alternatively, economic benefits could be evaluated first, and the other components of the study proceed only if economic projections were favorable. A sequential strategy would obviously save money if thorough cleaning isn’t feasible or if economic projections are disappointing; however, the strategy would extend the duration of the study if neither of these factors preclude ship sinking. If all feasibility components were conducted concurrently, the duration of the study should be approximately 18-24 months. We recommend the sequential strategy if cost efficiency is more important than minimizing the time required to complete the feasibility study. We also recommend choosing the full budget option for evaluating economic benefits because of the increased accuracy of predictions relative to those from the minimal options.

Introduction

Background

There is growing interest in starting a program to sink ships in Puget Sound to create one or more underwater dive sites. Experience in other parts of the world has indicated that sunken vessels are highly popular with divers and could provide a basis for increased recreation and attraction of out-of-state divers with attendant economic benefits to the State. The Washington State legislature reviewed this possibility during the 2006 session and determined that more information is required before the legislature could determine if this activity is feasible or desirable. The legislature directed several State agencies to undertake a preliminary study of the feasibility. The Washington Department of Fish and Wildlife (WDFW, lead State agency) in turn asked U.S. Geological Survey to conduct the study.

Action Being Considered

Sinking large (200 feet or longer), steel ships at one or more sites in Puget Sound (all inland marine waters of Washington State east of Cape Flattery) to create recreational diving sites. The ships would be obtained from the U.S. military or other sources, cleaned of contaminants and moved to Puget Sound where they would be intentionally sunk at predetermined locations. The locations would be chosen to provide safe and ready access for divers with minimum disruption to other uses of Puget Sound.

Sinking ships would have an impact on the biological resources and the economics of the area, so these two factors must be considered in determining the feasibility of this activity. However, the motivation for considering ship sinking is economic development, not creation of habitat for aquatic species. Therefore, the primary biological concern is negative impacts on existing biota. Any biological benefits (e.g., promotion of "desirable" species) will be viewed as a bonus but not as a reason to proceed with ship sinking.

Objectives

This scoping study describes a feasibility study and estimates the cost for conducting such a study (i.e., for assessing the feasibility of sinking ships in Puget Sound to serve as dive sites). Because the objectives for the scoping study follow from the objectives of the feasibility study, the latter are presented first.

Feasibility Study Objectives

Provide information to decision makers about the potential costs, benefits, and environmental impacts of sinking ships. Specifically:

- Estimate the costs (initial and ongoing) of sinking ships.
- Estimate the economic benefits that would be derived.
- Identify political and community stakeholders and gauge their support or opposition.
- Develop detailed information about environmental (physical, water quality, biological) impacts. This information must be sufficient for programmatic compliance with SEPA.

Scoping Study Objectives

Design the feasibility study and estimate the cost to conduct it. Specifically:

- List the questions or topics that must be addressed by the feasibility study.
- Suggest approaches or tasks to address each question or topic.
- Estimate the cost for each approach or task.

Scoping Study Methods and Format

We have been instructed that the feasibility study is to use pre-existing data unless a critical need for new data exists. Therefore, the primary methods of the feasibility study designed herein are literature review, consultation with experts or authorities, and analysis of pre-existing data.

In the main section of the scoping study we list the questions and topics that should be addressed by the feasibility study, suggest approaches to address them or tasks that must be executed to complete them, and estimate the costs of the approaches or tasks. This main section is divided into three subsections that roughly correspond to feasibility study objectives:

1. Projects costs: Initial costs of ship selection, acquisition, preparation, and deployment; site selection; permitting; liability coverage; and infrastructure development. Also, ongoing costs of maintenance and monitoring.
2. Environmental impacts: Physical effects such as changes in flow and sediment scouring or deposition; water quality impacts from residual contaminants and ship decomposition or ship colonizers; and biological impacts from colonizers, including competition with and predation on other species using the area.
3. Socio-economic impacts: Anticipated economic benefits; assessment of political and community support or opposition.

Cost estimates are derived by various methods (Appendix A). Estimates for several tasks under "project costs" were obtained from Jeff Dey of REEFMAKERS™.

Following the main section is a budget section containing a table where line item costs are listed and cumulated to estimate total study costs, a discussion section where findings are summarized and important issues highlighted, and a recommendations section.

Feasibility Study Questions, Tasks, and Costs

Project Costs

Ship Selection and Acquisition

The feasibility study should recommend criteria for ship selection, and investigate the availability and acquisition cost of ships. Because thorough contaminant removal will be required before sinking a vessel (see below), one of the most important ship selection criterion may be ease of cleaning — i.e., ease of identifying and locating all onboard contaminants, ease of removing them, and cost for these tasks. We note several points that relate to this criterion: vessels constructed after 1979 don't contain polychlorinated biphenyls (PCBs), those constructed after 1980 do not contain asbestos, and combatant vessels may be harder to clean than non-combatant vessels (DEMA 2006).

Another important criterion is ship size. Total cost of past ships-to-reefs projects averages about $500 per ton for ships ranging from 3,700 to 34,000 tons (Appendix B); thus cost is likely to be proportional to ship size with no cost efficiency gained for larger ships. Ship size also bears on siting (size of site required; ship stability under local conditions), diver safety (<80 feet wide recommended for safe, line-of-sight exit) (DEMA 2006), and diver preferences. Historical or cultural values may also be an important selection criterion. For example, crews that served on navy ships might prefer scuttling to scrapping when the ships are decommissioned (DEMA 2006).

Ships for scuttling may be available from the U.S. Navy or the Maritime Administration (MARAD) (DEMA 2006). These agencies offer partial subsidies for cleaning and transport; however, current offerings cover only a small fraction of the costs (Jeff Dey, REEFMAKERS™; personal communication). Other sources of ships also should be investigated. Two types and sizes of ships have been proposed as potentially good choices for Puget Sound (Mike Racine, Washington Scuba Alliance; personal communication). The first is Washington State Department of Transportation steel electric class ferries (~250 feet long; ~2,000 tons). They have cultural value in Washington and a relatively open structure that may allow for easy cleaning. One has been retired and several others remain in service but will be phased out in the next few years. They were purchased in the 1920s and have been rebuilt three or four times since. Some contaminants (e.g., PCBs; asbestos) may have been removed during the rebuilds. It should be possible to consult with the people who maintain these ferries, and service records should be available, thus facilitating the assessment of onboard contaminants. Introduction of invasive species is not an issue since the ferries are already in Puget Sound.

The second proposed vessel class is Canadian-class destroyers (~350 feet; ~3,000 tons). Several have been sunk in the Strait of Georgia in British Columbia. Note that all currently available decommissioned United States destroyers may be closer to 500 feet long (3000-6000 tons) (Jeff Dey, REEFMAKERS™, personal communication). Larger combatant ships (e.g., aircraft carriers) may not be a good choice for reasons given above.

Tasks and costs: Identify appropriate classes of ships and determine their availability and acquisition cost: $20,000.

Contaminant Removal and Effects

Ships contain a variety of materials known to be harmful to marine organisms. Furnishings that are easily detached from the ship’s structure must be removed to prevent them from breaking free later and becoming marine debris. The U.S. Environmental Protection Agency and U.S. Maritime Agency (2006) note that buoyant debris can endanger marine mammals and waterfowl. Toxic materials sometimes are an integral part of a ship's structure or its furnishing. The difficulty of removing these contaminants and the cost to prepare a ship for scuttling increases with the degree to which toxic materials are attached to the ship's structure.

The history of contaminant issues in scuttling Navy vessels for the construction of artificial reefs or dive attractions is informative. In 1972, the Liberty Ship Act (Public Law 92-402) provided for the transfer of Liberty vessels to coastal States for use as artificial reefs. Between 1974 and 1978, 26 Liberty Vessels were sunk off the Gulf Coast and eastern Florida. In 1977 the Toxics Substances Control Act was passed, and the production of polychlorinated biphenyls (PCBs) ceased in the USA. Between 1978 and 1992, only six former Navy vessels were sunk for artificial reefs. This decline was partially a result of the growing concerns about the environmental effects of the ships. Beginning in 1989, the Navy conducted an extensive sampling of ships and found PCBs in insulation, paint, gaskets, caulking, and sound-dampening felt materials. In 2001, the Environmental Protection Agency (EPA) Office of Pollution, Prevention, Pesticides and Toxics decided to consider the scuttling of a ship to create an artificial reef as a disposal action under Code of Federal Regulations 40 Part 761, for which a limit of 50 ppm ($\mu g\ kg^{-1}$) applied to all items remaining onboard. This level contrasts with a limit of 2 ppm PCBs for products whose actions are considered continued use, rather than disposal (Atlantic States Fisheries Commission, 2004). A study conducted in South Carolina found that PCBs in organisms collected around sunken Navy ships were not elevated relative to control sites even though materials onboard the ships were laden with PCBs (Atlantic States Fisheries Commission, 2004). Under EPA's 2001 disposal provision, the 510-ft landing ship dock *Spiegel Grove* was stripped of all items having a PCB concentration greater than 50 ppm at a cost of $550,000 in removal activities and $75,000 in PCB sampling (U.S. Environmental Protection Agency and U.S. Maritime Administration 2006). In contrast, some materials with > 50 ppm PCBs were left on the larger 911-foot aircraft carrier *ex-Oriskany* that was sunk off the coast of Pensacola, Florida on May 17, 2006, after the Navy developed a PCB Model and Risk Assessment (at a cost of $3.74 million) (U.S. Environmental Protection Agency and U.S. Maritime Administration 2006) that showed little biological effect from the presence of those materials (U.S. Navy 2006).

Recent efforts to reduce the release of contaminants from scuttled vessels have focused on asbestos, copper, lead, petroleum products, PCBs, tri-butyl tin, and zinc. The introduction of iron from rusting steel can also alter the ecosystem by stimulating primary productivity in iron-limited marine systems. Radioactive material is present in certain classes of Navy vessels but such vessels will not be addressed in this document. The feasibility study should assess the extent to which the contaminants listed above must be removed from the proposed classes of vessels to be scuttled and the ecological risk from materials remaining onboard. The U.S. Environmental Protection Agency and the U.S. Maritime Administration (2006) recently published a set of guidelines for preparing vessels for scuttling to create artificial reefs. These Best Management Practices (BMPs) were largely based on regulations under the Clean Water Act; the Clean Air Act; the Comprehensive Environmental Response, Compensation, and Liability Act; the Resource Conservation and Recovery Act; and the Toxic Substance Control Act. For the majority of vessel types and contaminants, BMPs for preparing vessels for use as artificial reefs have already been identified and biological assessments of the most toxic materials (e.g., PCBs) have already been conducted.

The feasibility study must estimate the inventory of toxic materials that are likely to be onboard each class of vessel examined in the feasibility study. These estimates probably can be derived from recent exercises undertaken for EPA disposal permits. The costs of removing materials known to contain any of the contaminants, and of any sampling needed to establish the presence and concentration of contaminants in particular materials, must be examined for each vessel class. During the implementation of any proposed project, the estimated inventory of hazardous materials must be verified with additional sampling.

The clean-up goals listed in the BMPs for each class of hazardous materials are summarized here. All debris that is not permanently attached to the vessel, including peeling paint, must be removed. The goal for petroleum products is to prevent any sheen from appearing on the water during sinking. All petroleum spills must be cleaned so that no visible sheen appears on decks and bulkheads. In general, all liquid petroleum products should be drained, flushed, and cleaned from fuel, lube, and fluid system equipment. Piping and interior fittings must be drained and flushed so that no product drains from the lines. Combustion engines must be drained of oil, filters and screens must be removed, and engine sumps must be flushed. During cleanup, strict operation procedures for handling materials must be observed to prevent spills, and flushed liquids require pre-treatment before disposal to municipal wastewater treatment plants.

Asbestos on ships built before 1980 is found in sound and thermal insulation, insulation for air and exhaust handling systems, and in packing used for a variety of purposes. All loose asbestos must be removed and friable asbestos must be sealed. The primary source of friable asbestos is pipe wrappings around the main boiler and steam fittings.

For ships built before 1980, PCBs are found as liquids in transformers, in a variety of insulation and gaskets throughout the ship, in electrical cables, and in paint. All liquids containing PCBs, including spills and transformers, are required to be removed. Solid materials containing PCBs at a concentration of greater than 50 ppm must be removed to receive a disposal permit, or a biological risk assessment must be undertaken to demonstrate that the biological effects of the release of PCBs from material left onboard would be minimal. In the case of the ex-Oriskany, electrical cables and paint contained the majority of the PCB inventory, but these materials released PCBs at the slowest rate in two-year tests with various materials and a variety of oceanographic conditions.

