Residential Shoreline Loan Program Feasibility Study
Cost Analysis Memo

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Prepared for Puget Sound Institute and Northern Economics

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Executive Summary

This report describes a database of projects and associated costs gathered to assist in the development of a residential revolving loan program for projects that preserve or enhance nearshore habitats in the Puget Sound region. The purpose of this proposed loan program is to incentivize the implementation of residential shoreline protection that also yield benefits such as habitat restoration and enhanced recreation access. Projects included in this study are (1) bulkhead (shore armor) removal, (2) soft shore protection, (3) structure relocation, and (4) structure elevation. Projects included were implemented in the last decade (2009-2019) in the Puget Sound region.

Data were collected from a wide variety of private and public sources including the Washington Department of Fish and Wildlife's (WDFW) Aquatic Protection Permitting System (APPS), the Washington State Recreation and Conservation Office's (RCO) PRISM online database, local Shore Friendly programs, Coastal Geologic Services' in-house files, county offices, non-profit and regional project sponsors, contractors, and homeowners. Where possible, we reported the county, construction access, and associated costs for each project. For bulkhead removal and soft shore protection projects, costs were broken down into design, permitting, and implementation. For structure relocation and elevation projects, construction, disposal, moving, foundation, and utilities costs were also reported when available. To allow for direct comparison, costs were escalated to a base year of 2019 based on the US Army Corps of Engineers' (USACE) price index for bank stabilization projects.

The resulting database includes 46 projects from ten counties and numerous design firms on a variety of shoretypes. Bulkhead removal projects ranged from $95/LF (linear foot) to $1,326/LF, with an average of $491/FT. Many bulkhead types are detailed such as creosote treated wood, concrete walls, riprap, and a mix of materials. Soft shore protection projects ranged from $135/LF to $817/LF and averaged $414/FT. Soft shore protection projects include techniques such as beach nourishment, installation of large anchored logs, revegetation and resloping. Structure relocation projects averaged $135,000 for total costs, with the moving costs alone averaging ~$67,400. Structure elevation moving costs averaged ~$23,600, with one total structure elevation cost reported at $62,000 for a 1,000 square foot (SF) structure (data was scarce on this technique).

This database of projects demonstrates the variability of techniques and costs to restore and install soft shore protections at residential structures. While the costs reported give reasonable estimates based on real projects, it is important to consider factors that may increase the costs of a project such as site access, existing conditions, wave exposure, and future maintenance. We hope that this database will inform the development of the revolving loan fund and lead to more projects that improve shoreline ecosystem health in the region.

Introduction

The shore of Puget Sound is dynamic, with wind, waves, and other processes constantly reshaping and moving sediment along the shore. These natural processes build beaches, maintain coastal habitat, and create a healthy ecosystem for many species including salmon (Johannessen and MacLennan, 2007). However, with increased development of the shoreline, especially for single-family residences, demand for property protection against erosion, storms, and flooding, resulted in the construction of hard armor such as bulkheads, seawalls, and revetment (Simenstad et al., 2011). Many were built before the ecological impacts and risks were well understood and are now failing or unnecessary at many sites (Johannessen et al., 2014). We now know these techniques can cause adverse impacts to nearshore processes, structures, and habitats for salmon, forage fish, and key species critical for orca recovery (Dethier et al., 2016).

Puget Sound has approximately 715 miles, or 29% of its shore lined with bulkheads, seawalls, and other "hard armor" (Coastal Geologic Services, 2017). Homeowners often build shore armor to slow erosion and protect structures where sufficient setback from shore has not been maintained or for other reasons such as landscaping (Johannessen et al., 2014). Recent permitted armor removal is increasing in the region. Between 2005 and 2018, 6.19 miles of armor were permitted for removal, averaging 0.44 miles per year, and from 2016 to 2018 an average of 0.78 miles were permitted for removal (Figure 1; https://www.pugetsoundinfo.wa.gov/). The combination of more strict shoreline management policy and increased understanding of the impacts on shore armor based on scientific study is thought to contribute to this substantial shift in coastal management. This also helped foster the conditions for the continued development of alternative techniques for shore protection.

