Current and Historic Coastal Geomorphic (Feeder Bluff) Mapping of San Juan County, Washington

Prepared for: Friends of the San Juans
By: Coastal Geologic Services, Inc.

Andrea MacLennan, MS
Jim Johannessen, MS, LEG
Stephanie Williams, BS/BA

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COASTAL GEOLOGIC SERVICES

TABLE OF CONTENTS

Table of Tables

Table of Figures

APPENDIX 1: Map Folio

APPENDIX 2: Net Shore Drift Revisions

INTRODUCTION

Purpose

This report represents the final compilation of three mapping efforts that documented the current and historic occurrence of nearshore sediment source bluffs and associated coastal geomorphic shoreforms. These eroding bluffs are generally referred to as "feeder bluffs" (Bauer 1976). Puget Sound region bluffs are thought to provide the large majority of sediment input to beaches (Keuler 1988), perhaps exceeding 90% of total sediment input in San Juan County. The conservation of bluffs and ideally restoration (bulkhead removal) is thought to be critical to recovering nearshore habitats and species (Schlenger et al 2010, Johannessen and MacLennan 2007).

This compiled report is comprised of the results of three mapping efforts. The first two mapping projects included field mapping the current geomorphic shoretype of all shores encompassed within the drift cells of San Juan County. This final phase entailed research of the historic condition of all currently armored or modified shores. The data from the two previous phases were integrated with the results of historic research to produce an integrated dataset that can be used to identify and highlight priority restoration and conservation areas throughout the county. Puget Sound Nearshore Restoration Partnership (PSNERP) Change Analysis data on rocky shoretypes and pocket beaches can accessed for additional information on areas with No Appreciable Drift. Together these data will provide a valuable tool for resource managers and planners to better protect San Juan County nearshore processes and habitats.

On a broader scale, feeder bluff mapping in San Jan County brings the total length of Puget Sound region current conditions mapping to over 800 miles and historic condition mapping to nearly 230 miles. Feeder bluff mapping and related issues surrounding Puget Sound coastal processes and armoring are discussed in the upcoming document entitled Shoreline Armoring in Puget Sound (US Geologic Survey, in press).

Background

Bedrock Geology

The San Juan Archipelago is the northernmost sub-basin of the larger Puget Sound Basin, also referred to as part of the Salish Sea. Consisting of over 172 Islands, the San Juan Archipelago largely falls within San Juan County, excluding a number of eastern islands (such as Lummi, Eliza, Cypress, and Guemes Islands), which are within Whatcom and Skagit Counties.

The shores of San Juan County are highly variable in geomorphic character and include a broad assemblage of shoretypes including spits and barriers, tombolos, sub-estuaries, bluffs, rocky platforms, plunging rocky shores, and pocket beaches. The geology of the northern and western portions of the county is predominantly of bedrock lithology, the history of which is complex and still somewhat in question. Generally the bedrock shores of the County are described as encompassing a number of distinct terranes of varying origin and ages ranging from early Paleozoic (approximately 500 million years ago) to the mid-Cretaceous Period. The major terranes of the San Juan Islands are described below in Table 1 (Brandon et al. 1988).

The San Juan Islands structural system is thought to be structurally above the larger Wrangellia terrane (McGroder 1991), which comprises Vancouver Island. Oblique subduction of the Pacific and Farallon Plates and right-lateral strike slip faulting along the western plate boundary of North America is thought to have created a series of thrust faults that occurred in the Late Cretaceous (McGroder 1991). Thrust faults have a general northeast-southwest orientation in the San Juan Islands and bound different terranes (Brandon et al. 1988, Maekawa and Brown 1991). Low-temperature, high-pressure metamorphic rocks are associated with thrust-related burial to approximately 12 mile depths. This was followed by relatively rapid uplift, still within the Late Cretaceous (McGroder 1991), exposing the rocks at the surface.

Table 1. Major bedrock terranes of the San Juan Archipelago (Brandon et al. 1988, Johannessen 1993).

Chilliwack Terrane: Upper Triassic	Arc-volcanic sequence	Small areas on the North sides of Orcas and San Juan Islands
Turtleback Terrane: Paleozoic	Arc-plutonic and volcanic	Northwest section of Orcas Island
Deadman Bay Terrane: Permian to Lower Jurassic	Ocean-island sequence	North and West border of San Juan Island with a mid-section through Orcas Island
Garrison Terrane: Permo-Triassic	High pressure metamorphic unit	Small areas located on the S and NE border of San Juan Island and SW Orcas
Decatur Terrane: Middle to Upper Jurassic	Ophiolite and superimposed volcanic sequence	Most of San Juan Island the SE part of Orcas and most of Lopez and surrounding areas
Nanaimo Group: Cretaceous	Marine and non-marine	Northwest of Orcas Island and north of San Juan Island into Canada
Chuckanut Formation: Eocene	Continental Sedimentary deposits, rocks	North of Orcas Island and San Juan Island in Canada

San Juan Islands and Puget Sound Bluffs and Beaches

Much of the shores of the county are of a similar glacially-derived character as the rest of the Puget Sound region. The repeated advance and scouring of glacial ice sheets carved the deep troughs and channels that surround the archipelago, and left behind an immense volume of sediment that currently makes up the region’s beaches and bluffs. Sequences of glacially derived deposits and less common interglacial deposits are exposed in large portions of the county. The geology of San Juan County is displayed in Map 1. Descriptions of the geologic units that comprise the region are found in Table 2 (WDNR 2001).

