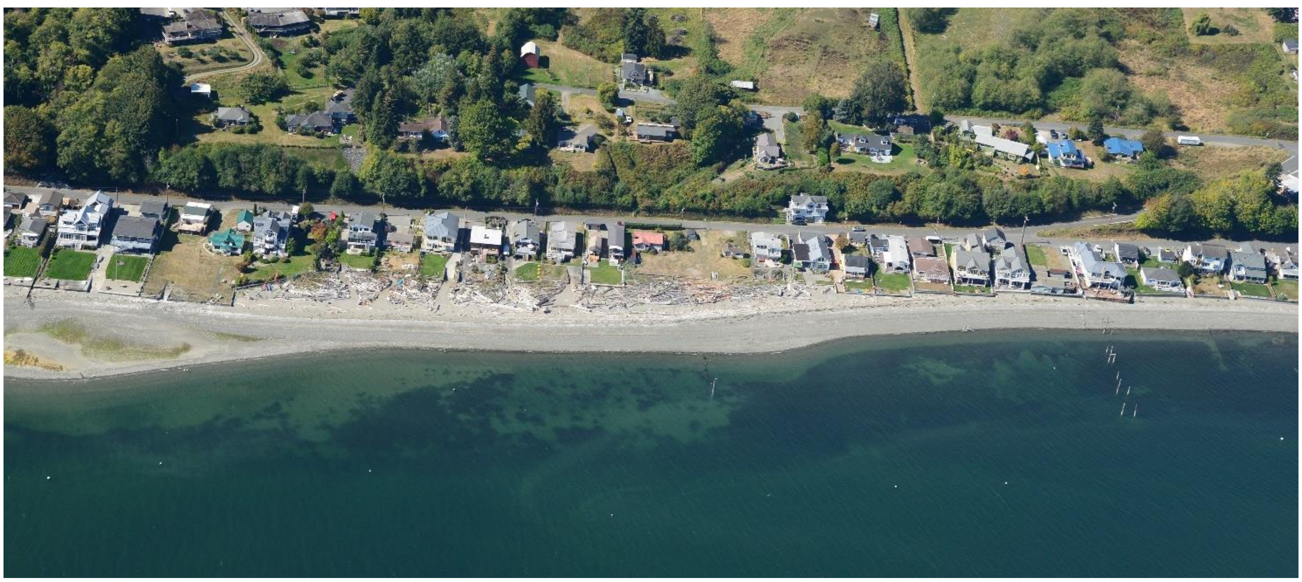
Benefit Cost Analysis of Shore Friendly Practices in Island County

Prepared for:

Island County Department of Natural Resources

February 14, 2019



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Prepared by:

Jessica Côté, PE, Blue Coast Engineering PS, Inc

Adam Domanski, ECONorthwest

Summary

There are 1,847 single family properties located along the shoreline in Island County. The majority of these shoreline properties (approximately 60%) have either a natural beach or an engineered soft shore protection which mimics a natural beach. The other 41% of these waterfront properties have some type of hard shoreline armoring. It has been widely recognized across the United States and in Puget Sound, that preserving or restoring shorelines to their natural state provide environmental and economic benefits to the public and shoreline property owners. These benefits include recreation and beach access, protection against erosion from storms and sea level rise, habitat and ecological function, aesthetic value of a view and cultural significance. Economists often categorize benefits by whether they can be exchanged in a market (i.e. private benefits) or whether they accrue to a broader population (i.e. public benefits). Different types of shoreline modifications can improve or impair both private and public benefits.

This study was conducted on behalf of the Island County Shore Friendly program to determine the economic benefits and costs of five shoreline protection strategies available to property owners. These strategies include installation of hard armor, armor removal to restore a natural beach, soft shore protection, moving a house inland or in elevation, and conserving the natural beach. These strategies were evaluated to determine the relative private benefits and costs, public benefits and costs, and ecosystem benefits and costs.

An assessment was conducted of the impacts to three private property values (risk reduction, aesthetic, and shoreline access) from changing the shoreline treatment from the baseline condition of a natural beach or hard armor to another treatment. The installation of soft shore protection generated a uniformly positive net result when either replacing a natural beach or hard armor. While hard armor was considered to be a decrease in both aesthetic value and shoreline access value, it increased risk reduction value. The net result on the three values of each of the treatments varies dependent on the characteristics of the property.

To further quantify the impact of shoreline treatment on private property values, a hedonic regression of property characteristics on assessed land value was conducted to test the relationship between price and shore treatment in Island County. The results showed hard armoring is correlated with lower land value for properties that are more easily accessed from the shoreline (low bluff), while land values with hard armor as compared to a natural shoreline are higher for mid-bluff and high-bluff parcels. The greatest monetary benefit is observed for mid-bluff parcels, while low-bluff parcel impacts are highly variable, indicating that hard armoring can have either a positive or negative effect on property value for these homes. A case study of one home inland relocation indicated that increasing the setback between a structure and an eroding bluff could increase the property value by approximately $50,000.

Shoreline armoring can directly or indirectly impact ecosystem functions, goods, and services by encroaching on or limiting habitats, disrupting natural processes and limiting recreational use. However, alternatives to hard armoring can allow natural systems to take place and convey increased ecosystem service values to the public. Hard armoring results in the greatest decrease in public value, while armor removal with or without the installation of soft shore protection results in the greatest increase in public value.

There is limited available data and high variability in the data that does exist on the costs of implementing shoreline treatments. The study was able to analyze the cost for 28 projects which included installation of new hard armor, removal of existing hard armor, and installation of soft shore protection. The projects evaluated were located within and outside of Island County. Replacing hard armor with new hard armor was the most expensive, while removing existing armor and allowing a natural beach to redevelop (without placement of soft shore) is the least expensive.

A framework for comparing the private and public benefits and costs of five shoreline strategies on benefits is presented in this report and utilized in a case study to show how property owners can apply the framework to make decisions about shoreline protection strategies. In general, installation of hard armor along low bluffs where a natural beach currently exists results in the largest reduction in overall private and public benefits, and is a relatively high cost to property owners as compared to other shoreline strategies. The removal of hard armor with soft shore installation along low bluffs results in the largest increase in private and public benefits, and can result in a moderate cost to property owners but may be eligible for financial assistance through Shore Friendly incentive programs. High bluff properties can increase both private and public benefits by removing shorelines structures and relocating the structure landward away from the top of the bluff, and case studies suggest the costs might be offset by an increase in property value.

Acknowledgements

Blue Coast Engineering, ECONorthwest and Island County DNR would like to thank the many people who contributed information to this study. We would like to thank the property owners of Island County who agreed to speak with our staff for their contributions, but they are not named to maintain their privacy.

Matt Kukuk, Saratoga Environmental Inc, Clinton, WA, for sharing extensive information about shoreline projects he has worked on in Island County.