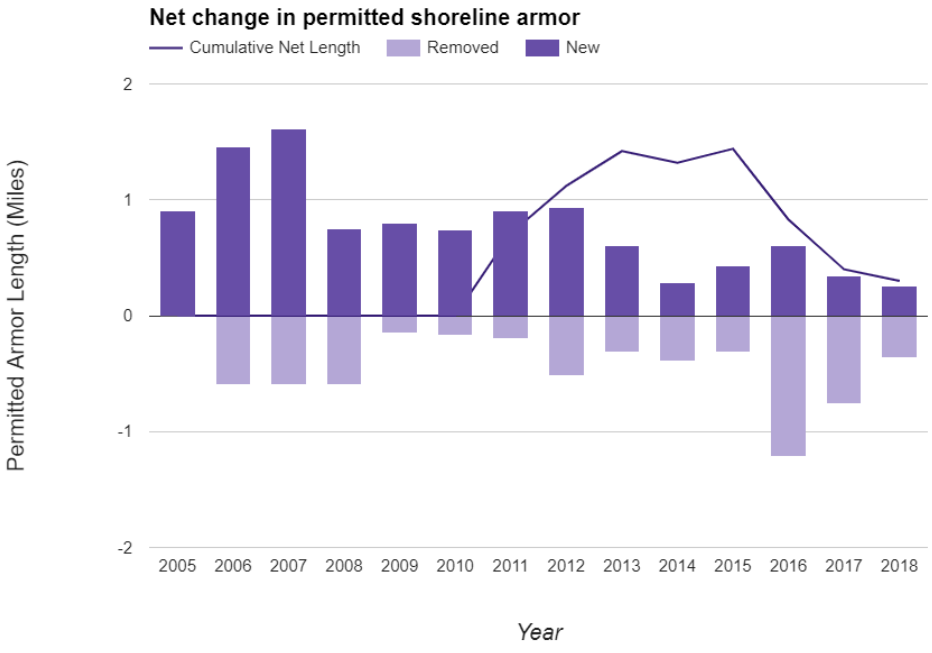

Figure 1. Shoreline miles of permitted bulkhead removal and new shoreline armor from 2005 to 2018. Cumulative net change in shoreline armor beginning in 2011 measured from armor permit data from the WDFW HPA system. Source: https://www.pugetsoundinfo.wa.gov/

Local Shore Friendly programs have engaged with hundreds of waterfront homeowners to encourage alternative solutions for shoreline protection that also yields benefits to fish and wildlife (Kinney and Francis, 2019). Many successful bulkhead removal and soft shore protection projects on public and private beaches have shown that these options are feasible and result in more attractive, accessible shores. However, cost is a significant barrier to those projects and existing financial incentives are not sufficient to meet the demand (Kinney and Francis, 2019).

In March 2018, Coastal Geologic Services (CGS), Puget Sound Institute (PSI), and Northern Economics (NE) submitted a Near Term Action proposal to the 2018-2022 Puget Sound Action Agenda for the development of a residential shoreline loan program feasibility study for projects. This work aims to address this cost barrier by supporting the establishment of a revolving loan fund (RLF), which will provide financial support to homeowners for the implementation of eligible projects on their coastal properties. An important part of establishing this RLF was developing a database of costs associated with implementing project types being considered for this proposed program including bulkhead removal (BR), soft shore protection (SSP), structure relocation (RERE), and structure elevation (ELEV). Our goal was to assemble project examples from across the Puget Sound region and from a host of different organizations.

This report was prepared for Puget Sound Institute and Northern Economics to use in their financial models to estimate the anticipated range of loan amounts. This report describes the data types, sources, and methods used to estimate the total implementation costs for the four project types being considered for the proposed program. This proposal was funded through the Habitat Strategic Initiative (Washington Department of Fish and Wildlife, Washington Department of Natural Resources). CGS is engaged to utilize our expertise in coastal geomorphology, project design and engineering, and coastal mapping. Ideally, this work will ultimately lead to more accessible funding sources and eventually more coastal enhancement and restoration in the region.

Methods

Data Types

In order to be included in the database, projects needed to meet the following requirements, and include the following information:

Project Requirements:

- Implementation between 2009 and 2019
- Residential property scale
- Action implemented with adequate records

Information Requirements:

- Geographic name (i.e. – street name, City/County, not the name of the property owner)
- Year of project implementation
- Existing shoreline treatment (armored/soft shore/natural)
- New shoreline treatment (MSDG techniques)
- Project objective/rationale
- Construction access (water/land)
- Costs (design, permitting, implementation)
- Overall project cost
- Linear feet (LF) of project shore

The four types of projects included in this analysis and are outlined in the *Marine Shoreline Design Guidelines* (MSDG) report (Johannessen et al., 2014) and include:

1) Bulkhead Removal (armor removal): removing all or sections of hard structure on the shoreline. This technique is typically applied along shores where coastal erosion is not substantial or where armor serves solely as a landscaping feature. The primary purpose of bulkhead removal is usually restoration and ecosystem enhancement and serves to increase beach resiliency and recreation value.

2) Soft Shore Protection: preserves the natural beach while providing erosion control. Projects typically rely on natural materials and include techniques such as gravel beach nourishment, installation of large wood, bank regrading, and revegetation.

3) Structure Relocation: also known as managed retreat or realignment, refers to moving coastal infrastructure (roads, houses, building, bridges, etc.) inland to allow the shore to recede naturally, and is considered a passive management technique.

4) Structure Elevation: raising a home to reduce the threat from flooding and storms and allows the resident to remain on the property preserving existing housing.

Many projects are implemented in combination, especially bulkhead removal and soft shore protection. However, we excluded projects that had anomalous project elements such as removing unusually large structures or projects with house additions included.