Coastal bluffs are relatively recent landforms. Bluffs have formed in the “fresh” landscape left behind after the most recent ice-sheet advance (Vashon advance) and melting. Sea levels generally rose during the Vashon deglaciation global melting of ice-sheets up until approximately 4,000-5,000 years ago, which is thought to be when the current bluff configuration began to evolve.

The elevation and morphology of coastal bluffs in the study area varies due to differences in upland relief, geologic composition and stratigraphy, hydrology, orientation and exposure, erosion rates, mass wasting mechanisms, and vegetation (Shipman 2004). Bluff heights reach over 200 ft in San Juan County. Bluffs are subjected to wave attack at the toe of the slope, which contributes to intermittent bluff retreat through mass wasting events (commonly referred to as landslides) such as slumps and debris avalanches. Landslides are also initiated by hydrologic processes and land use/development changes (Tubbs 1974).

Beaches in the study area are composed of gravel and sand, whether at the toe of bluffs or along very low elevation backshores. The morphology and composition of beaches in the study area are controlled by sediment input, wave climate, and shore orientation. Bluff sediment input, primarily glacially-deposited units, is the primary source of beach sediment in Puget Sound and the Northwest Straits (Keuler 1988, Johannessen and MacLennan 2007). Landslides and erosion of these bluffs deliver sediment to the beach in moderate quantities. A secondary sediment source is rivers and streams. However, river and stream sediment input is thought to contribute only minor quantities of beach sediment in the Sound and Straits, with the majority (~90%) originating from bluff erosion (Keuler 1988). As San Juan County has very limited stream flow, beaches are likely composed of greater than 90% bluff-derived sediment.

The most basic control over beach characteristics is wave climate, which is controlled by the open water distance over which winds blow unobstructed (fetch), and the orientation of a shore relative to incoming waves. Low wave energy beaches are composed of poorly sorted sediment with a relatively narrow backshore and intermittent vegetation. Higher wave energy beaches contain areas with well-sorted sediment, often consisting of cobble, over a broad intertidal and supratidal area. Beach sediment size is strongly influenced by the available sediment coming from bluff erosion as well as wave energy, and therefore varies across the study area.

Table 2. Geologic Units of San Juan County (WDNR 2001). See Map 1.

Geologic Unit	Age	Lithology	Sub Unit Name
pDit(t)	pre-Devonian	tonalite	Turtleback Complex
pDi	pre-Devonian	intrusive rocks, undivided	
pDi(t)	pre-Devonian	intrusive rocks, undivided	Turtleback Complex
PMDmt	Permian-Devonian	metased/metavolc, undivided	
PMDvs(e)	Permian-Devonian	Volcanic, sedimentary rocks	East Sound Group
pPMsh	pre-Permian	schist, low grade	
TRPMmv	Traissic-Permian	metavolcanic rocks	
TRPMv(d)	Traissic-Permian	metavolcanic rocks	Volcanics of Deadman Bay
TRn	Triassic	nearshore sedimentary rocks	
JTRmc	Jurassic-Triassic	metasedimentary cherty	
JTRmc(o)	Jurassic-Triassic	metasedimentary cherty	Orcas Chert, Deadman Bay terrane
JTRmct(o)	Jurassic-Triassic	metasedimentary cherty	Orcas Chert, Deadman Bay terrane
Jmv(fh)	Jurassic, mid-upper	metavolcanic rocks	Fidalgo igneous complex, Hunter Bay area
Ji(f)	Jurassic	intrusive rocks, undivided	Fidalgo ophiolite, Brown et al. 1979
Jvb(f)	Jurassic	basalt flows	Fidalgo ophiolite, Brown et al. 1979
Jvb(l)	Jurassic	basalt flows	Lopez structural complex, Brandon 1988
KJm(c)	Cretaceous-Jurassic	marine sedimentary rocks	Constitution Frm., Decatur terrane
KJm(f)	Cretaceous-Jurassic	marine sedimentary rocks	Fidalgo ophiolite, Brown et al. 1979
KJm(l)	Cretaceous-Jurassic	marine sedimentary rocks	Lummi Formation
KJm(lc)	Cretaceous-Jurassic	marine sedimentary rocks	Lopez structural complex, Constitution Frm.
KJm(ll)	Cretaceous-Jurassic	marine sedimentary rocks	Lopez structural complex, Lummi Frm.
KJmm	Cretaceous-Jurassic	marine metasedimentary rocks	
KJmm(c)	Cretaceous-Jurassic	marine metasedimentary rocks	Constitution Frm., Decatur terrane
KJmm(l)	Cretaceous-Jurassic	marine metasedimentary rocks	Lummi Formation, metagraywacke
KJn	Cretaceous-Jurassic	Nearshore sedimentary rocks	
Kvb(lr)	Cretaceous	basalt flows	Lopez Island, basalts of Richardson
Km(nc)	Cretaceous	marine sedimentary rocks	Nanaimo Group, Cedar District Formation
Km(nh)	Cretaceous	marine sedimentary rocks	Nanaimo Group, Haslam Formation
Km(np)	Cretaceous	marine sedimentary rocks	Nanaimo Group, Protection Formation
Kn	Cretaceous	nearshore sedimentary rocks	Nanaimo Group
Kn(nc)	Cretaceous	nearshore sedimentary rocks	Nanaimo Group, Comox Formation
Ec(cp)	Eocene	Continental sedimentary rocks	Padden Member, Chuckanut Formation
Qga	Pleistocene	Fraser advance glacial outwash	mostly Vashon Stade in western WA
Qgd	Pleistocene	Fraser-age glacial drift	mostly Vashon Stade in western WA
Qgt	Pleistocene	Frasier-age glacial till	mostly Vashon Stade in western WA
Qgdm	Pleistocene	Frasier-age glaciomarine drift	Everson Interstade
Qgdm(e)	Pleistocene	Frasier-age glaciomarine drift	Everson Glaciomarine Drift
Qgdm(es)	Pleistocene	Frasier-age glaciomarine drift	Everson-age glaciomarine drift subtidal
Qgo	Pleistocene	Frasier-age glacial outwash	mostly Vashon Stade in western WA
Qgom	Pleistocene	Frasier glacial outwash,marine	mostly Vashon Stade in western WA
Qgom(e)	Pleistocene	Frasier glacial outwash,marine	Everson Glaciomarine Drift outwash
Qd	Quaternary	dune sand	
Qp	Quaternary	peat deposits	
Qb	Holocene	beach deposits	
Qf	Holocene	artificial fill, modified land	
Qa	Holocene	alluvium	
tz	Fault related	tectonic zone	
tz(o)	Fault related	tectonic zone	Tectonic zone on Orcas Island