Todd Graves, Sound Slope & Shoreline, Inc, Freeland, WA, for sharing extensive information about the construction of shoreline projects he has completed in Island County.

Lisa Kaufman, Northwest Straits Foundation for providing information on Shore Friendly projects conducted in Island County.

Karin Strelioff and Katrinka Hibler, Mason Conservation District for providing information on armor removal projects conducted in Mason County.

Christina Kereki, Kitsap County, Department of Community Development for providing information on armor removal projects conducted in Kitsap County.

Keith Settle, Northwest Structural Moving for providing costs for relocating a house, http://www.nwstructuralmoving.com/

This project has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement PC-00J290701 to Washington Department of Fish and Wildlife. The contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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1 Introduction

The Island County Shore Friendly program is working to educate and promote property owners about alternative strategies to hard armor for protection of shoreline residential properties. These alternative strategies are designed to provide for the use and protection of residential properties while also supporting and maintaining the ecological functions of coastal ecosystems. Several tools have been developed to advise shoreline homeowners about the implementation of Shore Friendly practices in Island County and in the region. This report provides an overview of the economic and ecological costs and benefits of various shoreline protection strategies which have been selected by shoreline property owners. The framework presented in this report will serve as a tool for property owners in Island County to evaluate the benefits and costs of shoreline protection strategies for their own property.

The options to protect properties from erosion and flooding which have been evaluated in this report include:

1) Hard Armoring: installation of hard armoring, consisting of rip rap, timber, poured concrete or vinyl sheeting including installation of new structures where none existed before, repairing existing structures with new materials and replacing aging structures with new structures
2) Armor Removal: removing of all or nearly all hard structures on the shoreline to allow a natural beach to form
3) Soft Shore Protection: employment of beach nourishment, anchoring of natural logs, or installation of native vegetation to re-develop a beach that mimics what would be present under natural conditions.
4) Relocating House: moving a house from the existing position inland away from the shoreline or vertically to prevent flooding of livable interior space.
5) Natural Beach: leaving a natural beach in the existing condition with the augmentation of only logs or the re-grading of existing material, but not augmenting the sediment with beach nourishment.

Each of these shore protection strategies provides a different type of protection from erosion and/ or flooding. Hard armor is primarily used to control erosion and is not an effective strategy against flooding. Armor removal and soft shore are intended to allow for some erosion such that a shoreline can be more dynamic and adjust with changing conditions (accreting and eroding). A natural beach or soft shore provide the added benefit of dissipating wind-wave energy and therefore decrease coastal flooding. Relocation of a house can mitigate for both erosion and flooding.

In some cases, more than one of these strategies may be applied to reduce the risk of erosion or flooding on a property. For example, existing hard armoring can be removed and replaced with soft shore protection to reduce the time associated with formation of a natural beach. The relocation of a house to a position inland from the shoreline can allow for reduction of risk to the structure which might also allow for armor removal and a natural beach to form. However, for this analysis we have looked at each of the five strategies above as independent actions.

The five shoreline protection strategies were evaluated to determine the relative private benefits and costs, public benefits and costs, and ecosystem benefits and costs. Shorelines provide environmental and economic benefits to both the public and shoreline property owners. These benefits include recreation and beach access, the aesthetic value of a view and associated cultural significance of its existence, the habitat and ecological functions that a beach provides to support flora and fauna that are enjoyed by visitors and residents, and to protect against erosion from storms and sea level rise. Property owners and the general public enjoy these benefits, and different types of shoreline modifications can improve or impair them. Economists often categorize benefits by whether they can be exchanged in a market (i.e. private benefits) or whether they accrue to a broader population (i.e. public benefits). The environmental costs associated with residential shoreline protection strategies are evaluated as a reduction in both private and public benefits. However, the financial costs associated with residential shoreline protection strategies are only evaluated as an economic impact to the individual property owner.

When possible, we have further discretized the costs and benefits on private property values into three shoreline types based on the height of the top of the bank or bluff at the shoreline. For simplicity and the purposes of this report, these categories are defined as:

- Low Bluff: height of the bank or armoring at the shoreline is 0 to 5 feet
- Medium Bluff: height of the bank or armoring at the shoreline is 5 to 20 feet
- High Bluff: height of the bank or armoring at the shoreline is greater than 20 feet

2 Private Benefits

Many economic benefits can sometimes be exchanged in fully functioning markets, where the social costs and benefits are fully recognized within the market economy. Homes in Island County with attributes that are desirable but relatively scarce will be more expensive. A shoreline residence that has a view or direct access to the water will be relatively more expensive than inland properties. However, shoreline residences also have associated risks that can negatively impact property values. These homes are more exposed to winds and waves from storms and shoreline erosion, which may lead the property to become destabilized in the future.

Economists measure the value of these benefits and risks using hedonic property value models[1]. This regression approach measures the marginal effect of attributes on property value by evaluating the prices and attributes of hundreds or thousands of homes. These attributes can be classified into three categories: structural, neighborhood, and environmental characteristics.

- **Structural characteristics** include the age, square footage, number of rooms, building materials, heating system, or other attributes that vary between homes.
- **Neighborhood characteristics** include other local attributes such as crime rates, school quality, ease of access to social infrastructure (e.g. hospitals and parks).
- **Environmental characteristics** include air quality, water quality, highway noise, the presence of contaminants, and location along natural areas (e.g. shorelines).

[1] The hedonic theory in economics states that the price of a good is related to its underlying characteristics. A useful introduction to the approach is available in Taylor L.O. (2003) The Hedonic Method. In: Champ P.A., Boyle K.J., Brown T.C. (eds) A Primer on Nonmarket Valuation. The Economics of Non-Market Goods and Resources, vol 3. Springer, Dordrecht.

Property owners can directly control structural characteristics, while neighborhood and environmental characteristics are the result of primarily external forces and trends. When faced with an encroaching shoreline, property owners in Island County generally have the option of protecting their property with 1) hard armoring, 2) soft shore protection, or 3) relocating their house farther from the water (i.e. horizontal or vertical retreat). Properties that already have functional hard armoring have the additional option of removing that armoring. Each of these actions has implications for the risk to the property from encroachment, the aesthetic value, and the ability to physically access the shoreline.

Property owners who chose to maintain a natural beach have the option of increasing shoreline vegetation or reducing upland runoff which might be contributing to the shoreline erosion. For the purpose of this study any changes in vegetation are captured as soft shore protection. Furthermore, management of storm water is not captured in this analysis of shoreline strategies.

2.1 Private Property Value Impacts

The general change in direction (increase, decrease, or no change) of each action on three components of property value as a result in a change in the shoreline stabilization strategy is summarized in Table 1. There is insufficient data in the Island County assessor database to quantify the impacts of each of these changes, but with additional data this analysis could be refined in the future. All five shoreline strategies are encompassed in the table. Note while natural beach is only listed as an existing condition, the action of armor removal from an existing condition of hard armor results in a natural beach.