Data Sources

Project data were collected from several private and public sources. The Washington Department of Fish and Wildlife's (WDFW) Aquatic Protection Permitting System (APPS) hosts project information and permit status on all projects that requires Hydraulic Project Approval (HPA). We found several projects through APPS that fit our requirements and gathered information such as address, year, description, number of parcels, permitting biologist, designer, contractor, and in some cases designs and photos. Inquiries were sent out to the permit applicant, contractor, or permitting biologist to gather cost data.

The Washington State Recreation and Conservation Office (RCO) hosts the PRISM Online database which provides the public details on RCO grant funded project ("PRISM Project Search - Washington State Recreation and Conservation Office"). Each project has a Project Snapshot which provides detailed information such as costs, descriptions, locations, metrics, milestones, design plans, photographs, and a final project report. We found several bulkhead removal and soft shore projection projects through the PRISM Project Search to include in this report.

CGS has designed and engineered residential shoreline projects in Puget Sound for 26 years, which enabled a comprehensive synthesis of cost data from our projects. Often, CGS completed design, permitting, and assisting with implementation. For several projects, owners or contractors were contacted to acquire needed data for specific steps, usually for final implementation and permitting costs.

Another source came from data collected from by Blue Coast Engineering PS, Inc. for their 2019 report (Côté and Domanski, 2019). Their report focused on Island County bulkhead removal and soft shore protection projects by several firms including CGS. Their project data included existing and new shoreline treatment, shoreline type, county, rational, construction access, linear feet removed, and estimates on costs including design, permitting, and construction. Based on our accounting numbers for CGS projects and additional information from inquiries to proponents, project costs were adjusted when necessary as many of their costs were estimates.

We reached out to over 70 state agency employees, county shoreline planners, local Shore Friendly programs, consultants, and contractors, including those that specialized in structure relocation and elevation. In some cases, the owner or contractor could not provide exact figures but were able to give best estimates, which we used when necessary. Projects with the most complete set of cost data were selected that fit the project requirements. Project designs and associated costs were reviewed and compiled into the database. All information was then compiled and delineated into the four project types.

Cost Escalation

To reflect the modern costs of projects included in this report, in some cases 10 years later, we adjusted cost data to a common year (2019) based on the USACE's Civil Works Construction Cost Index System (CWCCIS) ("CWCCIS Indices"). The USACE's index tracks the costs of many civil works projects including "bank stabilization," which we used to develop an inflation factor for 2009-2018 to adjust them to 2019 costs. The USACE uses these indices to escalate their Civil Works project costs from past to present and are developed from actual historic data. Their data are prepared by fiscal year (FY), beginning October 2nd, ending September 30th/October 1st, with the indices based on the first day of each quarter. The indices applied in our analysis are developed by averaging quarterly indices for each year and are for use

in long-term forecasting. The CWCCIS uses 1967 as the base year, with an assigned value of 100.00. We adjusted our base year inflation factor to 2019 by dividing the FY indices by the 2019 FY index ("CWCCIS Indices").

We also explored other indexes such as the Producer Price Index Construction Metric, the U.S. Census Bureau National Construction Index, and the Mortenson Index. The Producer Price Index (PPI) tracks inputs to construction, largely new single and multi-family residential and commercial projects for almost all industries in the U.S. economy ("Producer Price Index (PPI)"). The U.S. Census Bureau National Construction Index provides price indices from single-family houses sold and under conduction. This index is mainly used to inflate previous years house prices to determine housing insurance replacement costs and to estimate price escalation for construction contracts. Their assumption is that inflation in existing housing or construction can be approximated by inflation in the sale prices for new houses sold (US Census Bureau). The Mortenson Construction cost index is calculated quarterly by pricing representative non-residential construction projects in many cities, including Seattle (Wagner and Greany, 2019). Mortenson's index relates to large increases in steel prices but "flat" growth in earthwork and concrete. While the Mortenson's index is specific to the Seattle region, the components that make up the index do not fully reflective of the type of projects we are interested in.

From our research we concluded that averaging the USACE's CWCCIS index for bank stabilization was the preferred method to develop a cost escalation index as it is the most reflective of the types of proposed projects for this study. Table 1 shows the reported yearly cost indices (top) and the 2019 inflation factor (bottom) for each year between 2009 and 2019. From this inflation factor we escalated projects costs to 2019 with Equation (1):

$$\boldsymbol{FY\ 2019\ Cost} = \left(\frac{\boldsymbol{FY19\ Index\ Value}}{\boldsymbol{Project\ year\ index\ value}}\right) * \boldsymbol{Cost} \qquad (1)$$

Table 1. Cost inflation factors derived from USACE's Civil Works Construction Cost Index System for fiscal years (FY) 2009 – 2018, with 2019 as the base year.