Ship paints are a source of metals including lead, copper, tri-butyl tin, cadmium and zinc. Anti-fouling coatings applied to the exterior hull below the water line are designed to release their biocides to prevent buildup of biological growth that can hinder hydrodynamic performance. If the coating on the hull was applied more than 12 years ago and if biological growth and diversity are evident on the hull, it is likely that the release rate has diminished to levels that are ineffective in controlling growth or harming marine organisms. In contrast to hull paints, superstructure and interior primers and paints are designed to last many years and their rate of release to water should be low. Nevertheless, blistering or peeling paint should be removed so that the metals in the paint do not enter the food chain when they are deposited in sediments near the ship.

Several other types of materials that contain hazardous materials should also be removed. Lead ballast bars should be removed and the area thoroughly cleaned to remove any lead particles that may have oxidized and been scraped off the bars. Thermometers, gauges, switches, and gyroscopes should be removed to limit the release of mercury. Sacrificial anodes should be removed to limit zinc release. The BMPs also suggest removing the fire extinguishing systems, which Moody and Field (2000) suggest might contain perfluorooctane sulfonate (PFOS) that is found in aqueous film-forming foams heavily used by the military.

The coastal areas of the mid-Atlantic, south-Atlantic and Gulf of Mexico, where the majority of artificial reefs in the United States have been created, are different from Puget Sound in two major respects, both of which indicate that contaminants are a greater concern in Puget Sound. The Atlantic coast and, to a lesser degree, the Gulf coast are continuously swept by strong surface currents that remove aqueous contaminants from the area. In addition, the shallow, near-shore coasts where many artificial reefs have been created are zones of erosion, and thus small particle debris from a scuttled ship will be transported in the direction of the prevailing currents. In contrast, Puget Sound is an inland sea with several sills. The sills in Admiralty Inlet, near the Hood Canal Bridge and in Dalco Passage near Tacoma tend to mix the outgoing surface water, which has the affect of retaining contaminants within Puget Sound (Cokelet et al., 1991; Paulson et al., 1993). Particulate contaminants are also retained within the deep basins of Puget Sound (Paulson et al., 1988) because of the bathtub-like shape of the basins. Hood Canal and south Puget Sound are particularly susceptible to retention of contaminants.

The second way in which Puget Sound differs from other coastal regions is that contaminants pose a threat to several species listed under the Endangered Species Act (ESA). Both southern resident killer whales and Puget Sound Chinook salmon are listed (the former as endangered and the latter as threatened) and spend a significant part of their lives in Puget Sound. Primary conservation measures identified in the proposed recovery plan for the southern resident killer whales are to clean up existing contaminated sites, minimize continuing inputs of contaminants, and monitor "emerging contaminants" (contaminants whose effects are less well known than for older contaminants such as PCBs) (National Marine Fisheries Service 2006). PCBs are of particular concern because they bio-accumulate through trophic transfer and occur at high levels in killer whales at the top of the food chain. Chinook salmon with extended residency in Puget Sound also have elevated PCB levels and are a preferred prey of the listed killer whale population (National Marine Fisheries Service 2006). PCB levels in sediments are higher in Puget Sound than farther to the north (e.g., in the Strait of Georgia), and so are levels in southern resident killer whales compared to other resident populations farther to the north which also primarily eat salmon (National Marine Fisheries Service 2006). PCB levels in Puget Sound peaked around 1960 and have since declined, levels in harbor seal pups from Puget Sound declined from 1972 to 1990 but have since leveled off, and recent modeling suggests that levels in killer whales have declined since 1970 (National Marine Fisheries Service 2006).

Polybrominated diphenyl esters (PBDEs) may be present on ships and are emerging contaminants of concern for killer whales (National Marine Fisheries Service 2006). PBDEs have been linked to health problems, and like PCBs they bio-accumulate and occur at higher levels in the listed killer whale population than in other resident populations farther to the north (National Marine Fisheries Service 2006). Unlike PCBs, their use has not been banned and their prevalence in the environment is increasing. PBDEs are flame retardants and are found in plastics, computer plastics, small appliances and upholstery foam (National Marine Fisheries Service 2006). It seems likely that they occur in materials on ships, but their presence and concentration levels have not been established, and in fact they are not even mentioned in the EPA BMPs for ship preparation. PFOS, also considered an emerging contaminant of concern for killer whales, is an aqueous film-forming foam used in fire extinguishing systems (U.S. Environmental Protection Agency and U.S. Maritime Administration 2006). Although the BMPs suggest removing all fire extinguishing systems, residue PFOS might be present on ships, especially if the fire extinguishing system was activated. The feasibility study must address the inventory of PBDEs and PFOS on a vessel and the cost of removing them. Accomplishing this will likely require collecting and processing samples (i.e., conducting hazardous material sampling) from each prospective vessel class.

If the proposed ship sinking program is implemented, permitting will require biological assessments of the program's potential effects on ESA listed species. Biological assessments synthesize existing data to evaluate whether the proposed action will affect the listed species, and if so the likely effect. The feasibility study should conduct biological assessments for killer whales and Chinook salmon similar to those required under the ESA and should consult with the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA Fisheries), the listing agency for both species. The feasibility study should include a review of the literature and consultations with experts on potential PCB introductions from materials left onboard (i.e., materials containing < 50 ppm PCBs) to assess whether EPA BMPs are acceptable for Puget Sound. The cost of more thorough PCB removal (i.e., beyond the 50 ppm limit) should also be investigated. The feasibility study should also review and synthesize all existing studies on the biological effects of PBDEs and other emerging contaminants. However, the long term multi-million dollar studies needed to establish acceptable levels of PCBs have not been conducted for emerging contaminants. If onboard sampling indicates widespread PBDE occurrence it is possible that regulators will invoke the precautionary principle and withhold permits for ship sinking until those data become available.

We note that concerns about PCBs and emerging contaminants are not limited to killer whales and Chinook salmon. Other species (e.g., rockfishes and herring) have higher PCB levels in Puget Sound than elsewhere (National Marine Fisheries Service 2006). Major initiatives are underway to prevent contaminants from entering the Sound and to remove or otherwise inactivate those that are already there (Puget Sound Action Team 2006). In addition to consulting with NOAA Fisheries about the listed species it will be necessary to consult with the Washington Department of Ecology (DOE), the agency responsible for Puget Sound water quality (i.e., ship sinking will require a water quality permit from DOE), and with other interested parties including those involved with cleanup activities.

We provide the following guidance for literature reviews on the biological effects of PCBs and emerging contaminants. An assessment of biological effects follows the risk assessment outline of source, transport, exposure, effect and biological endpoint. The source term would include releases of contaminants to the water column and weathering of paint coatings and steel structures that produce particles of various sizes that settle to the sediments. The release rates of contaminants to the aqueous phase should be coupled to a hydrodynamic model which would simulate the transport of each contaminant to the near- and far-field regimes of the study area around the proposed site. The concentrations modeled by the hydrodynamic model would suggest the level of exposure for affected marine organisms. In most cases, bioaccumulation of contaminants of hydrophobic compounds occurs between trophic levels of the food web. The initial step of bioaccumulation of hydrophobic compounds through the food web is uptake by primary producers, such as algae present in the euphotic zone. The bioaccumulation of hydrophobic compounds should be modeled through the food web to Chinook salmon and killer whales. For some metals and volatile compounds, such as mercury, the pathway of exposure and entrainment into the food web may be through direct uptake by the gills. In such cases, the transport model should be coupled to a variety of biological models, such as the Biotic Ligand Model (Di Toro et al., 2001).

In a somewhat independent pathway of transport and exposure, flakes or particles containing contaminants from the ship settle near the ship. Depending on the mass of settling particles and the local net and maximum tidal currents, these particles will either be transported away from the ship or be buried. A variety of approaches including total sediment concentrations, pore water concentrations, changes in benthic community, and toxicity tests have been used to evaluate the effects of contaminants on the biological community. The uptake of contaminants by benthic organisms would ultimately flow through the food web to Chinook salmon and killer whales. Likewise, the direct uptake of contaminants from benthic organisms that attach directly to the surfaces of the ship that contain contaminants must also be included in the food web model.

Tasks and costs: Estimate inventory of PCBs and the other “established” contaminants (i.e., those addressed in BMPs), and estimate removal costs for those contaminants, for each prospective vessel class. Cost assuming two vessel classes (WA State ferries and medium sized destroyers): $11,000.

Review literature on biological effects of PCBs, PBDEs, and other emerging contaminants, consult with experts, regulatory agencies (NOAA Fisheries, DOE), and other interested parties, and prepare a synthesis document. Cost: $18,000.

Total cost of studies using existing data (i.e., estimating "established" contaminant inventories and removal costs, and reviewing and synthesizing effects of "emerging" contaminants): $29,000.

Conduct onboard hazardous material sampling to establish presence and concentration of PBDEs and other emerging contaminants, and estimate removal costs. *Cost assuming two classes of vessel:* $150,000.

Ship Preparation, Towing, and Sinking

Preparation for diver safety will include removing sharp or protruding objects that might snag divers; removing doors and hatches and widening openings; widening corridors and removing wall paneling; providing holes in the ship exterior for light penetration; and sealing off restrictive compartments (U.S. Environmental Protection Agency and U.S. Maritime Administration 2006).

Towing the ship to the cleaning and preparation yard will happen before the ship is cleaned, so the contractor will need to purchase and show proof of insurance for any mishaps that occur in transit (e.g., contaminant spills).

Towing the ship from the cleaning yard to the final destination and sinking the ship will require a towing and sinking plan, final regulatory approvals, and adequate towing stability and watertight integrity. Other towing preparations may also be necessary, such as a plan for (*i*) a tertiary stop (if needed for final preparation and setting of charges), (*ii*) pre-anchoring at the permitted site, (*iii*) security, (*iv*) final positioning and sinking, and (*v*) any actions needed to prevent harm to marine mammals or other marine life in the vicinity. It will also be necessary to purchase navigation buoys (if required, see "permitting" below), determine how many mooring buoys will be needed, and purchase and deploy the buoys.

Tasks and costs: Obtain specifications (e.g., minimum width for openings) and estimate diver safety preparation costs by consulting with dive groups and persons from past ships-to-reefs programs, and by collecting bids from contractors. Cost assuming two vessel classes: $1,000.

Estimate costs of towing to the cleaning yard by evaluating towing contractors and collecting bids from those that are qualified. Cost, assuming two vessel classes: $2,000.

Estimate costs associated with towing from the cleaning yard to the final destination, including purchasing and deploying buoys. Cost, assuming two vessel classes: $6,000.

Total cost to estimate cost of ship preparation, towing, and sinking: $9,000.

Siting

A number of factors must be considered in selecting a site. Physical characteristics must ensure ship stability and preclude ship burial, provide safe diving conditions, and avoid undue scouring or deposition. Conflicts with navigation must be avoided. Distributions of sensitive species and habitats should be considered and avoided. Socio-economic factors also bear on siting. We propose a two stage approach for locating physically and biologically suitable sites and confirming their suitability. First, collect and synthesize existing data to suggest acceptable sites for scuttling, then conduct field surveys to assess the reliability of these predictions.

Puget Sound-wide map: Use existing data to conduct a general Puget Sound-wide query in a Geographical Information System (GIS) to roughly delineate areas that may be physically suitable and don't appear to conflict with navigation or sensitive species or habitats.

Query digital elevation models (DEM) for depth ranges suitable for diving and allowing adequate navigational clearance above a ship. Within that result query, calculate and remap the slope, and within that result, query and display areas with a footprint adequate for the larger vessel class (medium sized destroyer).
<u>*Cost:*</u> $2,500.

Assess water clarity and currents qualitatively by taking this map to dive shops and diver groups to highlight areas known for good water clarity and currents and to eliminate areas generally considered undesirable.
<u>*Cost:*</u> $2,500.

Further assess currents and circulation at potential sites on the map using University of Washington's PRISM model and "Tides and Currents" boater's guide. Each of these has uncertainties which are not necessarily published and the data may not be representative of the range of conditions that occur throughout the year and at the range of depths that divers and the sited ship will experience. However, this exercise should be useful for suggesting areas to avoid or favor.
<u>*Cost:*</u> $5,000.

Assess substrate characteristics of potential sites on the map to the extent possible from existing information. Data on substrate type are sparse and generally consist of isolated deeper basin sediment monitoring sites of DOE and a few sites recently monitored by King County. Several video surveys for fish exist and include information on substrate (Pacunski and Palsson 1998), but will require significant effort to review, analyze, and map substrate if the surveys were conducted within the potential sites queried above. Data on sediment thickness (sub-bottom sediment type and structural competency) occur along only a few transects generally in deeper basins. This information is essential for siting a ship and must be obtained through field surveys (see below).
<u>*Cost:*</u> $7,500.