Generally, any type of armoring increases property value through erosion risk reduction, but soft shore protection strategies are also considered a risk reduction for erosion and flooding. Aesthetic values are subjective, and although some individuals may consider well-manicured hard armoring to be more elegant than a natural beach, economic studies have found that in general, natural beaches or soft shore which appear as natural beaches convey greater increases in property value[2]. Hard armoring generally limits direct shoreline access except in cases where the superstructure supports stairs or a walkway to the shore, therefore results in a decrease in shoreline access.

Table 1: Average Private Property Value Impacts from Shore Stabilization Alternatives

Existing Condition	Action	Risk Reduction Value	Aesthetic Value	Shoreline Access Value
Natural Beach	Hard Armoring	⇑	⇓	⇓
	Soft Shore Protection	⇑	No Change	No Change
	Relocating House	⇑	⇓⇑*	No Change
Hard Armoring	Armor Removal	⇓	⇑	⇑
	Soft Shore Protection	No Change	⇑	⇑
	Relocating House	No Change	⇓⇑*	No Change

Source: ECONorthwest and Blue Coast Engineering
Note: *Results in an increase or a decrease in aesthetic value based on property specific attributes.

[2] Gopalakrishnan, S., M.D. Smith, J.M. Slott, A.B. Murray. 2011. The Value of Disappearing Beaches: A Hedonic Pricing Model with Endogenous Beach Width. J. Environ. Econ. Manage. 61(3), 297-310; Gopalakrishnan, S., C.E. Landry, M.D. Smith, and J.C. Whitehead. 2016b. Economics of Coastal Erosion and Adaptation to Sea Level Rise. Annu. Rev. Resour. Econ. 8, 119-139; and Dundas, S., 2017. "Benefits and ancillary costs of natural infrastructure: Evidence from the New Jersey coast," Journal of Environmental Economics and Management, Elsevier, vol. 85(C), pages 62-80.

Relocating a house has generally been implemented for high bluff properties which have the potential for slope failures and other shoreline protection strategies are typically not effective in reducing risk. The aesthetic value of relocating a house can either increase or decrease depending on the property. One homeowner observed an increase in aesthetic value as the move allowed for a deck and a larger yard adjacent to the shoreline. However, if the relocating of the house has an impact on the view, then it might be considered a decrease in aesthetic value.

The increase or decrease of each of these values will vary dependent on the shoreline characteristics of the property such as erodibility of the sediments, wind-wave exposure, groundwater flow and discharge, and height of the shoreline. In some cases, hard armoring may provide greater protection than soft shore protection. For some properties on high bluffs, there is no shoreline access value regardless of the type of shoreline protection. However, of all six shoreline alternatives described in Table 1, soft shore protection is the only option that generates a uniformly positive impact.

A number of economic studies have empirically measured the values of shoreline management interventions. Although there are no peer-reviewed studies evaluating impacts to properties in Island County, there are a number of studies from other regions in the U.S. that can inform the potential effects in Island County. A study in Tybee Island, Georgia, measured the property value effects of beach nourishment, shoreline armoring, and natural shoreline retreat[3]. The study found that every one-meter increase in beach width resulted in a $323 increase in property value, while homes that were located in a high-erosion zone sold for almost $13,000 less on average. A separate study of homes along coastal areas throughout the southeastern U.S. found that both hard armoring and beach nourishment increased the value of shorefront properties in erosion zones, however beach nourishment had the added benefit of increased values of adjacent inland properties as a result of improved beach access[4]. This two-dimensional effect isolates the risk reduction and shoreline access value gains from different types of shoreline stabilization practices. Similarly, a study in New Jersey concluded that waterfront residences with a seawall had an average marginal increase in property value of 10 percent[5]. Although coastal erosion patterns along the eastern U.S. are not equivalent to the challenges faced in Island County, the results generally describe the implications of changes in shoreline erosion risk on property values.

A similar limited evaluation can be conducted of properties in Island County using publicly available data. For this analysis the data set only provided for a comparison of properties with shoreline armoring or without shoreline armoring. The properties without shoreline armoring might have had a natural beach, soft shore stabilization installed or armor removed. The summary statistics of the analysis are shown in Table 2.

Of the 14,429 residential single-family properties in the county, 1,847 (12.8 percent) are located along the shoreline. Of these coastal properties, the average assessed land value is $408,578, and the average assessed improvement value (i.e. house and other structures) is $275,927. Approximately 25 percent of these properties are located in lowlands (low bluff) within 5 feet of sea level, another 25 percent are

[3] Landry, Keeler, Kriesel, W. (2003). An Economic Evaluation of Beach Erosion Management Alternatives. Marine Resource Economics, Vol 18, pp. 105 – 127.
[4] Kriesel, W. and Friedman, R. (2002). Coastal Hazards and Economic Externality: Implications for Beach Management Policies in the American Southeast. Heinz Center Discussion Paper.
[5] Jin, D. (2015). Shoreline Change, Seawalls, and Coastal Property Values. Ocean & Coastal Management, Vol 114, pp. 185 – 193.

located on lands between 5 and 20 feet, while the remaining 50 percent are located on bluffs over 20 feet high. Forty-one percent of waterfront properties have some type of hard shoreline armoring.

We conducted a hedonic regression of property characteristics on assessed land value to test the relationship between price and shore treatment (hard armor or no armor). In our regression, neighborhood and environmental characteristics are controlled for using a set of town fixed effects, and structural characteristics are excluded by only evaluating the land value. The results shown in Figure 1 indicate that on average, hard armoring is correlated with lower land value for properties near the water level (low bluff), while it is higher for mid-bluff and high-bluff parcels[6]. The greatest monetary benefit of hard armor is observed for mid-bluff parcels, while low-bluff parcel impacts are highly variable, indicating that hard armoring can have either a positive or negative effect on property value for these homes.

The differences in prices for properties in Island County reflect the effects of the different components of value. The increase in value for mid-bluff and high-bluff properties reflects the reduced risk of erosion and property loss from armoring. The lower high-bluff price impact possibly indicates the limited effect that hard armoring has on preventing erosion for homes high above the water. The negative value (yet highly variable) for low-bluff homes indicates that any positive erosion risk reduction may be overwhelmed by negative aesthetic or shoreline access values. In addition, low bluff homes are the most susceptible to coastal flooding and hard armor does not reduce the potential for coastal flooding which might be a contributing to the negative value. These low bluff homes are likely to gain the greatest private benefit from participation in the Shore Friendly program and incentives to conduct armor removal projects.