USACE Cost Index System	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19
Yearly Cost Indices – Bank Stabilization (1967 = 100)	723.28	739.03	760.03	779.97	797.82	820.25	840.77	864.44	887.18	907.07	943.46
FY19 index value/Project year index value	1.30	1.28	1.24	1.20	1.18	1.15	1.12	1.09	1.06	1.04	1.0

Results

Data compiled for this report includes information from 46 projects completed between 2009 and 2019 in 10 different counties. During the process of inquiring for data, we collected data on just over 80 projects, however we narrowed down the final database to 46 due to lack of adequate data, specificity, scale, or the complexity and associated anomalously high cost of several projects. Five projects were

included in both bulkhead removal and soft shore protection tables, as costs were detailed enough to separate the components. All project types exhibited a wide range of costs but on average structure relocation was the most expensive, followed by structure elevation, bulkhead removal, and the least expensive was soft shore protection (Table 2).

The summary of results showing low, average, and high costs for each project type are in Table 2. For bulkhead removal, these numbers came from projects < 400 FT in length (Table 3). Data from larger bulkhead removal projects are in Table 4. Soft shore protection costs came from Table 5. Structure elevation projects were limited in data; therefore, the low value is three times the lowest moving costs, based on professional guidance. The elevate high cost is from NW Structural Moving Service Rates for Whidbey Island service area to elevate a 3,000 SF to 5,000 SF house with "turnkey service," and the average is the average of low and high costs. Relocation costs came from Table 6.

Table 2. Overview of results for each project type. Data is reflective of Tables 3-7 below.

Activity	Number of Projects	Low (2019)	Average (2019)	High (2019)
Bulkhead Removal	22	$33,300*	$71,000*	$138,100*
Soft Shore Protection	11	$20,800	$51,100	$143,800
Elevate	9	$60,000	$100,000	$140,000
Relocate	9	$43,800	$135,000	$234,200

*Bulkhead removal costs for projects < 400 FT in length (Table 3).

Bulkhead Removal

The bulkhead removal projects in this report were conducted for the purposes of habitat improvement, restoration, and due to the desire to remove failing structures. These projects occurred in seven counties and were designed by seven different firms. The types of bulkheads removed include vertical bulkheads constructed with concrete, treated wood (creosoted), wood soldier piles, tires, and large rock (riprap or larger boulders). The shoretypes represent the diversity of Puget Sound shores: spanning large feeder bluffs, low banks, pocket beaches, and marshes.

Projects with < 400 FT of bulkhead removal were deemed representative of residential size projects (Table 2) and were analyzed separately from projects that were > 400 FT (Table 3). Residential sized project ranged from 60 FT to 380 FT, and larger projects ranged from 435 FT to 3,960 FT. We included projects that were accessed from land and water, and in some cases both. The goal of the projects included were to create more natural shorelines, and no projects involved bulkhead replacement.

Most residential bulkhead removal projects necessitated some amount of soft shore techniques included in the project (Figures 2 and 3). When records allowed, construction costs were altered to account for soft shore components. If records were not detailed enough to separate costs and the soft shore protection component was minor, costs were not altered. Table 2 and 3 details the project

county, existing armor type, the MSDG techniques involved in the project: bulkhead removal (BR), beach nourishment (BN), installation of large wood (LW), reslope and or revegetation (RE), and relocation of a structure (RERE), costs escalated to 2019, and cost per linear foot.

Figure 2. Example of a failing bulkhead where site conditions may necessitate soft shore protection with bulkhead structure removal.

Figure 3. Bulkhead removal project before (left) and after (right) in Kitsap County. After the failing creosote-treated bulkhead was removed, soft shore protection techniques were applied including beach nourishment, and limited installation of large wood, minor resloping, and revegetation.

The cost of removing a bulkhead varied greatly depending on several factors such as access and transportation and the type and size of the existing bulkhead. Out of the three costs categories (design, permitting, and implementation), permitting was the least costly, with an average of ~$5,400 for projects residential sized project (< 400 FT) and ~$13,700 for larger projects (> 400 FT). Design costs averaged ~$21,400 and ~$62,200, for residential and larger sized projects, respectively. Implementation averaged ~$44,200 and ~$320,100. While some projects achieved relatively low cost per feet removed

(~$140/LF), more complicated projects were upwards of ~$1,300/FT, with an average of $485/FT for residential scale and $502/FT for larger projects.

Removal of wooden bulkheads such as soldier piles correlated to the greatest cost per foot removed compared to rock (riprap and rockery), concrete, and a mix of materials (tires, railroad ties, gabions). Projects accessed by water compared to land had lower costs, however we have far fewer projects accessed by water included in our analysis which may affect this comparison. Projects located on feeder bluffs or bluff backed beaches experienced the greatest costs, then accretion shorelines, banks averaged, and the least costly was beaches without bluffs or banks or transition zones (Table A1-A2).

Table 3. Summary of residential sized bulkhead removal projects (< 400 FT) included in this report. Costs adjusted to 2019 using Eq. (1).