Beaches are accumulations of sediment along a shore. As sediment is transported along a beach, it must be continuously replaced for the beach to maintain its integrity. The erosional nature of the majority of Puget Sound and Northwest Straits beaches is evident in that most beaches generally consist of a thin veneer of sediment that is only 3-10 inches thick vertically, atop eroding glacial deposits (Johannessen and MacLennan 2007).

A beach serves as a buffer against direct wave attack at the bluff toe. The value of a "healthy" beach fronting a coastal bluff should not be underestimated for absorbing storm wave energy. A gravel berm can serve as a resilient landform with an ability to alter shape under different wave conditions, effectively dissipating most wave energy. Storm waves do reach bluffs, causing erosion and mass wasting, which delivers sediment to the beach and is vital to maintaining the beach. Therefore, bluffs, beaches, and nearshore areas are *completely connected as integral parts of* a coastal system. Past and current management typically treated the bluffs and beaches as separate parts of the coastal system, which has resulted in substantial negative impacts to coastal systems and nearshore habitats and wildlife.

Net Shore-drift

To understand the processes controlling nearshore systems and their continued evolution, the three-dimensional sediment transport system must be examined. The basic coastal processes that control the “behavior” of the beach will be explained first and then put into the context of “drift cells”. Shore drift is the combined effect of **longshore drift**, the sediment transported along a coast in the nearshore waters, and **beach drift,** the wave-induced motion of sediment on the beach face in an alongshore direction. While shore drift may vary in direction seasonally, **net shore-drift** is the long-term, net effect of shore drift occurring over a period of time along a particular coastal sector (Jacobsen and Schwartz 1981).

The concept of a **drift cell** has been employed in coastal studies to represent a sediment transport sector from source to terminus along a coast. A drift cell is defined as consisting of three components: a site (erosional feature or river mouth) that serves as the sediment source and origin of a drift cell; a zone of transport (and often additional sediment input), where wave energy moves drift material alongshore; and an area of deposition that is the terminus of a drift cell. Deposition of sediment occurs where wave energy is no longer sufficient to transport the sediment in the drift cell.

Previous drift cell mapping efforts such as the Coastal Zone Atlas of Washington (WDOE 1979) relied exclusively on historic wind records. That method is known as wave hindcasting, where inland wind data records were used for the determination of net shore-drift, without consideration of local variations in winds, landforms, or coastal morphology. Drift directions indicated in the atlas series have commonly been proven inaccurate by extensive field reconnaissance (i.e. Jacobsen and Schwartz 1981, Johannessen 1993). For example, wind records from the Bellingham Airport were used to hindcast waves for all of San Juan County in the Coastal Zone Atlas. When the geographic complexity of the Puget Sound and Northwest Straits, and subsequent variability of the surface winds, in addition to the seasonal variability of atmospheric circulation and the locally varying amount of drift sediment are considered, the geomorphic approach described above (Jacobson and Schwartz method) is better suited to the physical conditions of the region than traditional engineering methods like hindcasting.