Assemble geo-referenced data on areas to avoid because of navigation (e.g., shipping lanes) or other restrictions (e.g., military). Also assemble available data on distributions of sensitive or important species or habitats (e.g., geoduck beds) and on spatial variation in water quality. Particularly important for the latter would be minimum dissolved oxygen levels. Regardless of whether ship sinking has an effect on water quality (see "biological impacts below"), water quality may be relevant to siting. Areas that periodically experience poor water quality (e.g., south Hood Canal; Puget Sound Action Team 2006) may not be good sites for sinking ships because of diver reaction to the periodic fish kills. Add the data for restricted areas, sensitive species and habitats, and water quality to the map.
<u>*Cost:*</u> $12,000.

Total cost of Puget Sound-wide map from existing data: $27,500.

Field surveys: The second stage of this two-stage process is to conduct field surveys in order to confirm that sites will meet requirements of substrate type, seafloor structural integrity, water clarity, current speeds, and biological community. Quantitative data on these variables are needed to establish fundamental requirements for ship stability and diver safety. The purpose of field surveys is not to select a site for ship sinking but rather to "ground truth" the map and verify that sites suitable for ship sinking exist in Puget Sound. Field surveys also have great value for assessing potential environmental impacts. For example, knowledge of substrate type and currents will enable evaluation of potential scouring/deposition and how far those effects might extend from the sinking site (see "physical processes" under "environmental impacts" below). Field surveys will also be useful for pre-deployment analysis of ship stability and integrity (see below).

The feasibility study should survey substrate type and seafloor structural integrity at five of the potential sites found through querying the Puget Sound DEM, selected to provide some geographic variability, by collection and analyses of substrate data and sub-bottom seafloor structure data. An area of 500 m by 500 m would be surveyed to provide data covering an area that can accommodate the ship footprint in various orientations. The survey would include:

1. Substrate mapping of the entire area with sonar to identify substrate type, morphology and sediment bedform variability that reflects how mobile or dynamic the seafloor is.
   Cost (per site): $10,000.
2. Video drops at 50 m spacing across the area to refine interpretation of substrate type (i.e., whether rock or sediment).
   Cost (per site): $1,000 (if done in conjunction with substrate mapping).
3. Sediment grab samples at 50 m spacing (in areas characterized by a sediment substrate) to determine grain size and percent fine material that can be re-suspended to cause turbidity.
   Cost (per site): $7,000-$18,000 depending on the number of stations with sediment.
4. Seismic reflection profiling across sea floor areas covered with sediment to determine sediment thickness and capacity of the substrate to support a ship.
   Cost (per site): $8,000.
5. Collect sediment cores and analyze for sediment type, porosity, and organic content. Deploy a bulk density or an in situ pentretrometer to estimate competency if sediments are found to be thick and consisting of fine material susceptible to deformation.
   Cost (per site): $8,000-$10,000.

Total cost of surveying substrate and sea-floor structural integrity: $40,500 per site x 5 sites = $202,500.

Survey water clarity. Water clarity would be measured at 50 m spacing over substrates determined to be competent to support a ship. We suggest using a profiling CTD with OBS and PAR sensor to determine turbidity and light availability at two times in the year (seasons to be determined by dive groups based on either the influence of rivers on circulation or winds on surface currents) and over the range of ebb/flood tides over a neap and spring tide to determine tidal and seasonal variability.
Cost (per site two seasons): $21,000.

Measure currents using boat-mounted current profilers across dive sites concurrently with water clarity measurements to determine the range of current velocities and directions under extreme tidal conditions and seasons.
Cost (per site two seasons): $15,300.

Total cost of surveying water clarity and currents: $36,300 per site x 5 sites = $181,500.

Conduct two field surveys over one year to characterize the faunal and macrophyte communities in the study sites selected for physical surveys. Sampling will include 5-7 bottom grabs to characterize infauna, surveys along several transects with a remotely operated vehicle or video camera to characterize epibenthic communities, and at least two tows per site with a trawl and hydroacoustic gear to characterize fish communities.

Cost for biological surveys: $22,240 per site x 5 sites = $101,200.

Pre-Deployment Ship Stability and Integrity Analysis

Determine what the physical characteristics of the ship will be after pre-deployment preparation is completed. Given the prevalent substrate types, seafloor structural integrity, and currents, as indicated by the site specific surveys (see above), determine whether a ship from each vessel class would be supported and stable, whether ballast would be required, the optimum orientation with respect to dominant current direction, and whether the ship should be able to withstand 25, 50, and 100 year storm events.

Tasks and costs: Analyze the data from the site specific surveys (see "siting" above) to verify that ships would be supported and stable at these sites. Estimate the cost of a rigorous pre-deployment ship stability and integrity analysis. Note that this analysis will be conducted only if ship sinking is authorized and will be specific to the permitted site. Cost assuming two vessel classes: $10,000.

Permits

One can jointly apply for permits to sink a particular ship at a particular site with a Joint Aquatic Resources Permit Application (JARPA) available from Washington State. Required permits are:

Federal:

- U.S. Army Corps of Engineers (Corps): Section 10 (Rivers and Harbors Act) and 404 (Clean Water Act). Because the permits are issued by a federal agency the ESA is triggered. The applicant needs to include a Biological Assessment (BA) for each ESA listed species that might be affected. The Corps will consult with the appropriate listing agency (NOAA Fisheries or USFWS) on the proposed action. The need for federal permits also triggers the National Environmental Policy Act (NEPA). The Corps is the lead agency and will instruct the applicant on preparation of materials needed for NEPA compliance. It may be possible to prepare materials that jointly satisfy NEPA and State Environmental Policy Act (SEPA) requirements. According to EPA BMPs for ship preparation (U.S. Environmental Protection Agency and U.S. Maritime Administration 2006), a Marine Protection, Research and Sanctuaries Act ocean dumping permit will not be required because sinking ships for placement as an artificial reef is regulated under other federal laws.
- U.S. Coast Guard: Private Aids to Navigation. Attaching navigation buoys to the sunken ships may be required.

State:

- Washington Department of Ecology: 401 Water Quality Certifications. Issuance means that the project complies with State water quality standards. Consistency with the Coastal Zone Management Act is reviewed as an adjunct to 401 permitting. It appears that a National Pollution Discharge Elimination System permit will not be required because sinking a ship is a one time action, not an operation involving continuous discharge. DOE also administers SEPA, which ship sinking will need to comply with. SEPA will be triggered as part of JARPA.

- Washington Department of Fish and Wildlife: Hydraulic Project Approvals. The application must include plans and specifications for protection of fish and shellfish.
- Washington Department of Natural Resources: Use Authorizations for State-Owned Aquatic Lands. A permit will

Local (county or city):

- Each local government has development regulations in its Shoreline Master Program. All Puget Sound bedlands fall within county jurisdictions and some fall within city jurisdictions. At least one of the following three permits must be obtained from the county or city where the ship is sited to comply with that municipality's Shoreline Master Program: Shoreline Conditional Use, Shoreline Substantial Development, or Shoreline Variance. Issuance will depend on the extent to which ship sinking is compatible with or conflicts with a municipality's Shoreline Master Program. The feasibility study should explore this question with all counties bordering the Sound and with the appropriate cities for candidate sinking sites.

A task required for all permits is to determine which agency or entity will apply for the necessary permits and be responsible for complying with permit conditions. The Coastal Artificial Reef Planning Guide (Atlantic States Marine Fisheries Commission 2004) recommends that permits be held by State, county, or city governments because they are stable (i.e., likely to persist over time). Non-governmental organizations may be ephemeral. The feasibility study should explore who will hold the ship sinking permits.

Permits are needed only if ship sinking is authorized. Nevertheless, prudence suggests that the feasibility study follow the process far enough to determine whether permits would likely be granted and to explore the issues involved (i.e., identify the conditions that must be met for permits to be granted). For each of the permits listed above, the permitting agency should be contacted to determine whether they would grant a permit, what information they would need to make a determination, and what conditions they would impose before issuing a permit.

We have listed programmatic compliance with SEPA as a specific objective of the feasibility study. We think that the feasibility study designed herein will meet this objective because it will address all potential environmental impacts that should be addressed in an environmental impact statement for SEPA.

Tasks and costs: Estimate the cost of preparing materials needed to obtain the permits listed above and to obtain those permits. Explore whether ship sinking is compatible with Shoreline Master Programs of counties/cities where ships might be sunk. Determine whether permits would likely be granted and under what conditions they would be granted. Cost: $10,000.

Liability

Atlantic and Gulf States Marine Fisheries Commissions (1998) states that once a ship has been properly sunk (i.e., in the permitted location, with any needed aids to navigation attached, and with any required notification of interested parties) liability risk to the permits holder is low as long as conditions of those permits are met, including requirements for systematic monitoring . The permits holder shouldn't be liable for a recreational diving accident unless the accident was caused by a permit violation (Atlantic and Gulf States Marine Fisheries Commissions 1998). In this respect, liability issues for an artificial reef are like those for a public park. Most parks contain some dangers, and park visitors assume some risk of injury (Atlantic and Gulf States Marine Fisheries Commissions 1998). However, accidents probably would be evaluated on a case by case basis for negligence on the part of the permits holder, and negligence might be upheld depending on the circumstances (Atlantic and Gulf States Marine Fisheries Commissions 1998).

New Jersey holds permits for artificial reefs in State waters. New Jersey managers recently published an artificial reef plan in which they stated that they would consider purchasing appropriate insurance coverage for artificial reefs if it became available (Figley 2005). This statement implies that such insurance is not currently available.

The contactor that tows and sinks the ship should assume responsibility for the ship and be liable for mishaps such as missing the target site. The permits holder must write the contract appropriately, and the contractor should carry appropriate insurance.

Tasks and costs: The feasibility study must clarify all aspects of liability to the permits holder, investigate whether appropriate insurance is offered, and determine the cost of such insurance. Cost: $10,000.

Infrastructure

Infrastructure to support diving might include boat launches, marinas or other moorage space, parking, services such as law enforcement and schools (needed for new workers filling jobs created by ship sinking as well as for dive tourists), and shore-based facilities (e.g., showers, changing rooms). If sunken ships are accessible from shore then shore-based facilities must be substantial; however, it is likely that ships will only be accessible by boat due to depth requirements of sinking sites (100-130 feet).

The amount of new infrastructure needed will depend on where the ships are sited. If sites are near large population centers then existing facilities may be sufficient to accommodate increased use, but more remote sites associated with small communities may require substantial expansion of infrastructure. Infrastructure needs will also depend on the number of new divers expected (see “economic effects” section below). Any new infrastructure must be compatible with shoreline master programs and zoning (see “permitting” above). In addition to initial costs for any facility construction, ongoing maintenance costs or staffing needs also should be considered.

The feasibility study should estimate the amount of new infrastructure required and the cost to construct and maintain it. Because of dependence on siting and projected diver numbers, it may be necessary to wait until more is known about those variables (i.e., until the latter part of the feasibility study) to estimate infrastructure needs. Note that if ships are sited in areas where existing infrastructure is sufficient to absorb anticipated need, then feasibility study costs for infrastructure should be lower than that given below.

Tasks and costs: Estimate new infrastructure needs and associated construction and maintenance costs. Cost: $24,000.

Maintenance

Mooring and navigation buoys must be maintained, and maintenance can be expensive (Figley 2005). Monitoring programs must be administered (see "monitoring" below). The ship will need to be stabilized and loose pieces removed from the site if destabilization or break-up is detected during monitoring. All conditions of the permits issued for ship sinking must be met. Additionally, derelict nets must be removed when detected (see below).

Tasks and costs: Develop maintenance procedures and estimate maintenance costs on an annual basis: $5,000.

Derelict nets: A major initiative is under way to remove derelict nets and other lost fishing gear from Puget Sound because they cause significant harm to marine life (Puget Sound Action Team 2006). Derelict gear also poses a threat to divers. Derelict nets must be removed if or when they collect on the ships. The feasibility study should follow DNR's guidance on net removal to estimate the annual cost of removal, including an estimate of how often nets will snag and require removal. The study should investigate whether snagging can be minimized by site selection or pre-deployment ship preparation. Investigate whether voluntary reporting by recreational divers would provide sufficient monitoring. The latter might work since divers would benefit from prompt detection and removal of nets.

An initiative also is underway to remove derelict vessels from Puget Sound bedlands because they collect lost fishing gear but perhaps also for other reasons (e.g., ships were not part of the original Puget Sound ecosystem). The feasibility study must determine the conditions under which a ship sinking program can be reconciled with the initiative to remove derelict vessels. A thorough evaluation of potential physical and biological impacts of ship sinking, as outlined below under "environmental impacts", should provide sufficient information to address this issue.