County	Armor Type	MSDG Technique	Design Cost	Permitting Cost	Implementation Cost	Total Cost	Cost per FT
Jefferson	Rockery	BR, LW, RE	$13,100	$8,700	$52,700	$74,500	$438
San Juan	Revetment	BR, BN	$9,200	$6,400	$38,400	$54,000	$372
Kitsap	Concrete	BR, BN, LW, RE	$17,400	$7,000	$11,900	$36,300	$267
Island	Rock, Soldier Piles	BR, LW, RE	$4,600	$4,900	$23,800	$33,300	$95
Kitsap	Basalt Rock	BR	$11,200	$8,300	$91,300	$110,800	$672
Pierce	Soldier Piles	BR, BN, LW	$17,500	$5,000	$42,000	$64,500	$859
San Juan	Rock	BR, BN	$42,700	$6,700	$52,100	$101,500	$267
San Juan	Rock	BR, LW, RE	$13,700	$5,200	$19,000	$38,200	$229
Kitsap	Wood	BR, BN, LW	$15,400	$800	$26,000	$42,200	$439
Mason	Concrete	BR, RE, RERE	$34,300	$5,600	$53,500	$93,400	$622
Pierce	Railroad Ties, Gabions	BR	$27,300	$3,000	$44,600	$74,900	$1,247
Mason	Creosote Wood	BR	$13,800	$4,600	$17,300	$35,700	$594
Island	Creosote Wood Pile, Riprap	BR	$44,900	$4,600	$88,600	$138,100	$394
Kitsap	Creosoted Pile Wall	BR, LW	$36,200	$5,200	$69,000	$110,400	$291
Kitsap	Concrete	BR, BN, LW, RE	$19,800	$5,100	$33,200	$58,100	$492
Average			***$21,407***	***$5,407***	***$44,227***	***$71,040***	***$485***

Table 4. Summary of larger bulkhead removal projects (> 400 FT) included in this report. Costs adjusted to 2019 using Eq. (1).

County	Armor Type	MSDG Technique	Design Cost	Permitting Cost	Implementation Cost	Total Cost	Cost per FT
Clallam	Riprap, Concrete	BR, RERE	$26,600	$26,600	$489,200	$542,400	$137
Island	Tires, Creosoted Wood, Rock, Concrete	BR	$18,000	$20,800	$270,400	$309,200	$174
Kitsap	Rock	BR, BN	$87,100	$24,200	$318,100	$429,400	$286
Clallam	Rockery, Overwater Structure, Pier	BR	$95,400	$7,300	$190,900	$293,600	$652
Island	Rock Groin	BR, BN, LW	$126,800	$1,100	$448,800	$576,700	$1,326
Kitsap	Concrete, Riprap, Fill	BR, BN, LW, RE	$59,600	$11,500	$465,800	$536,900	$767
Mason	Concrete	BR	$21,700	$4,200	$57,500	$83,400	$174
Average			***$62,171***	***$13,671***	***$320,100***	***$395,943***	***$502***

A good number of bulkhead removal projects required soft shore protection to ensure the safety of the home over the longer term. For these project sites, the sites included in Table 2 were analyzed with soft shore costs not specifically excluded. This yielded an average cost of $577/LF. While the cost is not significantly greater than bulkhead removal alone, it is important to note that some costs such as mobilization to the site are the same for a bulkhead removal project with or without soft shore protection. Additionally, several of the more expensive bulkhead removal projects did not have a substantial soft shore protection portion and therefore were not included in this average.

Soft Shore Protection

Soft shore protection projects aim to preserve natural coastal dynamics while protecting the property from impacts from waves and flooding. The appropriate design for soft shore protection projects requires an understanding of specific site conditions and current and historical coastal processes. The main design techniques incorporated in soft shore approaches are beach nourishment, the addition of large wood, and regrading and revegetating. These techniques are designed to have some degree of flexibility, mimicking natural processes. In contrast to hard armor, soft shore protection techniques create a more natural shore that improves habitat, improves access for recreation, and establishes a more natural yard while integrating into its surroundings (Figure 4).

The purpose of the soft shore protection projects contained in this report include habitat enhancement, and avoiding the use of a hard armor structure, including several projects that occurred as the second part of an armor removal effort (Table A3). The projects were conducted in four counties with implementation conducted by several contractors. Most projects included used more than one MSDG component, usually including beach nourishment and installation of large wood. Projects included in this study covered shoretypes including accretion zones such as spits, low to medium banks, and beaches.

They cover a range of beach lengths, from 50 FT to 380 FT, and were accessed mostly commonly by land (Table A3).

Table 4 details the county, MSDG technique, costs (design, permitting, implementation), total costs, and cost per linear foot. The costs associated with soft shore protection projects are on average less then bulkhead removal. Design costs averaged ~$11,600, permitting costs averaged $5,400, and implementation averaged ~$34,100. The cost per foot ranged from $135/FT to $817/FT with an average of $414/FT. Projects that involved just one SSP technique accrued fewer costs than those with several techniques, with an average of $196/FT compared to $440/FT. Most projects occurred on properties with either a low bank or an accretion shoreform such as a spit. On average projects with banks were less expensive than at accretion shoreforms. In general, as the length and size (LF) of the project increased the cost per linear foot decreased.

Table 5. Summary of soft shore protection projects included in this report. Costs adjusted to 2019 using Eq. (1).