Net shore-drift is strongly influenced by several oceanographic parameters. The most important of which are waves, which provide the primary mechanism for sediment erosion, inclusion of sediment into the littoral system, and transport. The Puget Sound and Northwest Straits are composed of inland waters exhibiting an extreme range of wave regimes. Storm wave heights become relatively large during prolonged winds, in contrast to chop formed during light winds, which has little geomorphic effect on coasts (Keuler 1988). Ocean swells reach the southwest shore of San Juan Island, due to the direct connection through the Strait of Juan de Fuca.

Fetch has been proven to be the most important factor controlling net shore-drift in fetch-limited environments (Nordstrom 1992). This has been demonstrated locally by a number of workers (Downing 1983). Due to the elimination of ocean swell in protected waters, waves generated by local winds are the primary transport agents in the littoral zone. The direction of maximum fetch that acts on a shoreline segment will correspond with the direction of the largest possible wave generation, and subsequently, the direction of greatest potential shore drift. Where fetch is limited the wind generates the largest waves possible in fairly short time periods.

Shore Modifications

Erosion control or shore protection structures are common in the study area. Residential and industrial bulkheads (also called seawalls) are typically designed to limit the erosion of the backshore area or bluff, but have numerous direct and indirect impacts on nearshore systems (Johannessen and MacLennan 2007). Seawalls and bulkheads are installed more routinely as property values have raised and marginal lands are developed. The effects of bulkheads and other forms of shore armoring on physical processes have been the subject of much concern in the Puget Sound region (for example, PSAT 2003). MacDonald et al. (1994) completed studies assessing the impacts to the beach and nearshore system caused by shore armoring at a number of sites. Additional studies on impacts from shoreline armoring have quantitatively measured conditions in front of a bulkhead and at adjacent un-bulkheaded shores and showed that in front of a bulkhead the suspended sediment volume and littoral drift rate all increased substantially compared to unarmored shores, which resulted in beach scouring and lowering along the armored shores studied (Miles et al. 2001).

A bulkhead constructed near the ordinary high water mark (OHWM) in a moderate energy environment increases the reflectivity at the upper beach substantially, causing backwash (outgoing water after a wave strikes shore) to be more pronounced. Increased backwash velocity removes beach sediment from the beachface, thereby lowering the beach profile (MacDonald et al. 1994). A bulkhead constructed lower on the beach causes greater impacts (Pilkey and Wright 1988). Construction of a bulkhead at or below OHWM often results in coarsening of beach sediment in front of the bulkhead (MacDonald et al. 1994). Relatively fine-gain size sediment can be mobilized by the increased turbulence caused by the bulkhead (Miles et al. 2001), and is preferentially transported away, leaving the coarser material on the beach. This process also leads to the removal of large woody debris (LWD) from the upper beachface. Over the long term, the construction of bulkheads on an erosional coast often leads to the loss of the beach (Fletcher et al. 1997).

Of all the impacts of shore armoring in the Puget Sound and Northwest Straits, sediment impoundment is probably the most significant negative impact (Johannessen and MacLennan 2007). A structure such as a bulkhead, if functioning correctly, “locks up” bluff material that would otherwise be supplied to the net shore-drift system. This results in a decrease in the amount of sediment available for maintenance of down-drift beaches. The negative impact of sediment impoundment is most pronounced when armoring occurs along actively eroding bluffs (MacDonald et al. 1994, Griggs 2005). Additionally, the extent of cumulative impacts from several long runs of bulkheads is a subject of great debate in the coastal research and management communities.

Coastal Processes and Nearshore Habitat

Shore modifications, almost without exception, damage the ecological functioning of nearshore coastal systems. The proliferation of these structures has been viewed as one of the greatest threats to the ecological functioning of coastal systems in the Puget Sound region (PSAT 2003, Thom et al. 1994). Modifications often result in the loss of the very feature that attracted coastal property owners in the first place, the beach (Fletcher et al. 1997).

With bulkheading and other shore modifications such as filling and dredging, net shore-drift input from bluffs is reduced and beaches become “sediment starved.” The installation of structures typically results in the direct burial of the backshore area and portions of the beach face, resulting in reduced beach width (Griggs 2005) and loss of habitat area. Beaches would also become more coarse-grained as sand is winnowed out and transported away. When fines are removed from the upper intertidal beach due to bulkhead-induced impacts, the beach is often converted to a gravel beach (MacDonald et al. 1994). A gravel beach does not provide the same quality of habitat as a finer grained beach (Thom et al. 1994). Large woody debris (LWD) is usually also transported away from the shore following installation of bulkheads, with corresponding changes in habitat (Brennan 2007). This leads to a direct loss of nearshore habitats due to reduction in habitat patch area.

Habitats of particular value to the local nearshore system that may have been substantially impacted include forage fish (such as surf smelt and pacific sand lance) spawning habitat. These habitat areas are only found in the upper intertidal portion of fine gravel and sand beaches, with a high percentage of 1-7 mm sediment (Penttila 1978). Beach sediment coarsening can also affect hardshell clam habitat, by decreasing or locally eliminating habitat.

Bulkheading also leads to reduction in epibenthic prey items, potentially increased predation of salmonids, loss of organic debris (logs, algae) and shade, and other ecological impacts (Thom et al. 1994). The reduction in beach sediment supply can also lead to an increase in coastal flooding and wave-induced erosion of existing low elevation armoring structures and homes.