Tasks and costs: Estimate the cost of net detection and removal. Cost: $4,600.

Total required to estimate maintenance costs: $9,600.

Monitoring

Monitoring is necessary to evaluate the actual environmental and socio-economic impacts of ship sinking, as well as to assure compliance with conditions defined in granted permits (Atlantic States Marine Fisheries Commission 2004). We include monitoring in the "project costs" section because monitoring won't occur unless the decision is made to sink ships. The feasibility study only needs to design and estimate the cost of monitoring.

Physical impacts: Of interest are changes in water velocity and circulation patterns, scouring and deposition patterns, substrate type and seafloor surface topography, and water column turbidity. In addition, monitoring ship stability and integrity (i.e., tracking whether the ship stays in the permitted site), and perhaps other factors as well, will likely be required as conditions of permitting.
Cost to develop monitoring studies of physical effects: $8,000.

Contaminants monitoring: Two major approaches to monitoring the environmental effects of an action are to 1) sample the proposed site before the action to characterize baseline environmental conditions and then repeat the sampling to detect a change as a result of the action and 2) sample both near-field and far-field conditions after the action and deduce impacts from the actions at the site from geographical changes in the environmental conditions. The specific approach taken will depend on the temporal variability of the environmental parameter being studied. For parameters that change slowly, the before-and-after approach is more appropriate. For parameters that vary substantially among samples over short time periods, the geographical approach is more appropriate.

Since the concentrations of contaminants in sediments change slowly in depositional zones of Puget Sound, where the substrate is stable as required for placement of a ship, sediments at and around the site should not change rapidly in the absence of the ship. Therefore, the before-and-after sampling approach would be appropriate for sampling sediments. Assessing the effects of contaminated sediments on benthic organisms usually employs the sediment quality triad: total contaminant concentrations, toxicity tests, and benthic community structure. At a minimum, total concentrations of contaminants of concern should be sampled at the proposed site, in both directions of the dominant tidal current, and in at least one direction perpendicular to the dominant tidal direction. Contaminants of concern include: petroleum products, PCBs, asbestos, copper, lead, mercury, tri-butyl tin, and zinc. Emerging contaminants, such as polybrominated diphenyl esters and chemicals in aqueous film-forming foams may also need to be addressed. Identifying changes in benthic community structure not only will assist in identifying effects from chemicals of concern, but also will allow evaluation of changes of ecological processes, such as the pathways of organic matter and nutrients. The replication frequency for sediment sampling should be based on rigorous analysis of statistical power to detect changes resulting from the sunken ship.

The benthic organisms should also be analyzed for chemicals of concern to evaluate the pathways of these chemicals in the food web using the before-and-after sampling approach. However, changing contaminant concentrations in benthic organisms as a result of changing seasons and life history stage must also be considered. Marine organisms that attach directly to the surfaces of the ship also should be sampled after this new ecological niche is established at the site.

Since properties of the water column change rapidly due to changing physical forcing and seasonal effects (e.g., heat transfer and rainfall), the geographical approach is more appropriate for contaminants released into the water column. After some time period defined by the feasibility study, both near-ship and far-field samples should be collected and analyzed for contaminants of concern in both the dissolved and particulate phases. The concentrations of concern in the dissolved and particulate phases would be interpreted in relation to both the distance from the ship and other environmental parameters, such as salinity for dissolved constituents and particulate organic matter or particulate iron for particulate contaminants. While collection and analysis of samples for low-level concentrations of trace elements can be performed by a number of specialty laboratories, the analysis of samples for low-level concentrations of hydrophobic constituents that are necessary to provide the sensitivity to detect changes is a specialized field of expertise. The feasibility study will need to define the number of samples for hydrophobic chemicals of concern and the necessary detection limits.

The concentrations of certain constituents in the interstitial water between sediment particles provide valuable information about the biogeochemical state of the sediments. Microorganisms in the sediment use a specified sequence of naturally occurring, oxygen-containing substances that are present in sediments to facilitate breakdown of organic matter. The equilibrium between the oxidation-reduction couples of these oxidized-reduced pairs (dissolved oxygen-carbon dioxide, nitrate-ammonia, sedimentary manganese dioxide-manganous manganese, sedimentary ferric oxide-ferrous iron, sulfate-sulfide, and carbon dioxide-methane) provides a measure of the extent to which the sediment column reduces biochemical compounds. The redox potential also can be

measured with a platinum electrode. The equilibrium between the oxidized-reduced pairs is controlled by the deposition of organic matter to the sediment and the diffusion of water across the sediment-water interface. The redox condition of the sediments can also affect the availability of certain elements of concern to microorganisms. In particular, reducing conditions in the sediment can increase the conversion of mercury to methyl-mercury, which is highly bioavailable. Increased conversion of mercury to methyl-mercury might be caused by increased organic matter in the sediments due to the presence of the ship and not due to release of mercury from the ship. The feasibility study should develop a sampling plan to detect changes in the biogeochemistry of the sediments due to the concentrations of organisms around the ship while taking into consideration the seasonal variation of the deposition of organic matter from surface primary productivity and the heterogeneity of the type of sediment at the site.
Cost to develop contaminants monitoring plan: $20,000.

Biological impacts: Evaluating the extent to which organisms colonizing a ship were attracted from elsewhere versus produced at the ship will likely require some form of the Before-After-Control-Impact Paired Series experimental design (Osenberg et al. 2002). This involves collecting pre-deployment data from at least two spatially separated reefs, one near the ship site, and then monitoring the ship, the nearby reef (impact) and the distant reef (control). A modification might be to collect pre- and post-deployment data from reefs at increasing distances from the ship since the rate at which attraction decreases with distance would provide an improved basis for understanding the effects of sinking ships.

Another major concern is the effect of competition or predation from ship colonizers on organisms in the area surrounding the ship or on organisms passing the ship. Relevant species of concern should be identified and monitoring studies should be developed to address this concern. Changes in the benthic community due to ship sinking are addressed under “contaminants monitoring” above. The need for studies addressing other biological effects should also be evaluated.
Cost to develop biological monitoring studies: $10,000.

Long-term Economic Monitoring Plan: Long-term economic impacts can be assessed and monitored by comparing post-deployment spending by divers with their pre-deployment baseline spending. The monitoring design developed by NOAA for monitoring diving usage for ships sunk off the coast of Florida estimates total recreational diving use by using two sources: 1) dive logbook records from all dive charter operations in the study area; and 2) on-water survey sampling of diving sites in the study area on stratified random sample of days over a pre-determined time period (Bob Leeworthy, NOAA, personal communication). Annual log book data could be obtained from all for-hire dive operations that utilize dive sites in Puget Sound. The on-water data sampling can then be used to estimate the ratio of private household and rental boat use to charter dive boat use. This information is needed to extrapolate the dive charter logbook data to the population of all recreational users (Bob Leeworthy, NOAA, personal communication).

The costs for logbook data collection are greatly dependent on the number of dive shops and operators within the study area. Costs would include monthly data collection from all dive charter operators located within the study area, data entry, travel expenses, and report preparation. The costs for on-site survey sampling include vessel rental, observer salary, and data input. Annual costs would depend on the number of sites within the sample area as well as the overall time period and number of days of sampling (Bob Leeworthy, NOAA, personal communication).

The full design of dive logbook and on-water observation would be needed for establishing the pre-deployment baseline diving use. Costs will depend on the number of dive shops and operators included in the area and the number of days and sites for on-water sampling. To minimize the costs for long-term monitoring of diver use, the annual logbooks can be used to yield an indicator of trends. Then in every select year (such as the third or fifth year), the full design can be conducted to gather the on-water data for extrapolating to total use (Bob Leeworthy, NOAA, personal communication).
Cost to develop the sampling design and estimate the actual cost of data collection for a long-term economic monitoring plan: $8,000.

Total cost to design monitoring studies: $46,000.

Project Life Span and Post-Project Cleanup

Subway cars sunk off the coast of New Jersey deteriorated by an average of 33% after 14 years. The author of that study commented that ships might last from several decades to over 100 years because they are made of heavier gauge steel (Figley 2005). The feasibility study should investigate deterioration rates and frequency of major storms to predict life span. Tasks outlined in the “contaminant removal” section above will assess whether post-project sediment cleanup will be needed.

Tasks and costs: Obtain information on ship deterioration rates by reviewing literature and consulting with experts. Cost: $3,000

Environmental Impacts

Physical Processes

Altered currents may affect sediment transport (i.e., scouring and deposition patterns, increased or decreased water column turbidity). Using data on substrate type and current speed from field surveys (see “siting” under “project costs” above), and on physical characteristics of the ships (see “pre-deployment stability and integrity analysis” under “project costs”), assess how far scouring and deposition is likely to extend from the ship and how much it is likely to change the original level of the substrate surface. Using the same approach, assess whether the presence of a ship is likely to increase turbidity.

Tasks and costs: Predict effects of ship sinking on scouring/deposition patterns and water column turbidity. Cost: $10,000.

Biological Impacts

Sensitive or harvested species: The feasibility study should identify species (i.e., distinct population segments thereof) listed or proposed for listing under the ESA. Their physical and biological requirements, the factors that caused their decline, and the distribution of these species within Puget Sound should be determined from review and synthesis of existing information. Critical habitats and the primary constituent elements of those habitats should be described. Whether and how sinking ships is likely to impact listed species, and whether any negative impacts could be reduced through judicious site selection, altering ship preparation, or some other aspect of the ship sinking program, should be evaluated. Existing information includes species status reviews, critical habitat designations, and recovery plans, as well as other published and unpublished reports, and data files. The appropriate listing agency (NOAA Fisheries or U.S. Fish and Wildlife Service [USFWS]) and experts on the biology of each species in Puget Sound should be consulted. Currently listed or proposed species are southern resident killer whales, Puget Sound Chinook salmon, Hood Canal summer chum salmon, Puget Sound steelhead, bull trout, marbled murrelets, and bald eagles. Interviews with personnel from both listing agencies and a cursory review of literature indicated that southern resident killer whales and Puget Sound Chinook salmon are the species most likely to be negatively impacted, primarily because of concerns about contaminants (e.g., PCBs; see above).

The study should identify other sensitive species and species important for recreational or commercial harvest. These will include all marine mammals (protected under the Marine Mammals Protection Act), some seabirds, all salmon and trout, Pacific cod, most rockfishes, lingcod, dogfish, herring, surf smelt, sand lance, Dungeness crab, some shrimps, Pacific giant octopus, market squid, geoducks, several other clams, abalone, and perhaps additional species. The same issues that were addressed for listed species (see above) should be addressed for these species. The agencies having management authority (NOAA Fisheries, USFWS, WDFW, Northwest Indian Fisheries Commission [NIFC]) should be consulted. Literature and relevant data, including unpublished results from past and ongoing studies in Puget Sound, should be compiled, reviewed, and synthesized.

Rare or sensitive habitats or aquatic communities: These include eelgrass beds, bull kelp, rocky reefs (Pacunski and Palsson 1998), and perhaps other habitats or communities. The feasibility study should consult with appropriate agencies and review literature and geo-referenced data to determine locations of these habitats. These habitats, including buffer zones to prevent indirect effects, should be excluded from consideration during site selection. Investigators should survey potential ship sites to confirm that they don't contain these habitats or communities.

Ecological processes: The previous discussions focused on impacts to particular species. Here we explore impacts from the perspective of changes in ecological processes that might result from ship sinking. The processes and associated impacts are stated in general terms. Specifics about which species might be involved and how large effects might be should be investigated through consultation with experts and a thorough literature review and synthesis. Data collected during field surveys (see "siting" under "project costs" above) would provide improved knowledge on the range of biological communities and physical conditions to be found at sites suitable for ship sinking, thereby improving predictions of biological impacts.

The benthic community at the sinking site (i.e., under the ship) will unavoidably be lost or drastically altered. The need and possibility of mitigating for this loss, perhaps through restoration of similar habitat elsewhere, should be explored and the cost of such mitigation estimated.

The benthic topography and community near the ship will likely be altered due to changes in sediment transport (deposition or scouring) and detritus load (from deposition or ship colonizers). The feasibility study should estimate how far this effect is likely to extend from the ship (see "physical processes" above). The area likely to be affected might be subject to mitigation along with the area under the ship. Results of this assessment also should be used in recommending a minimum distance from a sunken ship to sensitive habitats (e.g., geoduck or eel grass beds).

Changes in currents, or simply the presence of a large object where none was before, might affect the behavior or survival of organisms passing the site. Factors to be investigated include larval settlement patterns and juvenile migration pathways. Existing information should be compiled and synthesized from consultation with experts and literature review.