County	MSDG Technique	Design Cost	Permitting Cost	Implementation Cost	Total Cost	Cost per FT
Kitsap	BN, LW, RE	$17,400	$7,000	$19,500	$43,900	$323
San Juan	BN	$9,200	$6,400	$26,500	$42,100	$290
Island	BN, LW, RE	$2,700	$3,300	$27,000	$33,000	$523
Island	BN, RE	$2,700	$3,300	$29,700	$35,700	$415
Skagit	BN, LW	$6,900	$6,900	$130,000	$143,800	$757
Kitsap	LW	$36,200	$5,200	$21,100	$62,500	$165
Island	LW, BN, RE	$4,600	$4,900	$44,300	$53,800	$154
Island	BN, LW, RE	$10,300	$12,000	$39,000	$61,300	$817
Island	LW, BN	$16,600	$4,400	$9,600	$30,600	$611
Kitsap	BN, LW, RE	$15,400	$800	$18,400	$34,600	$360
Island	LW	$5,200	$5,200	$10,400	$20,800	$135
Average		***$11,564***	***$5,400***	***$34,136***	***$51,100***	***$414***

Figure 4. Soft shore protection project before (left) and after (right) on Whidbey Island, Island County. Installation and anchoring of large drift logs and beach nourishment were applied to enhance resilience to storm damage while promoting and maintaining the ecological properties of the coastal ecosystem.

Structure Relocation

Structure relocation projects move coastal infrastructure inland to allow natural erosion to occur. This approach is also referred to as managed retreat or realignment (Figure 5). Relocation is an alternative to other shore protection techniques such as adding hard armor. Although relocation projects have fewer impacts to nearshore habitat then other forms of protection, it is often only used when no other option is viable. However, the use is increasing as shoreline management codes are making installation of new armor much more difficult. A benefit to structure relocation is that relocation is a permanent solution with no additional costs to protect the home. Other techniques, such as bulkhead removal and soft shore protection, require initial cost and periodic maintenance and eventual replacement for bulkheads.

The structure relocation projects assessed in this study consist of residential homes situated on top of coastal bluffs where setbacks were not sufficient, failing armor, and restoration after an overwater structure was removed. They occurred in six counties by three moving companies. The structures ranged in size from a small cabin (360 SF) to a medium sized residential home (2,200 SF). All projects were accessed by land apart from one being moved with a barge. If a specific cost was unknown, estimates were made based on averages of other project costs excluding the highest and lowest costs per costs category. Out of the major costs associated with these projects, permitting was the least expensive with an average of ~$5,100, then design with an average of ~$9,100. Construction and foundation expenses contributed a substantial cost, with an average of ~$25,500 and ~$27,900, respectively. The costs just associated with moving the structure averaged ~$67,400.

Consulting with several contractors who specialize in structure relocation, the cost to move a typical 1,200 SF to 1,500 SF rambler style residential home is estimated to be $40,000 to $60,000. However, the additional costs of permitting, design, construction, foundation, and utilities add a significant amount to the total implementation cost. One contractor estimated that all other costs associated with the move are about equal or greater than the cost to move alone, or upwards of $125,000 for the total implementation costs for a rambler style home. Several caveats need to be considered for special circumstances such as difficult access that may increase the implementation total.

Table 6. Summary of structure relocation projects included in this report. Costs adjusted to 2019 using Eq. (1).

County	Access	Permitting	Design	Construct-ion & Disposal	Moving Costs	Foundation & Utilities	Total Cost	House Area (FT^2)	Move Dist. (FT)
Island	Land	$4,900	$12,900	$103,400	$53,800	$59,200	$234,200	1,500	65
Mason	Land	$5,600	$4,500	$5,600	$71,300	$5,600	$92,600	960	5280
Pierce	Land	$4,500	$7,900	$3,400	$15,700	$12,300	$43,800	360	10
Island	Land	*$4,700*	*$7,800*	$23,500	$86,100	$40,100	$162,200	2,200	60
Snohomish	Land	$4,600	$9,200	$8,100	$57,500	$6,900	$86,300	--	--
Island	Water	*$5,200*	*$8,600*	*$13,200*	$109,300	*$21,300*	$157,600	--	--
King	Land	$5,800	$13,800	$46,000	$57,500	$63,300	$186,400	1,600	--
Clallam	Land	*$5,200*	*$8,600*	*$13,200*	$74,800	*$21,300*	$123,100	1,600	--
Snohomish	Land	*$5,200*	*$8,600*	*$13,200*	$80,500	*$21,300*	$107,600	--	--
Average		***$5,078***	***$9,100***	***$25,511***	***$67,389***	***$27,922***	***$135,000***		

*Italics represent estimated costs based on averaging costs of similar projects excluding the highest and lowest costs.

Figure 5. Structure relocation project on Whidbey Island, Island County. Oblique image (top) shows condos near bluff crest prior to relocation. Condos were moved (bottom) to establish a safe setback. Photo source DB Davis LLC.