Nearshore habitat assessments in the Puget Sound and Northwest Straits have found that large estuaries and small “pocket” estuaries provide very high value nearshore habitat for salmon as well as other species (Beamer et al. 2003, Redman and Fresh 2005). Reduction in net shore-drift volumes due to bulkheading and other modifications and site-specific impacts induced by modifications can cause partial or major loss of spits that form estuaries and embayments. Therefore, with consideration of all these factors, shore modifications can have substantial negative impacts on nearshore habitats.

Climate Change and Sea Level Rise

The predicted increased rate of sea-level rise, as a result of global warming, will generally lead to higher coastal water levels, thereby altering geomorphologic configurations, displacing ecosystems and increasing the vulnerability of infrastructure (IPCC 2001, Pethick 2001). Recent research has also reported that non-bedrock shores, such as the glacially-derived material that makes up most of the region’s bluffs, are likely to retreat more rapidly in the future due to an increase in toe erosion resulting from sea-level rise. Retreat rates may also be amplified in many areas due to increased precipitation, storminess (wave energy), storm frequency and higher ground water levels (Hosking and McInnes 2002, Pierre and Lahousse 2006).

Changes in sea level will also result in a spatial adjustment, landward and upwards, following a concept known as the Bruun law (1962). This basic idea (though its accurate application to individual beaches is not well understood) appears to apply to all coastal landforms (Pethick 2001). The landward migration of the shoreline is a response to the changes in energy inputs brought about by sea-level rise. Knowing that this translation is to occur offers resource managers a tool, allowing decisions to be made to accommodate and, where possible, facilitate such migration (Pethick 2001).

Accommodating space to enable shoreline translation can enable salt marshes, sand dunes, and beaches to transgress (move landwards while maintaining their overall form). This concept is commonly referred to as “managed retreat” (Cooper 2003). Accommodating sea level rise prevents the diminishment and loss of natural features such as intertidal, upper beach and dune habitats, from being lost between a static backshore (such as a bulkhead or rock revetment) and rising sea level. The concept is commonly referred to “the coastal squeeze”.

As a result of these processes related to global climate change, the shores of the San Juan Islands will undoubtedly incur considerable habitat loss along its modified shores, unless managers choose to take a proactive approach and start initiating programs focused on accommodating sea level rise and utilizing strategies such as managed retreat (e.g. removing shore armoring, relocating coastal roads, etc). There will also be further pressure to construct emergency erosion control structures as a result of increased erosion rates, storminess and storm frequency. Permitting the building of additional bulkheads is not likely to provide a long-term solution to the erosion control, and will only amplify habitat loss caused by the coastal squeeze.

San Juan County Coastal Processes

The entire study area is encompassed within the San Juan Archipelago in San Juan County, Washington. The water bodies that comprise the waters include Haro Strait, the Strait of Juan de Fuca, Rosario Strait, Boundary Pass, Spieden Channel, San Juan Channel, Harney Channel, and Presidents Channel . San Juan, Orcas, Lopez and Shaw Islands are substantially larger, have ferry service, and are considerably more developed that the other islands included in this mapping effort.

Tidal range, defined as the average difference in height between mean higher high water (MHHW) and mean lower low water (MLLW), is 4.3 to 4.9 feet (WDNR 2001). Stronger tidal currents are known to occur in Johns Pass between Stewart and Johns Island, Obstruction Pass between Orcas and Obstruction Islands and Peavine Pass between Obstruction and Blakely Islands. Maximum current velocities depend on tidal range and vary by season with the strongest currents occurring during December when the greatest tidal ranges are observed. Flooding currents flow north around the Islands from the Straits. Tide waters reverse on the ebb tide, flowing south through the Straits and then west out to the Pacific Ocean.

This coastal geomorphic assessment was initiated by assembling the most current data sets relating to coastal processes in the region. There are currently three different net shore-drift data sets for the study area. These include the original paper maps (Johannessen 1992, Johannessen 1993), the first digital version by the Washington State Department of Ecology (GIS data in the Washington Coastal Atlas by the Washington State Department of Ecology (DOE)), and a recently revised versions of that data. The original field mapping for San Juan County was conducted by Coastal Geologic Services president Jim Johannessen for his master's thesis research (1993) at Western Washington University, under the direction of Dr. Maury Schwartz. The net shore-drift studies were conducted through systematic field investigations of the entire coast to identify geomorphologic and sedimentologic indicators that revealed net shore-drift cells and drift direction (Jacobsen and Schwartz 1981). The methods employed in net shore-drift mapping utilized 9-10 well-documented, isolated indicators of net shore-drift in a systematic fashion (Johannessen 1993).