Sessile organisms, many of which are filter feeders, will colonize the hard substrate provided by the ship. The feasibility study should assess whether they could strip enough food, nutrients, or other material from the water column to create a down-current effect or to impose significant predation on larvae or other life stages. The ship and immediate vicinity will be a nutrient sink with the consequence that these nutrients won't be available elsewhere. The study should assess the importance of this "shadow" effect.

Mobile organisms may use the ship for shelter but forage in surrounding areas, thus increasing competition or predation in those areas. Alternatively, these organisms may forage near the ship, competing with or preying on organisms passing the ship. Predation on sensitive species, and in particular on juvenile salmon, is a major concern and must be thoroughly assessed through synthesis of existing information.

Sunken ships may attract organisms away from hard substrate habitat in surrounding areas. This would be especially problematic if the attraction resulted in reduced survival. Harvest, if allowed, could reduce survival because harvest rates can be higher at the ship than elsewhere when attraction leads to unusually high densities at the ship. Even without harvest, survival might be reduced by other factors including higher concentrations of predators or higher predation efficiency at the ship. Sunken ships may "intercept" pelagic larvae such that those larvae settle on the ship instead of on down-current habitats. Again, this would be problematic if survival was reduced at the ship compared to other hard substrate habitat. Whether the ship is likely to produce new organisms, thereby increasing regional production, or to simply attract organisms away from surrounding areas is an important issue that should be carefully investigated.

The feasibility study should address the question of whether sinking ships could negatively impact water quality other than through contaminants — e.g., significantly reduce dissolved oxygen levels. Such an effect seems unlikely but could conceivably result from increased detritus production, altered current patterns, or oxygen consumption by ship colonizers.

Invasive species: Ships may provide "toe holds" for invasive species that colonize hard substrates, thus facilitating dispersal to other parts of the Sound. The feasibility study should identify which invasive species are likely to colonize ships by obtaining invasive species lists and by consulting with experts. The study should evaluate any threat posed by the invasive species and investigate whether sites can be selected that discourage invasives (e.g., exclude sites near or down-current from known infestations). Also investigate whether sunken ships could facilitate invasive species monitoring in Puget Sound. Because the ships will be visited frequently by recreational divers and periodically monitored, they might provide an early detection system for new invasives or for range expansions of known invasives. Ship preparation should include thorough removal of live organisms to prevent introduction of invasives.

Cumulative effects: Sinking more than one ship in close proximity should result in cumulative effects. The feasibility study should investigate whether cumulative effects are likely to be additive. If the expected effects are positively or negatively synergistic, the likely magnitude of these effects should be assessed. Of course, work on this task will be hindered by a dearth of information about the impacts from even a single ship but data may be available from natural reefs or other habitats, and comparable situations may be addressed in the ecological or conservation literature.

Potential benefits: Fish and other organisms will inevitably colonize the ships, and habitat creation could be identified as a secondary goal. The motivation for sinking ships is to create recreational diving opportunities, but some options for siting or orientation also may maximize benefits for charismatic or sensitive species, species richness, or total biomass. Any of these biological effects should enhance the attractiveness to divers.

The study should contact management agencies (WDFW, NIFC) to see if they support this secondary goal. If the goal is supported, appropriate target species or communities — perhaps sensitive species that require hard substrate habitat such as rockfish – should be identified, and ways to alter the ship sinking program to benefit these species or communities should be investigated. The ship's structure might be altered, or "add-on" structures could be designed for attachment to the ship or placement on the seafloor near the ship. Ship sinking sites could be selected with the preferences and distributions of target species or communities in mind. Perhaps the needs of a particular life stage could be addressed; for example by providing juvenile habitat near or down-current from reproducing adults.

The feasibility study should design and estimate the cost of any promising and approved alterations or additions, and include procedures to prevent inadvertent harm to the target species or communities, or to other sensitive species. The problem of increased harvest rates at the ship could be solved by closing the area to harvest; however, the habitat alterations might be attractive to competitors or predators. The biological monitoring program should be designed to detect unwanted effects, and the alterations should be designed to be reversible or removable if unwanted effects are detected.

Tasks and costs for biological impacts: Address the preceding six biological issues by acquiring and synthesizing existing information on the species, communities, and the ecology of Puget Sound, including species distributions, food habits, and habitat preferences or requirements. Sources will be published and unpublished literature and data sets and interviews with experts. Formulate appropriate conceptual models, incorporate any data from field surveys (see "siting" under "project costs" above), and assess the likely range of biological responses to sinking a ship and how altering a ship-sinking program might change these responses. Cost: $119,500.

Socio-Economic Factors

When evaluating the feasibility of a project involving changes to an area's natural resources, it is important to address many socioeconomic factors that may be affected by the endeavor. For the purposes of this scoping document, the social and economic needs are addressed separately. However, in many instances, these needs can be addressed simultaneously or in tandem with the methods outlined with corresponding cost savings. For example, a single survey could address economic and social valuation of sinking ships to divers.

Social Issues

The feasibility study must address public understanding, attitudes, perceptions, and preferences regarding ship sinking and the social costs and benefits of such an endeavor (e.g., public perception of management policies associated with the ship; social values that would be met or conflicted by implementation). Obstacles and opportunities likely to arise in the public process for ship sinking must also be explored (e.g., clarification of key issues likely to arise in public discussions, likely support or opposition to the project, likely stakeholders and institutions to be involved in the public decision-making process).

Some evidence suggests that planning processes that include a broad array of stakeholders produce more comprehensive plans that are more likely to be implemented (Burby 2003). The challenge is structuring public involvement in ways that are meaningful and productive for agencies and the public. Studies of public involvement processes in environmental decision making have shown that participants evaluate these processes in terms of both process and outcome. Thus, stakeholders desire qualities such as accessibility and depth of deliberation (process components), and an otherwise satisfying experience (outcome) (Halvorsen, 2003). An accessible process is one that provides a comfortable and convenient setting and is respectful of participants' time. Deliberative processes include open discussion and a forum for respectful exchange of opinions; a deliberative process provides opportunities for learning. Finally, a satisfying process demonstrates that decision makers take public input seriously, and the results of citizen input are reflected in the final decision. Other process-focused measures of success in public involvement include the presence of learning opportunities, the development of relationships among group members, and a sense of efficacy (McCool and Guthrie, 2001).

Carr and Halvorsen (2001) drew on criteria proposed by Poisner (1996) to evaluate the effectiveness of public participation in environmental decision making. One interesting finding of their research was that local participants in land-use planning were not representative of the community. Women, young people, and those with lower income and education levels participated at a lower rate than their distribution in the community. The lesson is that public managers and planners must make special efforts to promote participation by a broad range of stakeholders. Documents from other ship sinking endeavors, such as in British Columbia and Florida stress the importance of public involvement in all stages of planning (Enemark, 1999).

The public meeting is the forum often used to collect citizen input. This is problematic for a process such as sinking ships. Attendance at public meetings is often inconvenient or impossible for some persons that may be affected by the potential action (e.g., those who may live long distances from the area of interest). In addition, those who most often attend meetings of this type may represent a vocal minority group that is usually not representative of the full range of user groups and local community members. Also, the type of scientific baseline data that can be collected through this forum is limited.

Several important approaches to understanding the social environment of a decision process such as the potential to sink a ship are outlined below, followed by a detailed explanation of the methods that could be used and a range of costs associated with conducting the efforts.

1. *Situation Assessment*

A first step to understanding the obstacles and opportunities inherent to any proposed project is the assessment of the current and possible future situation. A situation assessment consists of the exploration of any legal or regulatory context in which the project will be decided. A part of a situation assessment is an analysis of the policies, structures, and incentives that will likely drive the decision process. This is sometimes referred to as institutional analysis. This information can be important in determining political support for the project and strategies for proceeding in the decision process.

2. *Stakeholder Identification and Assessment*

Early in the process, it is critical to identify stakeholders who would be affected by the proposed project and who might support or object to the sinking of ships as well as those people, communities, or groups who would potentially benefit or be negatively impacted by the action.

These may be local groups, organizations or individuals, and may also be regional and national interests as well.

Some obvious stakeholders to be considered when exploring the feasibility of sinking ships in the Puget Sound might include the diving community, the commercial and recreational fishing community, the shipping industry, recreational boaters, tribal governments, environmental organizations in the immediate area, as well as the agencies and organizations that would likely be playing some role in the implementation and management of the endeavor. Other groups to be considered include tourism development councils and entities that are part of the infrastructure of the local tourism industry, including hotels, gas stations, restaurants, dive shops, town councils, chambers of commerce, and business development associations. While some stakeholders can be identified easily, others are more difficult. Their stake in the issue may be unknown to planners or decision makers or they may not be attentive to the issue until an initial decision is made that sparks their involvement.

Once stakeholders are identified, it is important to understand their interests, positions, concerns, and role in the decision process. For example, are divers supportive of such an endeavor? How likely would they be to visit such a site? What types of recreational diving are they currently engaged in? What are their concerns? And for the fishing community—do they perceive harvests could be affected or that their livelihood may be restricted or further regulated if ship sinking is pursued?

3. *Determining stakeholder and community understanding, perceptions, and preferences*
It is important to gain insight into the perceptions and attitudes of the public as a whole, not only key stakeholders. Doing so should provide baseline data on the public's understanding, preferences, and expectations. It also can provide managers and decision makers with a better understanding of public acceptability of the project.

In particular, it will be important to assess the social impacts of the potential project to the nearby communities. Note that the attitudes and preferences may not be unified across communities. This assessment will allow identification and gauging of the likely strength of support and opposition prior to implementation. Having objective data on resident concerns can help enhance the public process, should the proposal move forward, by documenting the views of a group of residents who may normally not participate or speak out at standard forums such as public meetings. Specifically, it will help determine the likely acceptability of the project in general and the likely acceptability of specific scenarios or alternatives (e.g., if the endeavor is undertaken, what factors will be important?). This is important in the political decision to proceed and if it is pursued, what features of the project will be considered socially beneficial or costly. This type of an assessment will also allow the social benefits and costs to be quantified so that they can be effectively weighed with the economic, biologic, hydrologic and other factors to be considered in the feasibility study.

Suggested Methods and Costs of Studies to Address Social Issues

There are several options available and widely used for the purposes of gaining insight into the social feasibility of an endeavor such as sinking ships in the Puget Sound. Some of these methods include analysis of secondary data, focus groups, public meetings, stakeholder assessments and stakeholder or community surveys. It is important to bear in mind that some methods will be more appropriate and feasible for the outlined purposes than others.

1. *Comparative studies*
Comparative studies involve identification and review of similar projects that have been completed or are ongoing. Use of these secondary data can be informative and is a good starting place regardless of other methods that are conducted afterwards.

Some information for the situation assessment and the stakeholder identification can be gleaned from secondary data sources (e.g., studies or information from other ship sinking projects for recreational diving). While gaining information from secondary sources would be useful, not all necessary information will likely be found through those sources. There are a limited number of previous instances in which ships have been sunk to increase recreation and tourism opportunities and a very limited amount of socioeconomic data related to these projects.

This scoping phase may also include personal interviews of individuals knowledgeable about sinking ships. This is an excellent way to gain a better understanding of the technical nature of a project and identify lessons learned from other applications and projects.
Cost: $10,000

2. *Focus groups (Qualitative)*
Focus groups are an established technique for qualitative explorations of attitudes, and perceptions of identified groups (in this case, divers or other identified stakeholders). They can be useful for determining potential support or opposition and clarifying likely issues of concern. They can also help determine strategic future communication, should the endeavor be pursued.

They involve a series of small group interviews or discussions on specific topics. They allow for group discussion, follow-up questions and observation of emotional reaction. The groups are usually led by an experienced, trained moderator through a discussion guide. The discussion guide allows for consistency in data collection and keeps the discussions within the purview of the topics of interest. The focus groups are ideally audio and video recorded to allow for later review and analysis by the moderator and other researchers (Morgan 1997).

Focus groups have limitations for producing generalized results. Even though organizers may make an effort to widely advertise a meeting or focus group, the attendees probably will be more representative of one view than of another. The conclusions are based more on the depth of analysis rather than the breadth of analysis.

Focus groups could be conducted independently or as is commonly done, as a precursor to a quantitative survey in order to clarify issues and determine focus before sampling a more representative cross section.

While it is difficult to determine the total number of focus groups that would be required prior to identification of stakeholder groups, it would likely range from 2 to 6 meetings.
Cost: $20,000 for one meeting and $10-15,000 for each ensuing meeting.