Structure Elevation

Building in coastal environments poses unique challenges, especially in Puget Sound. In low lying areas, the effects of storm surge, wave action, and erosion make coastal flooding particularly damaging to structures. Foundations are exposed to flood borne debris, erosion, and scour which can undermine foundations causing the building to fail.

There are several types of foundation typically constructed when elevating a structure such as slab-on-fill, perimeter wall, and open foundation (column, pier, or piles). Slab-on-fill increases the elevation of the structure to meet floodplain standards, while perimeter and open foundations allow water, sediment, and debris to travel through the foundation rather than applying pressure and lateral force to the foundation, which can lead to structural failure (FEMA, 2014).

The projects assessed in this report were elevated due to flooding or bluff failure (Figure 6). They occurred in five counties and by three moving companies. All were accessed by land. The average cost to elevate the structure, without all other expenses, averaged ~$23,600. Consulting with several other contractors, estimates to solely elevate and lower a 1,200 SF to 1,500 SF rambler style residential home ranged from ~$10,000 to ~$40,000. Based on the projects included in this study and from consulting with contractors, elevating the structure alone accounts for about a third of the total implementation cost. As noted earlier data was sparse for this project type, therefore to come up with a realistic low cost for structure elevation based on our data we took the lowest elevate costs (Table 7) and multiplied it by three (Table 2). To estimate the high costs, we used the rates to elevate a 3,000 SF to 5,000 SF house

with "turnkey service" for the Whidbey Island area from Northwest Structural Moving (Table 2). The average elevation costs came from averaging the low and high values (Table 2).

Table 7. Summary of structure elevation projects included in this report. Costs adjusted to 2019 using Eq. (1).

County	Access	Permitting	Design	Construction & Disposal	Moving Costs	Foundation & Utilities	Total Cost	SF	Elevation (FT)
King	Land	$5,000	$6,900	$21,500	$20,000	$8,600	$62,000	1,000	8
San Juan	Land	--	--	--	$23,000	--	--	--	--
San Juan	Land	--	--	--	$28,800	--	--	--	--
Skagit	Land	--	--	--	$20,700	--	--	--	--
Snohomish	Land	--	--	--	$21,300	--	--	--	--
Snohomish	Land	--	--	--	$23,000	--	--	--	--
Snohomish	Land	--	--	--	$23,000	--	--	--	--
Skagit	Land	--	--	--	$20,800	--	--	1,600	3.5
Island	Land	--	--	--	$32,000	--	--	1,500	4.5
Average					***$23,622***				

Figure 6. Structure elevation project. Photo source DB Davis LLC.

Discussion

The process of acquiring these data was not always straight forward and complete data for projects was not readily available. We reached out to over 70 contacts including many state agencies, private contractors, and homeowners with varying success. The WDFW APPS system was helpful to find Shore Friendly projects and contacts, however since its intended purpose is permit tracking project costs were not recorded. The RCO's PRISM system had the most detailed and systematic accounting for projects in their final reports, however only detailed RCO grant funded projects.

An aspect that complicated acquiring these data was that typically many different entities that were involved in each project. This was especially true for the relocation and elevation projects where there was a different contractor for construction, moving, foundation, and utilities, plus an engineer/designer, and an additional person who applied for permits or grants. A more systematic way to submit and access data on projects could provide a great resource for future projects and a better understanding of

the types of solutions available. Based on the complex nature of many of the projects, we are especially grateful to those who took time to organize and send us project information.

The compilation of projects highlighted the degree of variability in project designs and costs. The unique characteristics at each site necessitates the site-specific planning and implementation. In addition, there are many different approaches to implement bulkhead removal and soft shore protection techniques depending on the designer or contractor. For this project, we sought to represent more typical projects, although it must be clear that one solution does not fit all projects and each site has its unique characteristics that must be addressed. For the homeowner, components such as access, terrain, existing conditions (i.e. bulkhead type, amount of habitat degradation), and exposure are especially important factors when assessing potential project needs and costs.

Specifically, for structure relocation and elevation projects, pricing depends on the size of the structure and distance to be moved or elevated, as well as safety factors, move type (truck or barge), access (narrow roads, steep, windy, utilities overhead), types of construction (slabs or structures built with basements), and needed permits (county, city, Washington Department of Transportation, HPA), in addition to shoretype and exposure.

For all bulkhead removal and soft shore protection projects, considering any future costs after initial implementation is also important. With the dynamic nature of Puget Sound shores, the occurrence of periodic large storms, and anthropogenic alterations, many projects either necessitate or benefit from some degree of supervision and maintenance. For bulkhead removal and soft shore protection projects, the cost of maintaining or monitoring the shore was not included in the costs detailed in this project.

This database illustrates that projects exhibit a wide variety costs based on site conditions and overall goals. While the costs associated with projects can present an impediment for some, we hope the proposed RLF will ultimately lead to more accessible funding sources and eventually more coastal restoration and enhancement projects in the region to benefit nearshore habitat and species.

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Appendix

Tables A1-A3 are detailed summaries for bulkhead removal and soft shore protection projects.

Table A1. Detailed summary of bulkhead removal projects < 400 FT in length.

