Restoration Decision Support Based on Analysis of Ecological Services Using HEA

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Introduction

The Washington State Department of Natural Resources (WDNR) manages approximately 1,300 ac of upland and nearshore habitat as part of the Woodard Bay Natural Resources Conservation Area (NRCA) in Henderson Inlet, near Olympia, Washington (Figure 1). The NRCA and adjoining state-owned aquatic lands represent a relatively undisturbed ecosystem within the rapidly urbanizing Puget Sound watershed. The site includes forested uplands, several protected embayments, estuarine and freshwater wetlands, and streams that support a rich array of native species, including bald eagle, great blue heron, migratory waterfowl, shorebirds, bats, harbor seal, forage fish, salmon, and the native Olympia oyster. The site also has important historic and archaeological features and is visited by the public for a variety of activities, including hiking, kayaking, wildlife viewing, and environmental education.

Figure 1. Site features

Although the majority of the site is undeveloped, the NRCA was the location of the South Bay Log Dump, which was operated by the Weyerhaeuser Company for over 50 years. This facility received millions of logs by rail and truck; logs were offloaded, sorted, bundled, and stored in nearby Chapman Bay and Henderson Inlet before being towed to Weyerhaeuser's mills in Everett, Washington. Several historical features remain at the site (Figure 1). These include a railroad trestle at the mouth of Woodard Bay, a 3,000-ft-long pier across the mouth of Chapman Bay, and approximately 500 individual pilings and 30 dolphins (bound piling clusters). Many of these features are listed in the National Register of Historic Places, and the site is classified as a Historic Landscape District. Other existing features include a county road and bridge over Woodard Bay and limited upland development (i.e., parking, picnic areas, signage, and an interpretive center in the old foreman's shack near the pier).

WDNR suspected that in-water structures (e.g., piers, anchor pilings, trestles), fill materials, and other features of the historical log transfer facility had adversely affected the aquatic ecosystem through the alteration of nearshore processes, degradation of nearshore and riparian habitats, accumulation of wood debris, and release of potentially toxic chemicals from the decomposition of submerged wood waste and in-water wooden structures preserved with creosote.

WDNR, in partnership with the US Army Corps of Engineers, US Environmental Protection Agency, Washington State Department of Ecology, and The Nature Conservancy, conducted an assessment of the nature of the in-water structures and distribution of wood waste in aquatic portions of the site to identify potential wood waste impacts on sediment quality and to support restoration planning. The results of that assessment indicated that wood waste was not widespread at the site, and the sediment was generally of high quality. However, it also revealed that the more than 2,500 creosoted pilings present in the nearshore area could potentially represent a long-term threat to the environment as they continued to degrade and erode.

WDNR directed Windward Environmental LLC (Windward) and its team (Dalton, Olmsted & Fuglevand, Inc.; Sitts & Hill Engineers, Inc.; and Historical Research Associates, Inc.) to conduct a feasibility study (FS) (Windward 2008) to evaluate restoration options for the nearshore area of the Woodard Bay site. The overall objective of the FS was to determine the best approach for restoring the nearshore ecosystem while balancing the needs of the public and the diverse biological communities.

Feasibility Study

Specific objectives of the FS were to:

- Develop a conceptual site model (CSM) to describe the various natural resources and ecosystem processes provided by and impacts to the site and the natural resource services created by the site features within the NRCA.
- Select natural resources and ecosystem processes to preserve, enhance, or restore based on management goals for the site.
- Identify and evaluate discrete restoration actions that could benefit one or more ecological resources or processes and change the delivery of ecosystem services.
- Group individual restoration actions into alternatives and evaluate the cumulative change in ecological services and benefits to the ecosystem as a whole.
- Evaluate estimated costs relative to ecosystem benefits.
- Select a preferred alternative.

Conceptual Site Model

The CSM described overall relationships among constructed site features, natural resources, and ecosystem processes, which enabled resource managers to identify restoration priorities and provided a framework by which restoration actions could be judged (e.g., long-term monitoring). The CSM also identified ecological attributes (e.g., an ecosystem process), stressors to those attributes (i.e., aspects of the environment that might cause a deleterious impact), indicators of the condition of those attributes, and restoration goals. The Woodard Bay NRCA management plan (WDNR 2002) was the primary source of information for the development of the CSM, although refinements were made based on input from WDNR staff, agency partners, regional experts, and the public.

Targeted Ecological Resources and Processes

Ecological restoration targets were selected based on information compiled in the CSM (Table 1). These restoration targets reflected the management goals for the Woodard Bay NRCA and the ecological services valued by the public and other stakeholders. The site's historic and archaeological attributes, as well as educational and recreational resources (and potential impacts to them), were also taken into account.