Table 2. Island County Shorefront Property Summary Statistics

Location	Number of Shorefront Properties	Average Parcel Acres	Average Shore Length	Average Land Value	Average Improvement Value	Average Parcel Elevation	Percent with Armoring
Camano Island	532	2.03	3,352	$363,775	$276,086	25	56%
Clinton	227	1.78	2,989	$455,248	$280,929	20	52%
Coupeville	230	2.02	3,511	$351,325	$258,078	26	18%
Freeland	193	1.66	2,628	$700,395	$362,256	17	45%
Greenbank	124	2.88	2,761	$405,242	$282,393	28	37%
Langley	125	1.82	2,514	$421,981	$276,203	22	42%
Oak Harbor	261	1.79	3,168	$318,484	$272,806	19	24%
Other	155	2.02	3,059	$359,172	$186,908	21	36%
Island County Total	**1,847**	**1.97**	**3,094**	**$408,578**	**$275,927**	**22**	**41%**

Source: Island County Assessor's Department

[6] Other characteristics tested included acreage and an indicator for the town. The acreage of the parcel had a positive and statistically significant effect on assessed land value. Being located in any town also had a positive effect (as compared to being located outside of a town), and Freeland, Clinton, and Greenbank had the largest impacts on price.

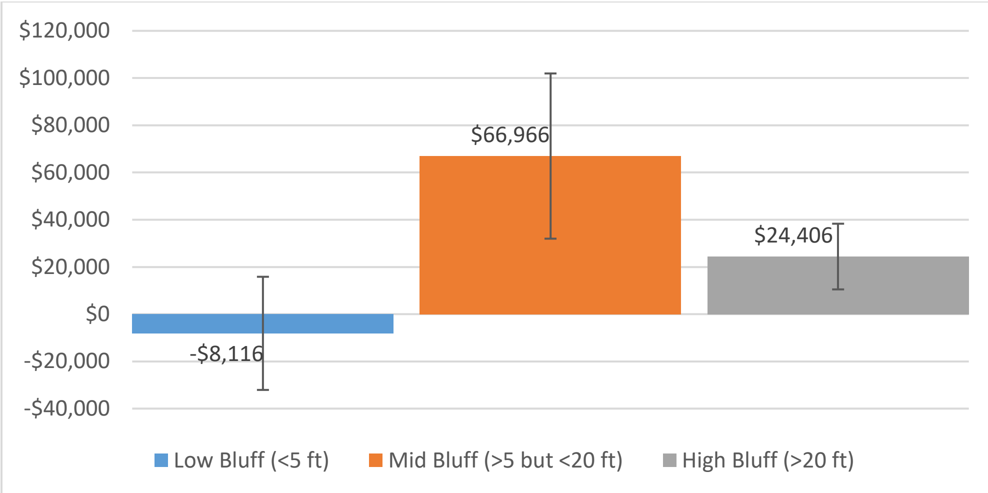


Figure 1. Property Value Impacts of Hard Armoring in Island County

A similar analysis could be conducted for other shoreline protection strategies if there was a county wide or Puget Sound wide data set which identified the shoreline strategies for each parcel. As an example, a case study was conducted of several high bluff properties and the value of the land based on setback distance from the top of the bluff (Table 3). All four properties are located within the same town and along the same stretch of shoreline, but no addresses or time periods are provided to protect the privacy of the property owners. Property 1 was moved inland approximately 30 ft to reduce the potential risk of the structure being damaged during a bluff failure (landslide). The year after the structure was moved, the value of the land increased by $50,000. During this same time period (year 1 to year 2), there was no change in land value for houses adjacent to this property which had setback distances of approximately 50 feet or more (Property 2 and three adjacent properties not listed here). However, two properties which had setback distance of 25 ft or less showed a decrease in land value of approximately $50,000 during that same time interval (Property 3 and 4). While a more rigorous data analysis and regression model is required to make this comparison statistically significant, this case study provides an observation of the potential for an increase in home value as a result of the shoreline protection strategy of moving a house inland.

Table 3. Island County High Bluff Property Case Study

	Property 1	Property 2	Property 3	Property 4
Linear Length of Shoreline	90 Feet	63 Feet	71 Feet	199 ft
Setback year 1	22 ft	70 ft	20 ft	25 ft
Setback year 2	56 ft (moved back)	70 ft	20 ft	25 ft
Risk Reduction Protection	Improved erosion risk	No change	No change	No change
Property Value Year 2 (Change in property value)	$200,000 (+$50,000)	$200,000 ($0)	$150,000 (-$50,000)	$200,000 (-$50,000)

Source: Island County Assessor's database and private property owner communication

2.2 Participation in the Shore Friendly Program

Since 2016, 52 residents of Island County have received site visits and technical assistance to evaluate their shoreline condition as part of the Shore Friendly Program. Twenty of the properties had some type of hard armoring in place, 11 of which were failing and needed to be replaced. Ultimately ten parcels (a mix of properties with existing armoring and without armor) have begun to implement a more shore friendly shoreline strategy. These strategies include armor removal, installation or soft shore protection and moving a house landward.

A different type of analysis, known as a logit model, can determine the characteristics of properties that are most likely to participate in the Shore Friendly Program. The characteristics listed in Table 4 have a statistically significant effect on the probability of participating in the program. Specifically, properties that are larger, higher above the water, and have longer shorelines are less likely to participate in the Shore Friendly Program. In addition, properties which are the primary residence of the homeowner (as opposed to a secondary residence) are less likely to participate in the program.

There were participants in the Shore Friendly Program who owned properties in the towns of Langley, Greenbank, Coupeville, Oak Harbor, Freeland, Clinton, and Camano Island. However, there were only a sufficient number of people from Camano Island, Coupeville, and Oak Harbor to test the likelihood of participation based on location. Of these three towns, Camano Island property owners were the most likely to participate in the Shore Friendly Program.

Table 4: Property Characteristics that Influence Participation in the Shore Friendly Program

Characteristic	Outcome
Acreage	Large properties are less likely to participate
Elevation	Properties that are higher above the water are less likely to participate
Shoreline Length	Properties with a longer shoreline are less likely to participate
Primary Residence	Homes claimed as the primary residence are less likely to participate
Location	
Camano Island	More likely to participate
Coupeville	Less likely to participate
Oak Harbor	Less likely to participate

Source: ECONorthwest analysis of Island County Assessor data and Shore Friendly Program records

3 Public Benefits

The natural world provides numerous services to the public. These ecosystem services are "the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly."[7] For example, shoreline vegetation slows the run-off of water across the ground surface during a storm event, reducing the risk of flooding, erosion, and property damage, while also improving water quality. Similarly, a natural beach width and slope will absorb wave energy running up the slope of the beach and provide a buffer of sediment and vegetation which can adjust seasonally to accommodate water levels.

Ecosystem services often are grouped into four categories:[8]

- *Regulating Services* that shape water flows, remove impurities from air and water, control diseases and pests, generate oxygen, and influence climate.
- *Provisioning Services* that enable the ecosystem to provide food, fresh water, wood, and genetic resources.
- *Cultural Services* that produce nonmaterial benefits, such as a sense of place, spiritual well-being, and aesthetic beauty.
- *Supporting Services* that provide the foundation for the other services, such as controlling the formation of soil and the flow of nutrients.