3. *Surveys (Quantitative)*
Surveys often are recommended and used to gain insight into the perceptions and attitudes of the public about a potential project in a way that allows for generalizing from the data. Surveys can be conducted numerous ways. The most common methods are telephone, on-site, or mail approaches. Costs of these different methods are quite variable, based on sample size, difficulty in locating intended audience (e.g., a random sample of local community members will be easier to determine than a sample of divers), length of the survey, and the type of report of results. Costs below are

based on a sample size of around 400-600 individuals—this is the size frequently recommended because it keeps costs down while providing acceptable levels of precision—plus or minus 5% at 95% confidence.

Any of these survey options have the advantage of providing quantitative, numerical data to inform the project. Not only can basic levels of support or preference be elucidated, but with an appropriate design underlying reasons for support, opposition, or preference can be inferred.

Socioeconomic knowledge of this type is a vital component in planning, as often groups that oppose such actions argue that the desires of the affected public were not taken into account. Although the elicitation of public participation is a worthy exercise, it is imperative that the socioeconomic feasibility of the potential endeavor of ship sinking be evidence-based and supported by sound science.

Telephone Surveys
Telephone surveys are widely used but labor-intensive processes. The resources necessary to conduct a telephone survey include individuals who can be trained to conduct surveys as well as a facility from which many phone calls can be made at one time. Telephone surveys are necessarily brief due to the nature of the media and have become increasingly difficult with the advent of caller identification systems and cellular telephones. A telephone survey would be appropriate for a survey of community residents, but likely not for a recreation user group such as divers due to difficulty in obtaining contact information (see Intercept-Mail Surveys, below).
Cost Range: $20,000-$50,000

Mail Surveys [1]
Mail surveys are an effective tool for obtaining a large amount of information from a potentially large pool of respondents. Because people have the opportunity to fill out the survey at their leisure, there is the opportunity to have a longer survey than would be feasible with other mediums. This also allows respondents time to critically evaluate their answer, potentially making responses more accurate. This option is not available in telephone surveys, in which respondents are required to answer immediately. There is also a chance to follow up with non-respondents in order to increase the number of overall responses. The feasibility of generalizing depends on the size of the population about which the researcher is trying to gain insight and the number of respondents.

A mail survey would be appropriate for determining perceptions, preferences and understanding of communities. Mail surveys tend to be good choices for general community surveys. A community survey would allow for a large amount of information to be obtained at one time about a variety of issues related to sinking ships. This would be valuable as the success of any endeavor is at least in part dependent on the level to which a community embraces the project.
Cost Range: $50,000–$75,000

[1] If surveys were to be conducted of two groups as outlined in the costs (e.g., both an identified user group or stakeholder (e.g., divers) *and* local community residents), the cost would be less than the totals of both surveys individually. While the cost saving is difficult to determine at this juncture, it would likely be on the order of 25-35% less.

Intercept-Mail Surveys[2]
The type and scope of the survey depends upon the group or groups to be sampled. A survey of divers can give decision makers an indication of the extent of interest in recreational diving in the area. Additional information related to the present types of diving as well as preferences for dive-related services and costs could also be gleaned. The range of focus for surveys can vary according to the requirements of planners. For instance, divers who currently participate in areas adjacent to Washington could be targeted, as could divers from other regions who do not currently travel to the Pacific Northwest to dive.

Depending on the availability of contact information for specified user groups (likely divers), it will likely be necessary to contact users on-site (e.g., at dive shops, boat launches, or marinas). Intercept-mail surveys begin with initial contact made on-site with users to introduce the information collection effort and to request their participation. For those who agree to participate, contact information is recorded so that a mail-survey can be sent to them at a later date (thereby minimizing intrusion on their recreation experience). The mail portion of this method is the same as for mail surveys described above. The addition of the on-site name collection adds cost and coordination efforts (such as with dive shops or marinas) but may be the only viable option if a valid reliable list of users is not available or readily accessible. Costs for an intercept-mail survey would be on the higher end of the cost range.

While a survey that is completed fully on-site is sometimes used in social science research, it is not recommended in settings where users are actively engaging in recreation activities as the research may have negative effects on the recreation experience and response rates may be compromised. Another factor with divers is that completing a survey on a boat or near water often is problematic.
Cost Range: $120,000-$175,000

Clearly a range of methods could be applied in a feasibility study. At a minimum, the comparative study and at least 2-3 focus groups that would include local community residents and members of the dive community should be conducted. Ideally, a comparative study, a series of focus groups of residents and divers and other interested parties (likely 4-6 meetings) followed by a quantitative survey of divers and communities would provide the most comprehensive information from which to judge feasibility.

Economics

Because the costs associated with sinking ships to create dive attractions can be significant, the economic benefits must be examined to determine if the project would be an advisable investment. By comparing anticipated project costs (discussed earlier in the report) with the value of benefits from sunken ships, the feasibility of the program can be evaluated. This allows an objective informed decision regarding the use of public funds for a ship sinking program. A sunken ship can potentially support a number of diverse uses and economic benefits including the creation of new destinations for scuba diving tourists, enhancement of cultural values (e.g., crew commemoration; historical significance), and education benefits (e.g., Puget Sound Awareness). The actual sinking of the ship will also create a tourist and media event that will generate economic benefits and exposure for the Puget Sound area. For the purposes of scoping the issues for the feasibility study, the economic value of benefits from sunken ships is exclusively focused on the benefits derived by

[2] There are many commonalities in methods for collecting social and economic information. If a survey of divers is chosen as part of the feasibility study, a single intercept-mail survey could answer both social and economic questions. The cost of a combined social/economic survey would likely not be additive and would be within the cost range identified for that method.

scuba divers. In the future, it might be desirable to expand the scope of the feasibility study to include the wider range of economic values associated with sinking ships.

The suggested steps for estimating the economic value associated with sinking ships for scuba diving is described below. Within these steps, several types of data are needed. Data collection techniques can range from using pre-existing studies to conducting surveys of current and potential Puget Sound divers. Within the steps, we note the data needed and will discuss the approaches and associated costs to obtain these data in the economic data methods section.

Steps for evaluating the economic benefits from sinking ships for scuba diving:

1. *Evaluate Economic Baseline Conditions:*

An assessment of baseline conditions will provide an understanding and evaluation of the local economy near the proposed ship sinking site. The assessment should incorporate a regional economic profile of the local communities near the proposed sinking site including the local tourism and dive tourism industries. The assessment should evaluate the advantages and disadvantages of selecting a particular community for ship placement including the availability and cost of transportation to the local area and the dive site, distance from airport, availability of diver related services, and the level of support from community businesses. Sinking ships for divers in British Columbia demonstrated that a long term dive tourism plan and broad tourism community support from more than the dive industry is needed to maximize the return on the investment in ship sinking. (Enemark, 1999).

2. *Estimate economic values of current diver use (pre-deployment) and anticipated changes following placement of the ship (post-deployment):*

The size and economic value of the existing dive tourism industry must first be calculated before estimating the potential growth from ship sinking. The economic impact of the current level of divers will form the baseline needed for assessing the potential increase in benefits from new divers as well as monitoring the actual economic impacts post-deployment.

Benefits derived by scuba divers involve both market and non-market values which makes quantification of total benefits difficult. Market impacts are typically measured by the total amount of money non-local divers spend in the local economy and the resulting impacts on local employment and income. The amount of spending by non-local divers represents the base upon which tax revenues can be generated (Pendleton 2005). While spending by divers represents local economic market effects, it does not measure the benefits to the divers themselves. This additional non-market value is reflected by the amount divers would pay over and above their existing costs to use a dive site.

The current and anticipated changes in market values can be measured by conducting a regional economic impact analysis. Economic input-output models are commonly used to predict the total level of regional economic activity that would result from a change in visitor spending. Regional economic impacts can include changes in sales revenue, jobs, net income, and tax revenues. The size of the region influences both the amount of spending captured and the multiplier effects. An economic impact analysis can be conducted for the *local* communities near the ship site (typically defined as all counties within a 30-60 mile radius of the travel destination) and the overall *regional* level (e.g., the State of Washington). For the *local* analysis, only spending by non-local visitors living outside the local area (non-local Washington residents and non-residents) is considered an infusion of new money into the local economy. The *regional* economic impact area will capture all spending by non-residents in the State of Washington.

To determine the regional economic baseline impacts of current diver use, data are needed on:

- the current annual number of divers
- the percent of divers that live outside of the Puget Sound area (non-local Washington residents and non-residents)
- the average spending of non-resident divers locally in the Puget Sound area (to determine the local spending impacts) and other areas in the State of Washington en-route to the Puget Sound area (to determine regional spending impacts)
- the average spending of non-local Washington resident divers locally in the Puget Sound area (to determine the local spending impacts)

In order to determine the change in economic effects associated with ship sinking, data are also needed on how current divers would change their number of visits and the anticipated number of new divers and how often they will visit the area.

Factors that can affect dive visitation include:

- Novelty: Are sites primarily used shortly after sinking or do divers continue to use (i.e., make repeat visits);
- Cluster of ships or sites versus single ships—how does appeal to divers increase as a function of the number of ships at a site (or within a 30 minute boat ride?);
- Proximity to good natural dive sites may be a benefit in a similar manner to multiple ships;
- Synergy from being part of the "British Columbia circuit;"
- Ship size and type;
- Remoteness: availability and cost of transportation to the local area and the dive site, distance from airport, and availability of diver related services;
- Amenities: proximity to other attractions including cities (movies, spectator sports, museums, etc) or alternatively the lack thereof (i.e., piece and quiet) or other outdoor activities (National Parks, hiking, kayaking, etc.).

The non-market value of a dive site to the individual diver will depend on diver interest, quality of the sunken ship, and substitute dive sites (Pendleton, 2005). The non-market benefits to the dive visitors are measured by how much the visitor would pay over and above their existing costs. To determine the non-market values of current diver use, data are needed on how much more than the existing costs divers would pay for their current trip experience. In order to determine the change in non-market values associated with ship sinking, data are also needed on how much more than the existing costs current and potential divers would pay for a trip to a sunken ship in Puget Sound. Economists have several methods for measuring non-market values. The most appropriate for this situation is the contingent valuation method. Contingent valuation is a method that uses a simulated or hypothetical market to determine how much more than the current costs visitors would pay for their trip experience. The method is recommended for use by federal agencies performing benefit cost analysis (U.S. Water Resources Council, 1983).

3. Determine the Net Economic Value:
The net economic benefit of sinking ships for scuba diving can be calculated by comparing the anticipated initial and ongoing project costs, including the cost of needed infrastructure (see "project costs" above) to the anticipated annual economic benefits (market and non-market) from new diving tourism. The feasibility study should address how the project costs will be distributed among community members. Equity concerns about an increased tax burden on local residents to pay for infrastructure has been highlighted by at least one stakeholder group. Other equity concerns relate to the initial economic status of the local community near the ship site (as a means of assisting a struggling economy). The feasibility study should also address potential conflicts of ship sinking with other activities. For example, creation of a no-harvest zone might cause recreational anglers to go elsewhere.

Clearly a range of methods could be applied in a feasibility study. At a minimum, the comparative study and at least 2-3 focus groups that would include local community residents and members of the dive community should be conducted. Ideally, a comparative study, a series of focus groups of residents and divers and other interested parties (likely 4-6 meetings) followed by a quantitative survey of divers and communities would provide the most comprehensive information from which to judge feasibility.

Economic Data Collection Methods and Costs

The cost of conducting the economic valuation steps outlined above would range from $55,000 to over $300,000 depending on the technique used to collect the economic data. To keep costs down, the feasibility study is designed to use pre-existing data when possible unless a critical need for collecting new data is identified. Given the significant project costs associated with sinking a ship, it is important to assess the potential benefits as accurately as possible to determine if the investment is advisable. The techniques for collecting the economic data range from using existing studies (secondary data) to collecting Puget Sound site-specific primary data by surveying current and potential Puget Sound divers. Ideally, the data needed on diver use, spending, non-market values, and changes in visitation would be obtained by surveying current and potential dive visitors. If those costs are prohibitive, data from existing sources can be used exclusively if appropriate. At the very least we suggest collecting site-specific data on the annual current number of Puget Sound divers because this estimate establishes the baseline and is what will drive both the regional economic analysis and non market values for which all future economic impact comparisons and resulting decisions will be made. For all other data sources, we provide a set of low, medium, and high cost and applicability methods for data collection. The advantages, disadvantages, and costs using the low, medium, and high data sources are discussed.