Table 1. Ecological restoration targets

Nearshore Processes
- Sediment transport processes
- Circulation
- Water quality
- Sediment quality
- Riparian functions

Waterfowl Habitat
- Foraging/loafing
- Nesting (specifically pigeon guillemots)

Bald Eagle Habitat
- Feeding/perching

Bat Habitat
- Roosting/pupping
- Protected flyways

Seal Habitat
- Molting, pupping
- Foraging

Olympia Oyster Habitat
- Feeding/spawning

Forage Fish Habitat
- Spawning
- Foraging

Juvenile Salmonid Habitat
- Foraging
- Smolting

Heron Habitat
- Foraging

Purple Martin Habitat
- Nesting

Shorebird Habitat
- Foraging/loafing

Riparian Vegetation
- Structure/cover

Discrete Restoration Actions

Discrete restoration actions that would address management goals for the site primarily relied upon the removal of anthropogenic structures or other features (e.g., shoreline fill). Three levels of effort were defined for each possible action – no removal, some removal, and complete removal.

Ecosystem Benefits from Restoration Actions

Habitat Equivalency Analysis (HEA), which was developed by the National Oceanic and Atmospheric Administration (NOAA) (2000), was used to quantify the benefits or impacts to restoration targets from restoration actions. HEA is a semi-quantitative tool used to evaluate the net natural resource benefits of different site-specific restoration actions. HEA model inputs include the area of effect (in acres), estimated present-day value of the resource based on current ecological function, estimated value after a particular action has been taken (the "recovered" habitat value), timeframe for the target to reach full ecological function, and a discount factor[1] that allows the final credit to be expressed in net present-day value. HEA model inputs and key assumptions were developed based on information in the CSM; direction provided by WDNR; and discussions with WDNR's partners, the tribes, and resource experts.

HEA generated a composite score that integrated the benefits and impacts for each resource or ecosystem process targeted for restoration at the site (i.e., the restoration actions). These scores allowed the environmental benefit of each action to be ranked and compared with those of other actions – the higher the score, the greater the benefit. Higher scores were a function of the area and duration of the benefit, as well as the ecological value assigned to a given action (some actions were valued more highly than others based on restoration goals for the site)(i.e., functional lift).

Based on the cumulative results, the restoration actions were grouped into several alternatives that represented a range of ecological benefits; a No Action alternative was included for comparison. The identified alternatives were:

- Alternative 1. No Action
- Alternative 2. Minimal Action
- Alternative 3. Moderate Action
- Alternative 4a. Maximum Action without Bridge Replacement
- Alternative 4b. Maximum Action with Partial Bridge Replacement
- Alternative 4c. Maximum Action with Complete Bridge Replacement

These alternatives integrated benefits to multiple resources and restoration targets through various combinations of restoration actions (Table 2 and Figure 2). HEA scores represent an aggregate of the benefits and impacts across all restoration targets for each proposed action included in an alternative.

Table 2. Restoration actions and HEA results for aquatic restoration alternatives

Restoration Action	HEA Scores for Restoration Actions					
	Alternative 1	Alternative 2	Alternative 3	Alternative 4a	Alternative 4b	Alternative 4c
Chapman fill removal	na	na	110.1	110.1	110.1	110.1
Chapman fill removal – no action	na	na	na	na	na	na
Pier removal 1 – 76%	na	na	na	76.5	76.5	76.5
Pier removal 2 – 49%	na	na	56.5	na	na	na
Pier removal 3 – 38%	na	23.2	na	na	na	na
Pier removal – no action	-5.3	na	na	na	na	na
Piling removal (north area) – 100%	na	na	-0.1	-0.1	-0.1	-0.1
Piling removal (north area) – no action	-0.6	na	na	na	na	na
Piling removal (central area) – 90%	na	2.8	2.8	2.8	2.8	2.8
Piling removal (central area) – no action	-2.0	na	na	na	na	na
Piling removal (south area) – 100%	na	na	-0.1	-0.1	-0.1	-0.1
Piling removal (south area) – no action	-1.5	na	na	na	na	na
Riparian restoration – Weyer Point (all)	na	na	9.7	9.7	9.7	9.7
Riparian restoration – Weyer Point (partial)	na	5.2	na	na	na	na
Riparian restoration – no action	-3.9	na	na	na	na	na
Seal haulout – maintain	na	1.0	1.0	1.0	1.0	1.0
Seal haulout – no action	-6.9	na	na	na	na	na
Trestle and fill removal (south and north sides)	na	na	na	68.9	68.9	68.9
Trestle and fill removal (south side only)	na	na	44.0	na	na	na
Trestle (only) removal	na	28.5	na	na	na	na
Trestle and fill removal – no action	-13.3	na	na	na	na	na
Woodard bridge complete removal/reconstruction	na	na	na	na	na	2.4
Woodard bridge partial removal/reconstruction	na	na	na	na	-1.4	na
Woodard bridge – no action	-26.3	-26.3	-26.3	-26.3	na	na
Total	**-59.8**	**34.4**	**197.6**	**242.5**	**267.4**	**271.2**

Note: Positive numbers reflect positive impacts; negative numbers reflect negative impacts.
HEA – Habitat Equivalency Analysis
na – not applicable

[1] The discount factor assumes that a future benefit is worth less than a present benefit.