The DOE interpreted and digitized the Johannessen (1993) mapping, during the process of which the mapping was altered somewhat. Large portions of the study area were digitized as "UN", or unidentified, in the DOE digital data. In 2007, CGS was contracted by the US Army Corps of Engineers to revise some errors in the DOE digital data as well as map historic drift throughout the Puget Sound and Northwest Straits. The revised Corps data set is still in the review process with DOE; therefore it could not be published as part of this study. However, for the purpose of this study, Coastal Geologic Services further revised the most up-to-date digital version of the net shore-drift mapping in San Juan County to represent current conditions. This new data set should be considered the most accurate and contemporary net shore-drift data for the county and will be included in the package of final deliverables for Phase 3.

San Juan County Nearshore Habitats

The San Juan County nearshore encompasses each of the major habitat types described as occurring in Washington State including eelgrass meadows, kelp forests, tidal flats, tidal marshes, sub-estuaries, sand spits, beaches and backshore, banks and bluffs, and marine riparian vegetation. These habitats support biological resources that are of value and concern to differing agencies and stakeholders. These include benthic macroinvertebrates (shellfish) that are of commercial or recreational significance, selected forage fish, groundfish, and salmonids of concern to Washington State Department of Fish & Wildlife (WDFW), and key marine birds and mammals of interest to WDFW.

Forage fish represent a critical link in the marine food chain and constitute a major portion of the diets of other fishes, including Endangered Species Act listed Puget Sound salmonids, seabirds and marine mammals. Forage fish spawning areas have been declared “saltwater habitats of special concern” (WAC 220-110-250; WAC 1994b). The preservation of forage-fish spawning habitat is known to benefit other species that utilize nearshore habitats including juvenile salmon and shorebirds (Penttila 2007).

Three species of forage fish (surf smelt, sand lance, and Pacific herring) utilize the San Juan County nearshore for spawning and rearing. Surf smelt spawn in the upper intertidal zone of beaches comprised of a mix of coarse sand and “pea” gravel. San Juan County supports year-round surf smelt spawning (Penttila 2000). Sand lance typically spawn on beaches with slightly finer sediment composition that extends slightly lower on the beach. Sand lance spawning activity has been identified on a number of beaches throughout San Juan County. Sand lance spawning occurs from early November through February (Penttila 1995).

Pacific herring’s demersal/adhesive eggs are generally deposited on broad intertidal and shallow subtidal beds of native eelgrass (*Zostera marina*), red algae (*Gracilariopsis*) and possibly brown kelp (*Laminaria*), and green sea lettuce (*Ulva sp*.) in San Juan County. Herring spawn in the Westcott-Garrison Bay-Roche Harbor area, West Sound and East Sound (Orcas Island), Blind Bay (Shaw Island) and Shoal and Mud-Hunter Bays (Lopez Island).

Despite the fact that numerous high quality habitats of recognized importance to resource agencies are found in San Juan County, considerable habitat alteration and degradation has occurred as a result of commercial and residential shoreline development. Numerous scientists have recommended better preservation of the remaining San Juan County nearshore resources as documented in *San Juan Initiative Protection Assessment Nearshore Case Study Area Characterization* (MacLennan and Johannessen 2008) and the San Juan County Marine Stewardship Area Plan (San Juan County Marine Resources Committee 2007). The primary objective of this study addresses this challenge by explicitly mapping coastal geomorphic processes within the drift cells of San Juan County, with the over-arching goal of informing resource managers and providing tools that will enable better preservation and restoration of San Juan County beaches, habitats, and the processes that sustain and maintain them.

METHODS

Purpose and Rationale

This study employed a process-based approach, which assumes that intact coastal geomorphic processes require functioning sediment sources and transport pathways to maintain beaches and depositional areas. The larger and more populated islands, Orcas and San Juan Islands, contain many anthropogenic alterations which have contributed to degradation of coastal geomorphic processes along portions of the study area shores. The relatively infrequent distribution of bluff (non-bedrock) shores and contrasting wave environments implies that preserving existing intact coastal processes is critical to maintaining ecological function. This mapping of the current geomorphic shoretypes can be used to measure how intact coastal processes are within the drift cells of the study area. Additionally, this mapping can inform planners and other resource managers as to where to best conserve and restore nearshore geomorphic processes.

Current conditions mapping was conducted in the field based on interpretation of coastal geomorphic and geologic features and trends, and was supplemented by aerial photo review, as explained below. Mapping was completed on the decadal to century time scale, meaning that geomorphic shoretypes mapped were characteristic of physical processes that take place over the decade to century time frame, although the characterization likely applies for longer-term processes in most areas. However, mapping feeder bluffs in the field is somewhat dependent on recent landslide activity at a particular site, such that mapping may not always apply to processes taking place over longer time scales.

The use of primarily geomorphic indicators observed in the field is not new in the Puget Sound region, as the net shore-drift mapping published by the Washington State Department of Ecology (DOE) that is now in wide use employed very similar methods (for example, Schwartz et al. 1991, Johannessen 1992). This same feeder bluff mapping approach has been applied to over 800 miles of the Puget Sound region shore to date. Net shore-drift mapping reported in the DOE digital drift cell dataset was updated by Coastal Geologic Services during this study. The updated net shore-drift mapping is displayed in Maps 2-4. The proceeding sections provide detailed descriptions of the methods applied to complete current and historic geomorphic mapping of San Juan County.