Methods for obtaining data on current annual number of divers: Total recreational diving use can be estimated from a combination of two sources: 1) dive logbook records from all dive charter operations in the study area; and 2) on-water survey sampling of diving sites in the study area on a stratified random sample of days over a pre-determined time period (Bob Leeworthy, NOAA, personal communication). Annual log book data can be obtained from all for-hire dive operations that utilize dive sites in Puget Sound. The on-water data sampling can then be used to estimate the ratio of private household or rental boat use to charter dive boat use. This information is needed to extrapolate the dive charter logbook data to the population of all recreational users (Bob Leeworthy, NOAA, personal communication). The costs for logbook data collection depend on the number of dive shops and charter operations within the study area. Tasks include monthly data collection from all dive charter operators located within the study area, data entry, travel expenses, and report preparation. The costs for on-site survey sampling include vessel rental, observer salary, and data input. Annual costs would depend on the number of sites within the sample area as well as the overall time period of sampling and the number of days that sampling would need to occur for the aforementioned procedures.

Total costs for dive logbook data collection and on-water observation would be $30,000 - $85,000 depending on number of dive charter operators included in the area and the number of days and sites for on-water sampling.

Range of methods for obtaining other data sources (based on cost and applicability):

A) Relying only on secondary data sources (low cost and low applicability or specificity to Puget Sound): Existing studies can be useful for understanding how previous ship sinking has benefited local communities. Using data from existing studies has the advantage of being much more affordable and quick to conduct as compared to a visitor survey. These secondary data sources on diver use, spending, and benefits can be applied if the situation of the previous study is similar to Puget Sound. A literature review on the value of recreational diving at artificial reefs in the United States was recently completed and provides a detailed summary of all existing studies (Pendleton 2005). Few studies have been conducted on the value of artificial reefs and only three included artificial reefs constructed of ships (two conducted in Florida and one in Texas). Average diver spending estimates from the studies including ships ranged from $50-$185 per day for residents and $90-$204 per day for non-residents, and non-market values from a study in Southeast Florida were $14 per visitor per day for maintaining existing reefs and $5.60 per visitor per day for constructing new artificial reefs (Pendleton, 2005). An average from the diver spending estimates and the non-market value estimates could be applied to Puget Sound. However, these studies are from warm water areas with well established dive tourism industries and were conducted after ship deployment. Therefore, the estimates for diver use do not transfer well to Puget Sound. In British Columbia, the Nanaimo Dive Association began keeping dive statistics before the sinking of the Saskatchewan in 1996. These data can provide an order of magnitude estimate of the potential impact (i.e., whether sinking a ship might generate a $100,000, $1 million or $10 million annual impact). Transferring these results to Puget Sound should also be done with caution because British Columbia already had an established reputation for artificial reef diving (seven scuttled ships) before the Saskatchewan was sunk.

The biggest drawback of using only data from existing studies is that it would not provide information on changes in visitation (from current and new divers) or on what sunken ship characteristics would attract the most divers. This information is needed to determine the change in economic effects associated with ship sinking. Existing studies would provide only a single estimate that would not vary by the different scenarios under consideration in Puget Sound (i.e., ship location, single ship or cluster of ships, ship type, close to airport or other outdoor activities, etc.). The question of how geographic location of a sunken ship in Puget Sound will affect appeal to non-local divers that live within driving distance (Portland area) versus non-local divers that fly into Seattle can be particularly important. A sunken ship located in Hood Canal or south of Seattle might attract many more visits from non-local divers who typically drive to the area rather than fly into Seattle than would a sunken ship located north of Seattle. In contrast, a sunken ship located near other activities or tourist attractions (i.e., San Juan Islands; Olympia National Park; etc.) might attract many more visits from divers from other out-of-state locations that would fly into Seattle.

The amount of time and money spent in the local area is very different for non-locals coming from Portland (often a one- day trip) versus non-locals flying in from farther away. A visitor survey is needed to understand these changes in visitation and what amenities interest divers most (and may not be available at other artificial reef sites). This information would give Puget Sound the opportunity to develop a niche market that divers are seeking.

Cost Range: $25,000 - $50,000

+ $30,000 - $85,000 for current diver data collection

= $55,000 - $135,000 Total Economic Evaluation Cost

B) Survey of current divers to Puget Sound area (medium cost and medium applicability or specificity to Puget Sound): As discussed in the social issues section, surveys have the advantage of providing site-specific quantitative, numerical data to inform the project. A visitor survey of current divers would provide for the economic valuation, including data on current use and trip frequency, visitor spending, benefit values, and preferences for the ship-sinking amenities of greatest interest to current Puget Sound divers.

Anticipated changes in current diver visitation can also be estimated by using information on the potential sunken ship scenarios (i.e., single ship or cluster of ships, ship type, close to airport or other outdoor activities, etc.). Current divers would be asked to report how the number of visits would change with each scenario. This approach is known as the contingent visitation or intended behavior approach. To estimate the non-market values, a dichotomous choice question should be used to make the contingent valuation question more closely approximate market-like conditions.

For surveying current divers, sampling procedures could involve a modification of the on-water survey sampling procedures of diving sites in the study area (described above for estimating the annual number of current visitors) to conduct an intercept-mail survey. The procedures for conducting an intercept-mail survey are discussed in the social issues section.

The disadvantage of only conducting a survey of current divers is that the survey is limited to individuals already visiting the area. It excludes the potential new divers that would come to Puget Sound as a result of sinking ships and therefore would only provide a very conservative estimate of increased use, benefits, and spending impacts that would be generated by sinking a ship because it would miss participation of new divers. Besides being costly, surveys are also time intensive. The process includes survey development, pre-testing, and survey implementation, and might require up to 12 months depending on the diving season plus additional time for data analysis. Study duration would be approximately 18 months.

Cost Range: $125,000 - $175,000

+ $30,000 - $85,000 for current diver data collection

= $155,000 - $260,000 Total Economic Evaluation Cost

C) Conducting a survey of current divers and potential new divers (high cost and applicability or specificity to Puget Sound): In addition to surveying current divers, conducting a survey of the general scuba diving population to reach potential new divers would provide all the data and advantages mentioned above in the current diver survey plus it would have the additional advantage of including the increased use, benefits, and spending of potential new divers. This is the only method that would provide all data needed for conducting the economic analysis and provide the most accurate evaluation of the anticipated total economic impact associated with sinking ships.

Possible techniques for obtaining a representative sample of general scuba divers include subscription lists from Scuba Diving Magazine, member lists from a scuba organization (e.g., PADI; DAN), or random digit dialing. Disadvantages are that it would be costly and time intensive.
Cost Range: $200,000 - $250,000
+ $30,000 - $85,000 for current diver data collection
= $230,000 - $335,000 Total Economic Valuation Costs

Feasibility Study Budget

We present three funding options for the feasibility study; others are possible. The Full option includes consideration of two vessel classes (ferries and destroyers), provides a rigorous analysis of existing data, and for some tasks includes significant development of new data. The purpose for these new data is to validate, refine, or provide critical information for making predictions and conclusions. The Full option will provide the most reliable assessment of feasibility across Puget Sound. Two Minimal options are presented, one with consideration of two ship types and the other for ferries only. The latter is included to provide a cheaper option and because ferries may be a better option than destroyers for Puget Sound (see “ship selection and acquisition” under “project costs” above). Where the Minimal level differs from the Full level, the former includes field sampling at only one site rather than at five sites (Siting) or provides no or qualitative results rather than quantitative results (Socio-economic factors). The Minimal level relies more on existing data whose relevance or accuracy for Puget Sound or for specific sites of interest in Puget Sound often is unknown or modest. The uncertainty or risk associated with predictions based on the Minimal options will be substantially greater than with the Full option but the cost is approximately 50% lower. Selecting only one site for field surveys (i.e., Minimal options) seems most appropriate if the feasibility study is done sequentially so that one site has been selected as the desired location for sinking a ship, subject to final field verification. Note that a fourth budget option—the Full option with consideration only of ferries—can be computed from values in the table (below) by subtracting the difference between the two Minimal options from the Full option.

Values in the following budget table are derived from the means of the ranges given in the text unless otherwise noted. Most of the direct costs (i.e., without overhead or indirect costs) were those that would be incurred if USGS conducted the feasibility study. Details supporting those costs are provided in Appendix A. We believe that the direct costs would be similar for most consultants or other potential contractors; however, overhead rates vary substantially, ranging from less than 50% (e.g., USGS) to well over 100% (some consultants). We used 100% here to avoid overly optimistic expectations.

Section	Task	Funding level: Full (two ship types)	Minimal: Two ship types	Minimal: Ferries only
Project costs	**Ship selection and acquisition**	$20,000	$20,000	$10,000
	Contaminant removal and effects			
	Estimate contaminant inventories and removal costs; review emerging contaminant effects	$29,000	$29,000	$23,500
	Hazmat sampling for emerging contaminants (e.g., PBDEs)	$150,000	$150,000	$75,000
	Ship preparation, towing, and sinking	$9,000	$9,000	$4,500
	Siting			
	Puget Sound-wide map from existing data	$29,500	$29,500	$29,500
	Field surveys, seafloor	$202,500	$40,500	$40,500
	Field surveys, visibility and currents	$181,500	$36,300	$36,300
	Field surveys, biological	$101,200	$20,240	$20,240
	Predeployoment ship stability analysis	$10,000	$10,000	$5,000
	Permits	$10,000	$10,000	$10,000
	Liability	$10,000	$10,000	$10,000
	Infrastructure	$24,000	$24,000	$24,000
	Maintenance	$9,600	$9,600	$9,600
	Monitoring	$46,000	$46,000	$46,000
	Project life span	$3,000	$3,000	$3,000
Environmental impacts	**Physical processes**	$10,000	$10,000	$10,000
	Biological impacts	$119,500	$119,500	$119,500
Socio-economic factors	**Social issues**			
	Comparative studies	$10,000	$10,000	$10,000
	Focus groups[a]	$70,000	$33,000	$33,000
	Survey (community)[b]	$47,000		
	Economics			
	Estimating current diver use	$58,000	$58,000	$58,000
	Estimating economic impact from existing data[c]	$10,000	$38,000	$38,000
	Socio-economic survey (divers)[d]	$250,000		
Sub-total	**Sub-total**	$1,409,800	$715,640	$615,640
Overhead[e]	**Overhead**	$1,409,800	$715,640	$615,640
Total	**Total**	$2,819,600	$1,431,280	$1,231,280

[a]Five focus groups are suggested; two are minimal.

[b]The value reflects a 25% discount on the mean of the range for mail surveys given in the text.

[c]The suggested value is less than the minimal because most data needed to estimate economic impact will come from the survey.

[d]The value is at the upper end of the range given in the text because quesitions on economic valuation and social issues are included.

[e]Overhead rates vary substantially, ranging from less than 50% (e.g., USGS) to over 100% (some consultants). We chose to use 100% to reduce the chance of underestimating the actual cost regardless of the contractor.

Discussion

The Minimal budget options include collection of new data in three instances. The first is onboard hazardous material sampling for PBDEs and other emerging contaminants. We included this element in the Minimal options because as far as we know the presence and concentration of emerging contaminants in onboard materials has not been established by previous studies. The other two instances are field surveys at one site (rather than at five for the Full level), and two focus groups (rather than five) to provide at least some information on community support or opposition to ship sinking. Note that if a minimal option is selected, we recommend that the single field survey be conducted at the site judged to be the most desirable from other data and results of the feasibility study. This sampling would be necessary to confirm the many preliminary conclusions about site suitability and benign ecological consequences; authorizing ship sinking without such a survey would be risky because confirmation of the existence of suitable sites would be lacking. Physical and biological field surveys at a candidate site will be an essential prerequisite to ship sinking, required by permitting, regardless of whether such surveys are conducted during a feasibility study or postponed until afterwards (i.e., only conducted in the event that the decision to go forward with ship sinking is made).

Contaminant removal may be the single most important issue to resolve for a ship sinking program in Puget Sound. Contaminants tend to be retained in Puget Sound due to basin morphology and current circulation patterns, and sediments and biota show high levels of contaminants. PCBs and PBDEs bio-accumulate up the food web and occur at high levels in ESA-listed killer whales. Major initiatives are underway to prevent contaminants from entering the Sound and to clean up those that are already present. Thorough ship cleaning will be required if ship sinking is to proceed. For this reason, a good strategy for the feasibility study might be to accept the strictest contaminants standards at the outset. The advantage would be to save the time and expense needed to review and reach consensus on acceptable contaminant levels since the endpoint of such deliberations would likely be the same (i.e., very strict standards). For PCBs this might mean adopting a maximum of 2 ppm, based on EPA criteria for "continued use" of materials (Atlantic States Fisheries Commission 2004), rather than the 50 ppm maximum given in the BMPs for creating artificial reefs from ships (U.S. Environmental Protection Agency and U.S. Maritime Administration 2006) which is based on criteria for "disposal" of materials. If attaining the 2 ppm level appears to be cost prohibitive, past studies could be reviewed to see if a higher level would be acceptable. Because standards for PBDEs and other emerging contaminants are currently lacking, past studies must be reviewed and standards set for these chemicals unless it proves feasible to completely remove materials containing them from ships.