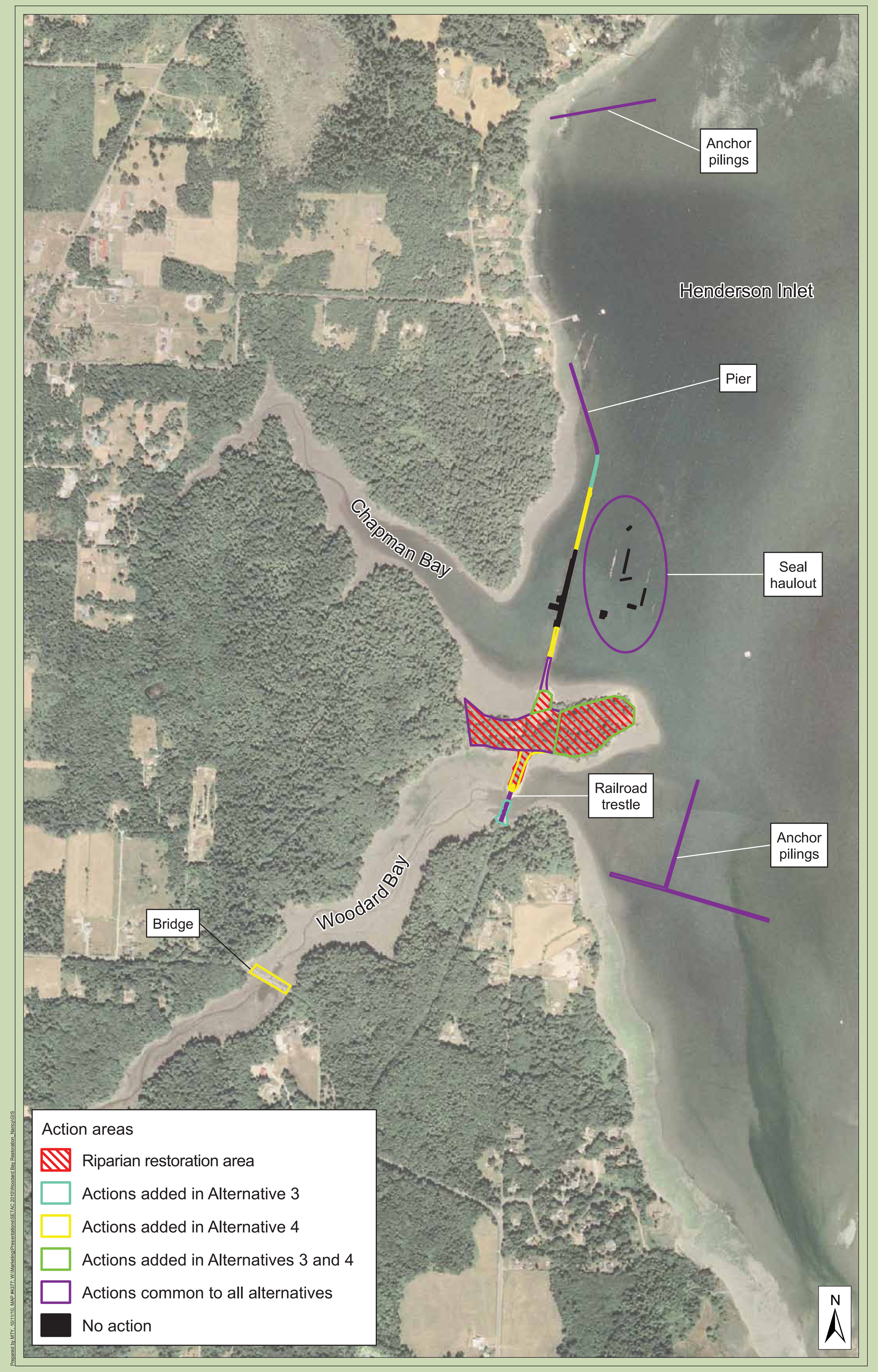

Figure 2. Locations of restoration actions included in Alternatives 3 and 4

Costs vs. Benefits

A cost estimate was developed for each alternative to allow for the performance of a cost-benefit analysis and a comparison of alternatives. The estimate represented a reasonable amount that a construction contractor might charge for the work under the anticipated conditions. Surcharges were applied to address the limited work window (and likelihood of overtime pay), seasonal constraints associated with working through the winter, and overall uncertainty. Costs for engineering and design, permitting, and WDNR's administration and oversight were not included.