Current Conditions Mapping

This task was accomplished primarily through new field mapping, based on applying a mapping criteria (Table 3) developed primarily for feeder bluff mapping of Island County (Johannessen and Chase 2005) and King and southern Snohomish Counties (Johannessen et al. 2005). As previously mentioned the study area consisted of all the drift cells that comprise San Juan County, for this compiled report. The entire shore of this study area was visited during field mapping. Additional analysis was carried out using field observations, field photos, and aerial photography. Field mapping data were checked through a review of oblique aerial photos taken in August of 2006 by the Department of Ecology, vertical aerial high resolution Color IR (WDNR) orthophotos from 2004 and 2006, and Best Available Science (BAS) documents. Relevant data sources used to augment field observations include geologic maps, atlases, and historic T-sheet maps.

Mapping Segments

All of the shore included in the study area was delineated into one of 5 different alongshore segments: feeder bluff exceptional, feeder bluff, transport zone, accretion shoreform, and modified. Three other CGS shoretypes were not included this mapping effort: no appreciable drift, no appreciable drift-bedrock, and pocket beach. These shoretypes are typically found outside of net shore-drift cells which were not addressed in this mapping effort. Bedrock shoretypes and pocket beaches were mapped as part of another recently completed regional mapping effort (PSNERP Change Analysis; Simenstad et al. 2009), the data from which will be integrated with the CGS mapping during phase 3 of this multi-phase project. Toe erosion and landslides were mapped as ancillary data within/across these five different shoretype segments. The segments were delineated into the following shoretypes:

The **Feeder Bluff Exceptional (FBE)** classification was applied to rapidly eroding bluff segments. This classification was meant to identify the highest volume sediment input areas per lineal foot (Figure 1a). This classification was not common in the study area. Feeder bluff exceptional segments were characterized by the presence of recent large landslide scarps, and/or bluff toe erosion. Additionally, a general absence of vegetative cover and/or portions of bluff face fully exposed were often used for this classification. Other indicators included the presence of colluvium (slide debris), boulder or cobble lag deposits on the beach, and fallen trees across the beachface. Feeder bluff exceptional segments lacked a backshore, old or rotten logs, and coniferous bluff vegetation. See Table 3 for a summary of mapping criteria.

The **Feeder Bluff (FB)** classification was used for areas of substantial sediment input into the net shore-drift system (Figure 1b). Feeder bluff segments have periodic sediment input with a longer recurrence interval as compared to feeder bluff exceptional segments. Feeder bluff segments were characterized by the presence of historic slide scarps, a lack of mature vegetation on the bank, and intermittent bank toe erosion. Other indicators included downed trees over the beach, coarse lag deposits on the foreshore, and bank slope.

Transport Zone segments represented areas that did not appear to be contributing appreciable amounts of sediment to the net shore-drift system, nor showed evidence of past long-term accretion. Transport zones are shore segments where net shore-drift sediment is primarily transported alongshore (Figure 1c). The segments were delineated based on the lack of erosional indicators (discussed above for feeder bluff exceptional and feeder bluff segments) and the lack of accretion shoreform indicators such as a wide backshore area or a spit. This classification was meant to exclude areas that were actively eroding; however, transport zones typically occur along banks that experience landsliding and/or erosion at a very slow long-term rate, such that sediment input is minimal.

The **Accretion Shoreform** classification was used to identify areas that were depositional in the past or present. These segments were classified based on the presence of several of the following features: broad backshore area (greater than 10 ft), backshore vegetation community, spit and/or lagoon landward of a spit. Additional indicators for delineating an accretion shoreform were the presence of relatively fine-grained sediment or very old drift logs in the backshore (Figure 1d).

The **Modified** classification was used to designate areas that have shore modifications such as bulkheads or have otherwise been altered to a state where the natural geomorphic character of the shore is largely concealed such that the bank no longer provides sediment input to the beach system (Figure 1e). This included armored areas where the bulkhead was still generally intact and functional, as well as areas with substantial fill at the shore. Fill areas could be large, industrial areas, marinas with revetments, road ends extending over the beach, or residential areas with smaller amounts of fill and structures.

a) Feeder bluff exceptional - north Waldron Island b) Feeder bluff - White Cliffs, Decatur Island

c) Transport zone - Blind Bay, Shaw Island d) Accretion shoreform - Indian Cove, Shaw Island

e) Modified - southeast East Sound, Orcas Island

Figure 1. Photos of representative geomorphic shoretypes for the study area. Photos a-e by CGS.

Table 3. Current conditions field mapping criteria (adapted from Johannessen and Chase 2005).