Project #	Armor Type	MSDG components**	Shoretype (low bank, medium bank, high bluff, estuary, other)	County	Construction access (water vs land)	Total Cost (2019)	Adjusted Cost for SSP	Cost per FT ($/FT) (2019)
1	Rockery	BR, LW, RE	Feeder bluff	Jefferson	Land	$74,500	--	$438
2	Revetment	BR, BN	Accretion shoreform	San Juan	Land	$54,000	$18,857	$372
3	Concrete bulkhead	BR, BN, LW, RE	Low-med bank	Kitsap	Land	$36,300	$19,526	$267
4	Rock revetment, solider pile wall	BR, RV, RE, LW	No bank, no appreciable drift	Island	Land	$33,300	$54,050	$95
5	Basalt rock	BR	High bluff, feeder bluff, transition zone	Kitsap	Water	$110,800	--	$672
6	Soldier pile walls, not creosote treated	BR, BN, LW	Low bank, marsh	Pierce	Land	$64,500	--	$859
7	Rock	BR, BN, RV	Low bank	San Juan	Water	$101,500	$45,466	$267
8	Low elevation rock	BR, LW, RE	Marsh, low elevation beach, no appreciable net-shore drift	San Juan	Land	$37,900	--	$229
9	Wood bulkhead	BR, BN, LW, RE	Transition zone	Kitsap	Land	$42,200	$18,419	$439
10	Concrete bulkhead	BR, RERE, RE	Pocket estuary	Mason	Land	$93,400	--	$622
11	Creosote treated railroad tie steps, gabions	BR	Feeder bluff	Pierce	Land	$74,900	--	$1,247
12	Creosote treated wood	BR	Low bank	Mason	Land	$35,700	--	$594
13	Creosote treated pile, riprap	BR	Beach	Island	Land	$138,100	--	$394
14	Creosote treated log wall	BR, LW	Medium bank	Kitsap	Water	$110,400	$21,082	$291
15	Concrete bulkhead	BR, BN, LW, RE	Transition zone	Kitsap	Land	$58,100	--	$492
Average						***$71,040***		***$485***

** BR=Bulkhead Removal, BN=Beach Nourishment, LW=Large Wood, RE =Reslope/Revegetation, RERE=Structure Removal

Table A2. Detailed summary of bulkhead removal projects > 400 FT in length.

Project #	Armor Type	MSDG components**	Shoretype (low bank, medium bank, high bluff, estuary, other)	County	Construction access (water vs land)	Total Cost (2019)	Adjusted Cost for SSP	Cost per FT ($/FT) (2019)
1	Riprap, concrete slab	BR, RERE	Beach, no bank	Clallam	Land	$542,400	--	$137
2	Tires, creosote treated wood pile, rock, concrete	BR	Beach to low bank	Island	Water	$309,200	--	$174
3	Rockery	BR, BN	No appreciable net-shore drift, low energy	Kitsap	Water	$429,400	--	$286
4	Rockery, overwater structures, including a pier, fill	BR	Accretion shoreform	Clallam	Land	$293,600	--	$652
5	Rock groin	BR, BN, LW	Spit	Island	Land	$576,700	--	$1,326
6	Creosoted treated wood, riprap, fill	BR, BN, RE, LW	Spit	Kitsap	Water	$536,900	--	$767
7	Concrete wall	BR	Low bank	Mason	Land	$83,400	--	$174
Average						***$395,943***		***$502***

** BR=Bulkhead Removal, BN=Beach Nourishment, LW=Large Wood, RE =Reslope/Revegetation, RERE=Structure Removal

Table A3. Detailed summary of soft shore protection projects.

Project #	MSDG components**	Shoretype (low bank, medium bank, high bluff, estuary, other)	County	Construction access (water vs land)	Total Cost (2019)	Adjusted Cost for BR	Cost per FT ($/FT) (2019)
1	BN, LW, RE	Low-med bank	Kitsap	Land	$43,900	$11,868	$323
2	BN	Accretion shoreform	San Juan	Land	$42,100	$30,754	$290
3	BN, LW, RE	No bank, accretion beach	Island	Land	$33,000	-	$523
4	BN, RE	No bank, accretion beach	Island	Land	$35,700	-	$415
5	BN, LW	Accretion beach	Skagit	Water	$143,800	-	$757
6	LW	Medium bank	Kitsap	Water	$62,500	$69,013	$165
7	RV, RE, LW	No bank, no appreciable drift	Island	Land	$53,800	$33,550	$154
8	BN, LW, RE	No bank, accretion beach	Island	Water and Land	$61,300	-	$817
9	LW, BN	Accretion beach	Island	Land	$30,600	-	$611
10	BN, LW	Transition zone	Kitsap	Land	$34,600	$26,003	$360
11	LW	Low bank	Island	Land	$20,800	-	$135
Average					***$51,100***		***$414***

** BR=Bulkhead Removal, BN=Beach Nourishment, LW=Large Wood, RE =Reslope/Revegetation, RERE=Structure Removal