Changes in the ecosystem's ability to provide ecosystem services have immediate consequences, affecting businesses, governments, property owners, and households. Those immediate consequences can develop into longer-term and more fundamental change to ecosystem service provision which is more difficult to predict and therefore difficult to attribute value. The following sections focus on the shorter-term and more measurable ecosystem services of shoreline armoring that are relevant to the Puget Sound region.

3.1 Ecological Effects of Shoreline Protection

Hard armoring can change the characteristics of the natural infrastructure of a shoreline, disrupting ecosystem functions and processes, and ultimately reducing the quantity and quality of goods and services that people derive from them. Armoring marine shorelines can alter a variety of processes at multiple spatial and temporal scales.

Studies have found Puget Sound shoreline armoring related to reductions in beach width, riparian vegetation, numbers of accumulated logs, and the amount and types of beach wrack[9] and associated

[7] De Groot, R., Wilson, M. and Boumans, R. (1992). A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics, Vol. 41 (3), pp. 393-408.
8 Millennium Ecosystem Assessment (2006). Millennium Ecosystem Assessment Synthesis Report. Retrieved from http://www.millenniumassessment.org/en/Products.Synthesis.aspx.
For further information about ecosystem services, see Leschine, T. and Petersen, A. (2007). Valuing Puget Sound's Valued Ecosystem Components. Puget Sound Nearshore Partnership, Technical Report 1007-07.
[9] Beach wrack is a term for seaweed, surf grass and other organic materials produced in coastal ecosystems that wash ashore on the beach. They serve as food and shelter for a variety of beach inhabitants including sand-dwelling invertebrates like beach hoppers and kelp flies.

invertebrates.[10] These effects have broader and more long-term implications for the ecosystem functions provided by shoreline and nearshore marine habitats. For example, changes in plant material accumulation can lead to more substantial structural changes in habitat and beach profile. Initially, hard shoreline armoring can reduce plants/wrack on the shore and in the nearshore environment, subsequently threatening the habitat, refuge and food sources for larger species like terrestrial birds and spawning fish. Shoreline armoring also changes the physical characteristics of the shoreline, both directly and in un-altered areas adjacent to treatments. Loss of woody debris and introduction of other structures has the potential to change wave impacts and sedimentation patterns, affecting beach width and natural erosion stabilization mechanisms.

For Island County residents, these changes could affect these coastal ecosystem goods and services, and the economic benefits people derive from them:

- Impairment in services, such as water filtration (drinking water and stormwater runoff), and storm surge protection.
- Limited habitat availability and food-chain support for plants and animals that ultimately support recreation opportunities (fishing/food gathering, wildlife watching) and the subsistence/commercial fisheries in Puget Sound.
- Decline in quality of or access to shoreline areas that support recreation, including hiking/walking, boating, swimming, and picnicking.

The categories above outline the final goods and services people demand, which can be broken up into seven ecological functions that researchers have identified that shoreline armoring in the Puget Sound region may affect (Table 5).[11] The impacts of shoreline armoring directly or indirectly impact the provision of each ecosystem service by encroaching on or limiting habitats, disrupting connectivity between habitats and natural processes, preventing sediment from eroding and replenishing beaches, and increasing impacts from wave reflection[12].

Alternative shore management strategies (armor removal, soft shore protection, and relocating a house further from the shore) allow natural ecosystem processes to take place, conveying increased ecosystem service values to the public. In contrast to the private benefits, these benefits accrue to all residents in Island County.

[10] Dethier, M. et al. (2016). Multiscale impacts of armoring on Salish Sea shorelines: Evidence for cumulative and threshold effects. *Estuarine, Coastal and Shelf Science,* 175: 106-117.
[11] Detheir, M., Toft, J. and Shipman, H. (2017). Shoreline Armoring in an Inland Sea: Science-Based Recommendations for Policy Implementation. *Conservation Letters,* Vol. 10 (5), pp. 626-633
[12] Waves hitting armoring and reflecting back onto the beach instead of wave energy being gradually dissipated while running up a natural beach slope and substrate

Table 5: Shoreline Armoring Effects on Ecosystem Functions, Goods, and Services

Functions, goods, and services	Mechanism			
	Habitat Encroachment	Loss of Connectivity	Sediment Impoundment	Wave Reflection
Recreation non-consumptive: park use and outdoor education	Indirect –	Indirect -	Indirect -	Indirect -
Recreation, consumptive: shellfish, seaweed, and fish	Direct -	Indirect -	Indirect -	
Forage fish spawning: surf smelt and sand lance	Direct -	Direct -	Direct -	Direct -
Trophic support: supply of insects, crustacea, and worms	Direct -	Direct -	Indirect -	
Nutrient cycling: from marine and terrestrial wrack	Direct -	Direct -	Indirect -	
Habitat provision: logs and wrack microhabitats	Direct -	Direct -	Indirect -	Direct -
Groundwater filtering	Direct -	Direct -	Indirect -	Indirect -
Resilience to sea-level rise	Direct -	Indirect -	Direct -	Direct -

Source: Adapted from Detheir, M., Toft, J. and Shipman, H. (2017). Shoreline Armoring in an Inland Sea: Science-Based Recommendations for Policy Implementation. Conservation Letters, Vol. 10 (5), pp. 626-633.

3.2 Ecosystem Valuation Framework

Unlike the private benefits described above, many of the ecosystem service benefits of soft shore protection are not exchanged in a market. Residents of Island County generally do not have the opportunity to purchase their ideal air or water quality at a given price. The level of ecosystem services provided are determined by both private and government actions. The Island County Shore Friendly program is one way that the county and local property owners are working together to ensure the best combination of private and public benefits.

While there is no residential market for shore-friendly protection in Puget Sound, there is a market for habitat restoration. Elsewhere in the region, there are a number of hazardous waste sites that have led to long-term impairment of coastal and marine habitats. Byproducts of industrial activities have contaminated sediments and reduced the ecosystem function of nearshore habitats. Through the Natural Resource Damage Assessment (NRDA) process, public agencies responsible for protecting environmental resources determine environmental harm and identify restoration projects that fully compensate the public.

Through an approach called "Habitat Equivalency Analysis," (HEA) the ecosystem services of different habitats can be compared, ultimately determining the amount of habitat restoration necessary. The services produced by an acre of habitat is summed over time using an economic discount rate and calculated in "discounted service acre years," or DSAYs. These services can be converted between habitat types based on their relative value to different ecological receptors. Current federal guidance on restoration banking[13] uses a set of criteria to define habitat types and relative habitat values, listed in Table 6.

[13] NOAA. (2016). "Guidance for Recognition and Use of Restoration Banks in Natural Resource Damage Assessments." Technical Report.