A cost-benefit analysis was then conducted to identify the most cost-effective restoration alternative. A traditional cost-benefit analysis compares the financial costs and benefits of an action. However, a major shortcoming of this type of analysis is that it does not account for non-financial costs or benefits. This can be significant for environmental restoration projects because the benefits are not readily monetized. Thus, the benefits associated with the Woodard Bay aquatic restoration alternatives were evaluated using an ecological service approach. Under this approach, HEA results were used to calculate ecological service benefits, and a conventional cost estimate was used to quantify construction costs (Table 3). Alternative 2 had the lowest cost and ecological service, and Alternative 4c had the highest cost and ecological service.

The cost effectiveness of each alternative was then evaluated by comparing the ecological service (sums of the HEA scores) with the estimated cost to calculate an anticipated level of ecological benefit per million dollars spent (Figure 3). Alternative 2 produced the least ecological service per million dollars spent (7), and Alternative 3 produced the greatest ecological service per million dollars spent (28), making it the most cost-effective alternative for restoring ecological services.

Table 3. Relative ecological service and estimated cost for aquatic restoration alternatives

Alternative	Ecological Service (HEA score)	Estimated Cost ($ million)
2 – Minimal action	34	$4.6
3 – Moderate action	198	$7.1
4a – Maximum action without bridge replacement	242	$10.2
4b – Maximum action with partial bridge replacement	267	$10.6
4c – Maximum action with complete bridge replacement	271	$18.4

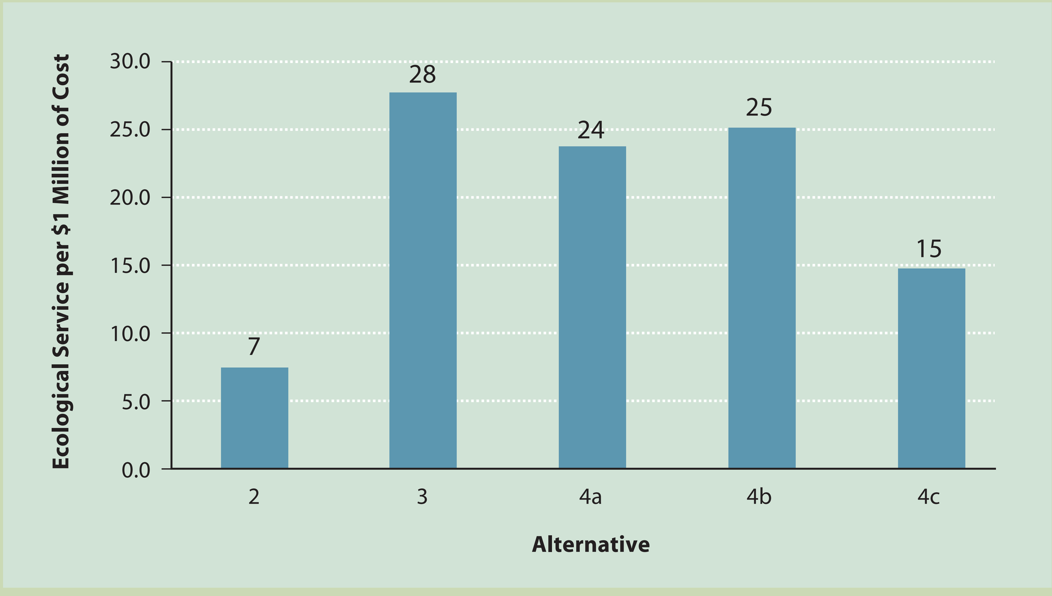

Figure 3. Ecological service per $1 million of cost for aquatic habitat restoration alternatives

Selected Alternative

Alternative 3 provided the highest level of ecological service in relation to cost and was therefore the most cost-effective alternative. It also accomplished many of the objectives expressed by the public, agencies, and stakeholders and preserved some elements of the historical landscape that triggered the site's listing on the National Register of Historic Places. Alternative 3 balanced the goals for the site, thus creating a reasonable probability that the alternative could be implemented through likely funding mechanisms.

Summary

The development and comparison of restoration alternatives for the Woodard Bay NRCA relied on HEA to quantify and aggregate the ecological service costs or benefits of various restoration actions on more than a dozen target resources or ecosystem attributes. The net changes in the habitat value or ecological services provided by each action were weighted according to the consensus restoration priority for each resource or attribute. Costs associated with each restoration alternative were used to standardize the relative change in habitat value and ecosystem service. HEA provided decision-makers with a valuable tool for optimizing the benefits to multiple natural resources. The FS identified a preferred alternative for the restoration of the Woodard Bay NRCA by identifying the most cost-effective restoration approach.

References

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