Economic benefit is also an important issue. Tourism economic development is the primary goal for ship sinking. The extent to which economic benefits outweigh monetary and environmental costs will be a major factor in deciding whether to proceed with ship sinking. Note that there is a large difference in accuracy of economic predictions between the Full and Minimal budget levels. The Full level includes a survey of divers nation-wide as well as in Washington, which will estimate the number of non-resident divers attracted to the State by ship sinking and the average spending by such divers. The survey will also allow evaluation of how economic benefit varies among regions within Puget Sound. In contrast, the Minimal level relies on a few studies from warm water areas and on statistics from British Columbia that roughly estimate economic benefits from sinking ships in the Strait of Georgia. These data may not transfer well to Puget Sound and will not provide information on variation in economic benefit among regions. Choosing the Full budget level seems advisable due to the importance of accurate economic predictions.

The feasibility study could be conducted in stages. For example, contaminant issues could be evaluated first because of their overriding importance. If thorough cleaning were found to be feasible for ships of interest, then other components of the study could proceed. Alternatively, economic benefits could be evaluated first, and the other components of the study would proceed only if economic projections were favorable, commensurate with claims for ships-to-reefs programs in other areas. A sequential strategy would obviously save money if thorough cleaning isn't feasible or if economic projections are judged to be inadequate; however the strategy would extend the duration of the study if neither of these factors preclude ship sinking. Whether ship sinking is compatible with the initiative to remove derelict vessels from Puget Sound seems to us a less critical issue than are contaminants or economic benefits, particularly because a ship sinking program can and should include removal of derelict fishing gear. Nevertheless, it would still be wise to investigate resolution of this potential conflict early in the feasibility study. If all feasibility components were conducted concurrently, the duration of the study should be approximately 18-24 months. Significant milestones, such as completion of syntheses of existing data, would be achieved at various times during this interval.

Our cost estimates for the feasibility study seem high relative to those for other ships-to-reefs programs. The total cost to sink a ship, including feasibility determination, typically averages about $500 per ton (Appendix A). On this basis, the larger of our two vessel classes (medium sized destroyer; ~3000 tons) should cost about $1.5 million to sink, yet our Minimal estimate for a feasibility study alone is $1.4 million (or $1.2 million if only ferries are considered) and our Full estimate is $2.8 million (budget table, with 100% overhead). One reason is that the study we describe needs to determine programmatic feasibility for a region with no past history of similar programs, a task that should be expected to cost more than simply determining feasibility for a single ship and site in regions with pre-existing policy and regulatory frameworks and a positive track record from ship sinking (i.e., where monitoring of past projects indicates that environmental impacts are acceptable). Another reason may be that Puget Sound differs from the Atlantic and Gulf coasts, where most ships-to-reefs programs in the United States have occurred, in being more sensitive to environmental impacts (e.g., contaminant retention; vulnerability of ESA-listed species), and also in the strong environmental ethic of people living in the area. Puget Sound therefore requires a thorough assessment of potential environmental impacts, which is expensive. Finally, results of the studies we propose will be scientifically defensible, which comes at a greater cost than do less rigorous studies. We have described the tasks that we think should be included in a feasibility study, along with a cost estimate for each task and information on how we derived the estimate. From this information the reader may wish to adjust, eliminate, or add additional tasks, or to adjust cost estimates to create other alternatives for study intensity or cost. For example, decision makers might select one of the Minimal options but add the socio-economic diver surveys from the Full option to ensure reliable estimates of economic benefit.

If a feasibility study is conducted, the investigators must work closely with the regulatory agencies that set the environmental criteria and standards against which decisions are made and that ultimately make those decisions. Since ship sinking, as proposed herein, is new to Puget Sound, new criteria and standards may need to be established, and regulators may need to direct the efforts of the feasibility study to accomplish this. For example, removal standards will need to be reviewed and set for emerging contaminants and perhaps also for established contaminants such as PCBs, and this will likely require investigators to provide specific information at the request of the regulators.

It would be desirable for the scoping study to include rigorous definition of minimum sampling intensities, statistical power, and other criteria defining the quality of the products from the feasibility study. Unfortunately the time and funding allocations for this study did not allow that degree of elaboration. If the legislature decides to move forward with a program to sink ships for divers so that a request for proposals results from the scoping study, personnel charged with soliciting or reviewing such proposals may bear some extra burden to ensure adequate rigor.

Recommendations

We recommend choosing the Full budget option for estimating economic benefits (i.e., costs listed under Economics in Full column of the budget table) due to the importance of accurate economic predictions, as discussed above. Other recommendations must follow from the priorities of the decision makers. If cost efficiency is deemed more important than minimizing the time required to complete the feasibility study, then conducting the feasibility study sequentially is recommended. The most important issues appear to be contaminant removal and economic benefits for reasons discussed above. Contaminant removal could be investigated first, perhaps for ferries only since they may offer greater ease of cleaning than destroyers (see “ship selection and acquisition” under “project costs” above). If thorough removal proves economically feasible, then anticipated economic benefits from ship sinking could be evaluated. If results from this step are favorable, then the study could proceed further. Alternatively, economic benefits could be evaluated first, followed by contaminant removal if economic projections are favorable. We recommend conducting all feasibility study components concurrently if minimizing time to feasibility study completion is more important than cost efficiency.

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Appendixes

Appendix A: Budget with cost estimate details: The following budget table shows the basis for cost estimates presented in the Budget section of the report (see above). The details apply to our Full option for the feasibility study except in the one instance noted below.

Section	**Task**/Subtask	Cost category		Hours	Cost
Project costs					
	Ship selection and acquisition				
		Subcontract—Modified from estimate by Jeff Dey, REEFMAKERS™	**Total**		**$20,000**
	Contaminant removal and effects				
	Estimate contaminant inventories; review emerging contaminant effects				
		Senior scientist—Lit. review & synth for emerging contaminants		200	$18,000
		Subcontract—Assess & remove PCB's (estimate from Jeff Dey, REEFMAKERS™)			$11,000
			Total		**$29,000**
	Hazmat sampling for emerging contaminants (e.g., PBDEs)				
		Subcontract—Estimate based on costs for Spiegel Grove hazmat sampling (EPA & MARAD 2006)	**Total**		**$150,000**
	Ship preparation, towing, and sinking				
		Subcontract—cost estimate by Jeff Dey, REEFMAKERS™	**Total**		**$9,000**
	Siting				
	Puget Sound-wide map from existing data				
		Senior scientist		220	$12,000
		Junior scientist		380	$12,000
		Biotechnician/clerical		30	$600
		Information management (GIS; database mgmt; ...)			$4,000
		Equipment, supplies, travel			$900
			Total		**$29,500**
	Field surveys, seafloor				
		Senior scientist		1,100	$60,000
		Junior scientist		2,000	$55,000
		Biotechnician/clerical		250	$5,000
		Information management (GIS; database mgmt; ...)			$20,000
		Equipment, supplies, travel			$25,000
		Subcontract for vessel			$37,500
			Total (5 sites)		**$202,500**
	Field surveys, water clarity and currents (2 seasons; per site)				
		Senior scientist		950	$51,500
		Junior scientist		1,750	$45,000
		Biotechnician/clerical		125	$2,500
		Information management (GIS; database mgmt; ...)			$20,000
		Equipment, supplies, travel			$25,000
		Subcontract for vessel			$37,500
			Total (5 sites)		**$181,500**
	Field surveys, biological				
		Senior scientist		100	$6,000
		Junior scientist		560	$17,000
		Biotechnician/clerical		160	$4,200
		Information management (GIS; database mgmt; ...)			$6,000
		Equipment, supplies, travel			$5,000
		Subcontract for vessel and ROV			$49,000
		Subcontract for benthos sorting and taxonomy			$14,000
			Total (5 sites)		**$101,200**
	Predeployoment ship stability analysis				
		Modified from estimate by Jeff Dey, REEFMAKERS™	**Total**		**$10,000**
	Permits				
		Subcontract —cost estimate by Jeff Dey, REEFMAKERS™	**Total**		**$10,000**

Section	Task/Subtask	Cost category		Hours	Cost
	Liability				
		Senior scientist		50	$3,000
		Junior scientist		100	$3,500
		Biotechnician/clerical		140	$3,500
			Total		**$10,000**
	Infrastructure needs assessment				
		Senior scientist		200	$12,000
		Junior scientist		110	$3,800
		Biotechnician/clerical		160	$4,200
		Information management (modeling)			$2,000
		Equipment, supplies, travel			$2,000
			Total		**$24,000**
	Maintenance needs assessment				
		Modified from estimate by Jeff Dey, REEFMAKERS™	**Total**		**$9,600**
	Monitoring needs assessment				
		Senior scientist		300	$18,000
		Junior scientist		220	$7,600
		Biotechnician/clerical		320	$8,400
		Information management			$2,000
		Equipment, supplies			$2,000
		Travel			$8,000
			Total		**$46,000**
	Project life span				
		Senior scientist		20	$1,200
		Junior scientist		50	$1,800
			Total		**$3,000**
Environmental impacts					
	Physical processes				
		Senior scientist		120	$6,500
		Junior scientist		100	$2,800
		Biotechnician/clerical		10	$200
		Equipment, supplies, travel			$500
			Total		**$10,000**
	Biological impacts				
		Senior scientist		1,360	$69,300
		Junior scientist		580	$18,200
		Biotechnician/clerical		920	$23,400
		Information management (GIS; database mgmt; ...)			$8,000
		Equipment, supplies, travel			$600
			Total		**$119,500**
Socio-economic factors					
	Social issues				
	Comparative studies				
		Senior scientist		25	$2,500
		Junior scientist		100	$5,000
		Information management (GIS; database mgmt; ...)			$500
		Travel			$2,000
			Total		**$10,000**

Section	**Task**/Subtask	Cost category	Hours	Cost
	Focus groups[a]			
		Senior scientist	100	$10,000
		Junior scientist	360	$18,000
		Recorder		$5,000
		Information management (GIS; database mgmt; ...)		$2,000
		Equipment, supplies		$10,000
		Travel		$25,000
		Total		**$70,000**
	Survey (community)[b]			
		Senior scientist	100	$10,000
		Junior scientist	240	$12,000
		Survey (postage, printing, data entry, …)		$15,000
		Information management (GIS; database mgmt; ...)		$2,000
		Equipment, supplies		$2,000
		Travel		$6,000
		Total		**$47,000**
	Economics			
	Estimating current diver use			
		Estimated from similar efforts in Florida[c] **Total**		**$58,000**
	Estimating economic impact from existing data[d]			
		Senior economist	150	$15,000
		Economist/Contractor	200	$20,000
		Equipment, supplies		$1,500
		Travel		$1,500
		(Minimum option)Total		**$38,000**
	Socio-economic surveys (divers)[e]			
		Senior scientist	300	$30,000
		Senior economist	300	$30,000
		Junior scientist	1,000	$50,000
		Survey costs (current divers)		$80,000
		Survey costs (general divers)		$30,000
		Information management (GIS; database mgmt; ...)		$7,000
		Equipment, supplies		$8,000
		Travel		$15,000
		Total		**$250,000**

[a]Five focus groups are suggested; two are minimal.

[b]The value reflects a 25% discount on the mean of the range for mail surveys given in the text.

[c]Depending on the number of dive shops and operators in the area and the number of days and sites for on-water sampling, the cost could range from $32,000 to $85,000 based on costs incurred for a similar project in Florida.

[d]The Suggested value is less than the Minimal (given here) because most data needed to estimate economic impact will come from the survey.

[e]The value is at the upper end of the range given in the text because questions on economic valuation and social issues are included.

Appendix B: Ship sinking costs from other programs: The following table shows turnkey costs for sinking large ships from past or ongoing ships-to-reefs programs. The table was provided by Jeff Dey of REEFMAKERS™.

Ship	Site	Deployed yet?	Deploy date	Weight (tons)	Cost (US $)	Cost per ton
Yukon	California	Yes	2000	3,700	$2,000,000	$541
Scylla	England	Yes	2004	3,700	$3,019,688	$816
Perth	AUS	Yes	2001	4,000	$2,073,567	$518
Hobart	AUS	Yes	2002	4,000	$2,015,984	$504
Brisbane	AUS	Yes	2006	4,000	$2,073,567	$518
Balarus	Spain	No	In process	4,700	$2,294,963	$488
Speigel Grove	Florida	Yes	2002	7,000	$1,300,000	$186
Texas Clipper	Texas	No	2007	10,000	$5,000,000	$500
Vandenberg	Florida	No	2008	13,000	$5,700,000	$438
Oriskany	Florida	Yes	2006	34,000	$23,600,000	$694
Average				8,810	$4,907,777	$520