Table 6: Relative Habitat Service Values

Habitat Type	Elevation (ft) Relative to MLLW	Relative Value for Salmon	Relative Value for Birds	Relative Value for English Sole	Relative Combined Value for all Species
Marsh	+6 to +12	1.00	1.00	1.00	1.00
Intertidal	-4 to +12	0.67	0.67	1.00	0.75
Shallow Subtidal	-14 to -4	0.40	0.40	1.00	0.55
Rip-rap	-4 to +12	0.10	0.10	0.15	0.11

Source: NOAA. (2016). "Guidance for Recognition and Use of Restoration Banks in Natural Resource Damage Assessments." *Technical Report.*
Notes: MLLW: Mean Lower Low Water.

DSAYs are ultimately monetized by estimating the cost required to implement restoration projects that deliver ecological benefits. A one-acre wetland restoration project that takes five years to reach full function and operates for 25 years generates 18.4 DSAYs. Conversely, 1/18.4 acres (approximately 2,366 square feet) of the same wetland restoration project generates one DSAY.

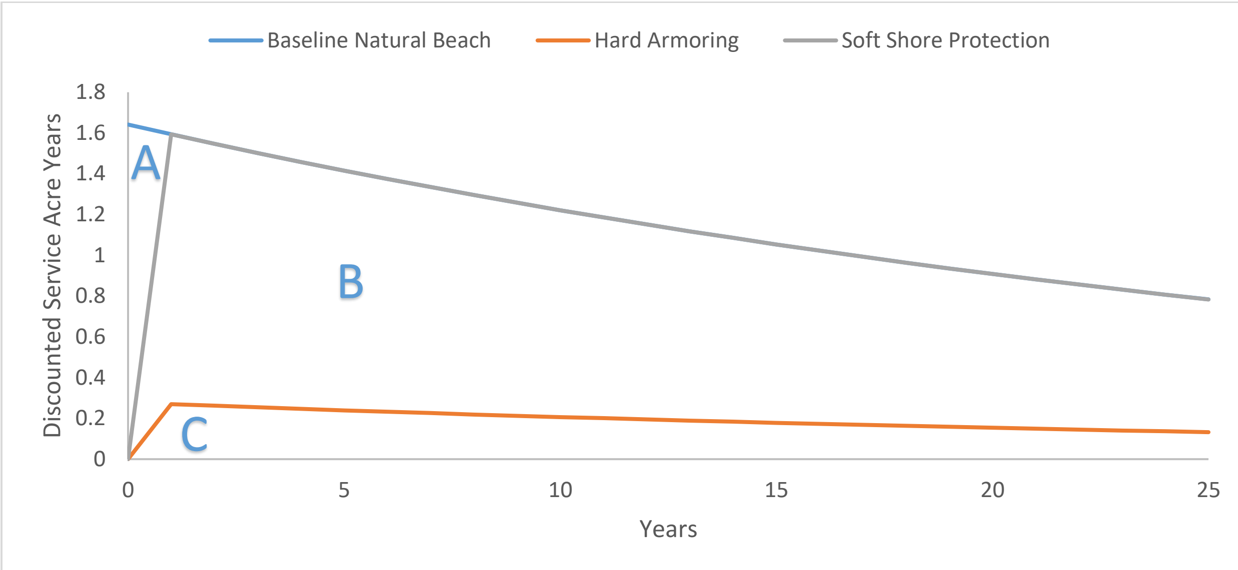
3.3 Public Value of Shore Friendly Practices

The public value of alternative shore friendly practices can be calculated using the ecological effects and HEA framework described above. Any disturbance along the shore will temporarily decrease the habitat function before recovering to a new steady state. Installation or removal of hard armoring or soft shore protection causes a decline in ecological services relative to relocating a house. The net benefits from any action are relative to their baseline condition, and only changes in value matter. Figure 2 illustrates how a HEA calculates the change in ecological services from conversion of a natural beach, with all values presented in discounted present value. The blue line represents the present value baseline ecological services[14]. During construction of any type of shore protection, the ecological services drop to zero and then recover to their new stable ecological function. Soft shore protection, represented by the grey line, generates equivalent ecological services to a natural beach, while hard armoring, represented by the orange line, generates only a fraction. The ecological services are summed over time, and the baseline DSAYs are equal to the areas of the figure denoted by the letters A, B, and C. Soft shore DSAYs are limited to areas B and C, while hard armoring DSAYs are only equal to area C. Any change in the type of shoreline results in a loss of ecological services, with the hard armoring causing the greatest reduction.

Figure 3 illustrates the change in ecological services from conversion of existing hard armoring. The baseline level of services is represented by the blue line, while the gain in services from removing hard armoring is represented by the orange line. The gain in DSAYs from installation of soft shore protection is equal to area D.

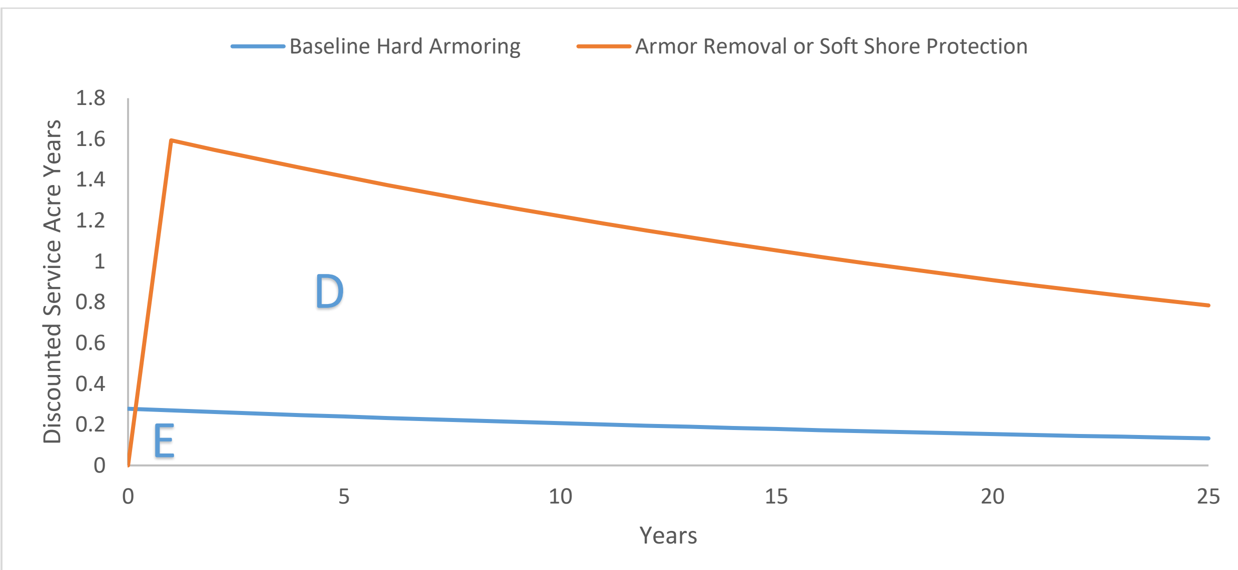
Using a defined geography, the changes in DSAYs illustrated in Figures 2 and 3 can be calculated. Table 7 details the change in public value relative to each action scenario for 2,200[15] linear feet of shoreline.

[14] Although the nominal ecological function remains unchanged over time, the application of an economic discount rate causes the line to slope downward, reflecting the higher value for benefits that are more immediate.
[15] Roughly the average length of armored shoreline in Island County (2,212 ft).



Source: ECONorthwest. Note: All values are discounted to present value using a 3% discount rate.

Figure 2. Conversion of a Natural Beach



Source: ECONorthwest. Note: All values are discounted to present value using a 3% discount rate.

Figure 3. Conversion of Existing Hard Armoring

These public values are not capitalized in property values, but rather represent relative ecological service gains from each change in shoreline type. This approach is regularly used to calculate natural resource injuries for environmental damaging events such as oil spills and contaminated sites. In the Puget Sound area, businesses that have outstanding environmental liability can purchase restoration credits at a price of $140,000 per DSAY.[16] Although there is no existing framework for monetizing the public benefits of shoreline stabilization treatments, this approach gives an indication of the relative value of these habitats in the region.

Table 7: Public Value of Shoreline Stabilization Actions

Existing Condition	Baseline DSAYs	Action	DSAYs After Action	Net Change in DSAYS
Natural Beach		Hard Armoring	4.8	-25.4
	30.2	Soft Shore Protection	28.6	-1.6
		Relocating House	30.2	0
Hard Armoring		Armor Removal	28.6	23.5
	5.1	Soft Shore Protection	28.6	23.5
		Relocating House	5.1	0

Note: Assuming a 25-foot-wide intertidal and subtidal area. Calculated using a 3% discount rate and 25-year project life.

[16] Elliot Bay Trustee Council (2016). "2016 Cost/DSAY Update for Lower Duwamish River NRDA Settlements." Resolution 2016-01.

4 Shoreline Treatment Cost Analysis

This study compiled information from twenty-eight residential properties in the region where shoreline stabilization projects have been performed in the past five years. Twenty of these projects were on properties located in Island County. Fifteen of the projects installed some type of hard armoring, five installed soft shore protection, and 11 removed hard armoring and restored a natural beach. Projects involving the moving of a house inland or vertically were not included in this list of 28 projects since they do not vary with shoreline linear feet. The costs for moving a house are provided based on information from a structural moving company and two projects which were conducted in Island County.

4.1 Shoreline Protection Strategy Costs

All projects contain fixed costs including permitting, design, engineering, biological studies and cultural investigations that will vary with specific property circumstances, but do not vary with the size of the property or project. Other costs such as materials, equipment, and labor are typically variable with the size and type of the project and can be scaled by the linear feet of shoreline of a project.

The costs for each project were provided by a variety of sources including private consultants, conservation districts, and local agencies. Projects which were conducted with grant funding from the state or federal sources were discretized into costs which a property owner would normally incur if paying for the project directly and costs which were considered part of the grant process. In this way, the management of grant funding and additional requirements for reports, stages of design, and deliverables which would not be required if privately funded were removed from the project costs.

We performed a statistical analysis of all 28 projects to demonstrate the factors that affect cost. The results show that any project, regardless of size or type, will incur an average of $15,000 of fixed costs. Removal of existing armoring will cost an additional $27,000 on average. The type of installation adds additional cost, and finally, there is a cost per linear foot. The results of this analysis are described in Table 8.

To use this model to generate a rough estimate of shoreline treatment cost (based on historical prices), start with the fixed costs, then add each of the subsequent rows that are relevant to the proposed project including the price per linear foot. For example, a 50-foot soft shoreline project that requires removal of existing armoring will cost:

$$\$15,700 + \$26,500 + \$22,800 + (50 \text{ ft} \times \$148/\text{ft}) = \$72,400$$

It is important to note that these are average values based on a very small sample set. Site-specific idiosyncrasies will lead to higher or lower prices. This table can be used to calculate the removal and replacement of shoreline treatments as well as the removal and replacement of a portion of shoreline treatment. The cost of a bulkhead repair which involves the removal and replacement of a portion of the shoreline treatment can be estimated using the length of linear feet of the repaired section and reducing the cost to Remove Existing Armoring by up to 50% for repairs where 50% or less of the shoreline is affected by the repair.

In general, project costs ranged from $30,000 to $100,000 per property and the most efficient projects were conducted on multiple parcels at one time such that the fixed costs for engineering, permitting, biological and cultural studies were divided amongst the property owners. The most expensive projects included the installation of hard armor, and the materials used for the hard armor had an impact of costs. While the installation of a concrete bulkhead is the least expensive hard armor, it has a shorter lifespan than RipRap or Vinyl. Projects the property owner removed existing armor and left a natural beach were the least expensive. It is also important to note that leaving a natural beach or adding soft shore stabilization measures to an eroding beach that does not have existing armor will have significantly lower costs because it eliminates the cost of removing the existing armor ($26,500).

Table 8: Average Shoreline Treatment Costs

Cost Components		Price
Fixed Cost		$15,700
Remove Existing Armoring	+	$26,500
Type of Shoreline After Project		
- Natural Beach with logs	+	$5,000
- Concrete Bulkhead	+	$8,900
- Soft Shoreline	+	$22,800
- Vinyl or RipRap Bulkhead	+	$44,200
Cost per Foot	+	$148 per foot

Source: ECONorthwest analysis of data provided by Blue Coast Engineering

4.2 House Moving Costs

Determining the costs for moving a house inland or vertically are dependent on several structural factors such as weight, size, and foundation type. Two projects were identified in Island County where property owners paid to have their structures moved inland to increase the setback by approximately 40 ft from the top of an eroding bluff. The cost to physical move the house ranged from $35,000 to $50,000 per property owner and both houses were approximately 1,500 square feet in size. The additional costs to build a new foundation and install the new utilities including the replacement of the septic system were estimated to cost an additional $50,000. A few other properties where a house move has occurred in Island County were identified through the study, but the costs were not obtained in time to be included in this report.

Northwest Structural Movers provided the rates listed in Table 9 to estimate the costs to lift a house vertically and to move a house on the same property within Island County. The costs in Table 9 only represent the costs for the physical move of the house and do not include the additional costs for excavation, foundation construction, utilities and permits which can be an additional $50,000 to $75,000. The costs for moving a house that exceeds 5,000 square feet must be quoted on a per home basis as they can require more specialized equipment.

Table 9: Range of costs to raise in elevation or setback a house

Size of Structure	House Lift	House Move
Less than 1,500 sf	$30,000 - $40,000	$50,000 - $60,000
1,500 – 3,000 sf	$35,000 - $45,000	$55,000 - $65,000
3,000 – 5,000 sf	$40,000 - $50,000	$60,000 - $70,000

Source: Northwest Structural Moving

5 Island County Case Study

This report describes the general effects of different residential shore treatment options on both private and public benefits. A case study on three adjacent properties in Island County that have undertaken different shoreline treatment actions provide an example of the relative costs and impacts of hard armoring versus soft shoreline treatments.

These three properties are adjacent to each other and located along a low-bluff accreting sandy beach[17]. Two of the properties installed a vertical bulkhead (hard armor), while the third installed a soft-shoreline treatment. Using the framework provided in this document and information known about the parcels, the effects of each treatment are compared in Table 10.

Table 10: Island County Hard Armor vs Natural Beach Case Study

	Property 1	Property 2	Property 3
Linear Length of Shoreline	68 Feet	54 Feet	86 Feet
Previous Shore Treatment	Hard armoring	Natural beach	Mix of rip rap and natural beach
New Shore Treatment	Hard armoring	Hard armoring	Soft shore protection
Risk Reduction Protection	Improved erosion protection although minimal existing erosion risk	Improved erosion protection although minimal existing erosion risk	Improved erosion and strom surge protection although minimal existing erosion risk
Aesthetic Condition	No change: 3-4 foot vertical bulkhead between yard and beach	Decreased: 3-4 foot vertical bulkhead between yard and beach	Increased: Natural slope from yard to beach
Shoreline Access Condition	No change: None apparent	Decrease: None apparent	Possibly increased
Ecological Benefits	0 DSAYs	-0.6 DSAYs	+0.9 DSAYs
Change in Land Value	No change	Possible decrease	Possible increase
Cost of Project	$69,400	$57,447	$32,729

All three projects provide the same relative risk reduction. Since these homes are located along an accreting beach, the erosion risk is low, however all homes do benefit from additional storm surge protection. The aesthetic conditions of the shore treatments clearly vary, with the hard-armored properties having a visible bulkhead between the yards and the beach, while the soft shore property has a more natural transition zone. As described earlier, the relative preferences between homeowners can vary, with some preferring a bulkhead, while others preferring the natural beach, but based on existing literature we have attributed a bulkhead to a lower aesthetic value than a natural beach. In terms of shoreline access, the hard-armored properties do not appear to have any direct access to the narrow

[17] The addresses of the properties are not included to protect the confidentiality of the property owners.

beach below. Similarly, the soft shore protected home does not have a clearly delineated access, however access to the shore is not encumbered by a bulkhead and shoreline access is possible.

The ecological benefits of each property vary by the type of existing shore treatment, the new treatment installed, and the length of the shoreline. The first property replaced existing hard armoring with new vertical bulkhead. This action resulted in no change in ecological benefits. The second property installed a vertical bulkhead where a natural beach had been located prior. This action reduced the ecological services provided by that shore segment. The third property replaced a mix of hard armoring and natural beach with a soft shore treatment, which conveyed an increase in ecological benefits.

In this framework, low bank properties with armor were correlated with lower land values than low bank shorelines without armor. Since all three properties are on low bank, we can assume the potential for changes in land value associated with the change in the three shoreline treatments. Hard armor replaced with hard armor does not change the land value (property 1), while a natural beach replaced with hard armor might decrease the land value (property 2). Conversely, hard armor replaced with soft shore might increase the land value (property 3).

Finally, a comparison of costs indicates that the soft shore treatment cost approximately half as much (46% - 57%) as the vertical bulkhead projects. Although the conditions and needs of each parcel will vary, this analysis indicates that soft shore treatment options should be investigated by homeowners due to the ability to deliver the same risk reduction combined with possible increased aesthetic and shoreline access values, all at a potentially lower cost.

6 Conclusion and Discussion

A framework for comparing the private and public benefits and costs of five shoreline strategies is presented in this report and utilized in a case study to show how property owners can apply the framework to make decisions about shoreline protection strategies.

We have summarized the results for the three categories of shoreline properties based on height of the bank or bluff above the shoreline as considered in this framework:

> *Low bank properties* benefit the most from maintaining a natural beach or removing hard armor and allowing a natural beach to reform if the risk to the structure is minimized. This shoreline strategy provides erosion and flood risk reduction value, aesthetic value and access value and is low in cost. In addition, low bank properties without armor are generally higher in land value.
>
> *Medium bluff properties* can also benefit from a natural beach in terms of erosion risk reduction and aesthetic value, but access value is decreased with this shoreline strategy. In addition, medium bluff properties with armor are correlated with higher land values than unarmored medium bluff properties. The greatest private and public benefits to medium bluff property owners can be achieved using a combination of shoreline strategies where access to the shoreline can be maintained using limited hard armor and aesthetic value and ecological benefits can be maximized through soft shore protection. However, the costs for achieving these benefits is generally higher on medium bluff properties as compared to low bank or high bluff properties.
>
> *High bluff properties* benefit the most from relocating a house inland in a manner that maintains the aesthetic value and increases the reduced risk value. High bluff properties have a reduced set of private values because they lack shoreline access, but can provide an increased benefit to the public by allowing the erosion of high bluffs to contribute sediment to surrounding beaches (feeder bluffs).

The results contained in this report are constrained by limited data. Additional data gathering and analyses could refine these results on several dimensions:

- A more robust hedonic property analysis would be able to disentangle the many different land and structure characteristics of each parcel to better isolate the effect of shoreline treatments. Additional data on actual property transactions as well as the attributes of those homes (number of bedrooms and bathrooms, heating systems, county, city, school district) would be necessary. This analysis could be expanded to include all shorefront properties in the Puget Sound region to increase the number of observations. The County would be used as a control to tailor the analysis to a more specific location while utilizing the larger data set.
- There is a relatively small number of parcels that have completed the shoreline strategies alternatives to hard armor: armor removal, soft shore protection, and relocating a house inland. There are no properties that could be identified where the house was moved vertically. The wide variability of prices in the alternative strategies data indicates that there are many property-specific variables that affect construction cost. In addition, the funding of these projects through grant money with oversight by a third party further complicates the comparison of costs to the installation of hard armor which is funded privately. A more refined

analysis could be completed that includes all shorefront properties where alternative strategies have been implemented in the Puget Sound region and the information on fixed and variable costs can be determined.

- The ecological benefits have been calculated based on a framework for relative habitat service values for the following habitat types: marsh, intertidal, shallow subtidal, and rip-rap. High bluffs with exposed faces that contribute sediment to the beaches (feeder bluff) have an additional public benefit. Providing a method to quantify the DSAYs of feeder bluffs would be important for determining the overall benefits of armor removal on these shoreline types.