Feeder Bluff Exceptional Mapping

Presence of (priority in order):	*Absence of:*
1. Bluff/ bank	1. Shoreline bulkhead/ fill
2. Recent landslide scarps	2. Backshore
3. Bluff toe erosion	3. Old/ rotten logs
4. Abundant sand/gravel in bluff	4. Coniferous bluff vegetation
5. Colluvium/ slide debris	5. Bulkhead
6. Primarily unvegetated or vegetated slumps	
7. Trees across beach	
8. Boulder/ cobble lag	
9. Steep bluff (relative alongshore)	

Feeder Bluff Mapping

Presence of (priority in order):	*Absence of:*
1. Bluff/ bank	1. Shoreline bulkhead/fill
2. Past landslide scarps	2. Backshore
3. Intermittent toe erosion	3. Old/rotten logs
4. Moderate amount sand/gravel in bluff	4. Coniferous bluff vegetation
5. Intermittent colluvium	5. Bulkhead
6. Minimal vegetation	
7. Trees across beach	
8. Boulder/ cobble lag	
9. Steep bluff (relative alongshore)	

Transport Zone Mapping

Presence of (priority in order):	*Absence of:*
1. Coniferous bluff vegetation	1. Visible landslide scarps
2. Apparent relative bluff stability	2. Toe erosion
3. Gentle slope bluff (relative alongshore)	3. Backshore & backshore vegetation
4. Unbulkheaded transport zone adjacent	4. Old/rotten logs
	5. Colluvium
	6. Trees across beach
	7. Bulkhead

Modified Mapping

Presence of (priority in order):	*Absence of:*
1. Bluff/bank	1. Backshore & backshore vegetation
2. Shoreline bulkhead (mostly intact)	2. Lagoon/wetland/marsh behind berm
3. Substantial shoreline fill	3. Backshore “platform”
	4. Old/rotten logs
	5. Fine, well sorted sediment (relative alongshore)

Accretion Shoreform Mapping

Presence of (priority in order):	*Absence of:*
1. Backshore & backshore vegetation	1. Bluff/bank in backshore
2. Lagoon/wetland/marsh behind berm	2. Toe erosion at bank
3. Backshore “platform”	3. Landslide scarps
4. Old/rotten logs	4. Boulders on beachface
5. Fine, well-sorted sediment (relative alongshore)	5. Bulkhead

NOTE: Criteria in order of importance & features present take priority over features absent

Ancillary Data

Ancillary data, including toe erosion and recent landslides, was collected to supply additional information for potential future work and to support the mapping of feeder bluff exceptional and feeder bluff segments. These two data sets were mapped in independent of shoretype mapping and were buffered offshore in GIS for display in maps.

Bluff **Toe Erosion** was mapped where a discernable erosional scarp, created by direct wave attack, was present at the toe of the bluff/bank. Toe erosion scarps consisted of portions of the bluff toe where all lower bluff and backshore vegetation was absent/removed, and the lower bluff contained very steep cuts into native bluff deposits and/or non-native fill based on field reconnaissance. In some areas these features were present along with minor (recent) accumulations of drift logs. Toe erosion was mapped only where it appeared to have occurred in the preceding 2-3 years. If the toe erosion scarp extended more than 10 ft vertically such that it triggered some amount of mass wasting, it was mapped as toe erosion and as a landslide area.

Landslides were mapped in areas where evidence of recent slides was present based on field reconnaissance. This classification was mapped in areas where landslides appeared to be active in the preceding 2-3 years. Landslide segments were field-mapped in areas that typically had an exposed bluff face devoid of vegetation (or with very thin grass or other pioneer species) with an arc shaped or scalloped scarp pattern at the upper extent of the landslide, and some evidence of the recent nature of the slide such as downed trees and/or presence of colluvium (slide debris) at the toe of the slope. Although typically indicative of feeder bluffs, landslides were also occasionally located within transport zones. Mapped recent landslides within shoretypes other than feeder bluffs generally occurred within protected (lower wave energy) shores. This counter-intuitive scenario can be attributed to the number of variables of influence to coastal geomorphic processes including shore orientation and geologic exposures within the more protected portions of San Juan County. In general, the more protected portions of San Juan County shores are some of the most complex and variable shore reaches within the greater Puget Sound region, and this has contributed to some of the apparent contradiction of having landslides within non-feeder bluff segments.

Field Mapping Procedure and GIS Processing

All features were mapped from a small boat at mid to high water times with good visibility. Field mapping criteria (Table 3) were used to map individual segments in the field based on observed shoreline features. Positional data were recorded using a handheld *Trimble GeoXH 2008* GPS unit in the UTM NAD83 coordinate system. The GPS unit was WAAS (wide area augmentation system) enabled, and generally had accuracy of +/- 1.5 ft after post processing. Positions were recorded at the beginning and end of each field-mapped segment as close inshore to the position of mean high water (MHW) as possible. The positions were correlated to segments, ancillary data, photographs and notes that were recorded on field forms. A total of 1413 positions were collected over the course of 11 days of field mapping from the spring and fall of 2009.

The GPS data were downloaded for processing using Pathfinder Office (Trimble Corporation), where the data were post-processed using reference station SC02 from Washington State Reference Network (http://www.wsrn.org/). Post-processed data were then exported into ESRI shapefile format. The shapefile was renamed and assigned the appropriate projection that they were collected in (UTM NAD83), and then ready for use in ArcMap 9.2 where the FID_1 field correlated to field data forms.

The GPS points were added into ArcMap, along with digital background information, which included US Geological Survey (USGS) quadrangles, high resolution Color IR (WDNR) orthophotos from 2004 and 2006, the Shorezone shoreline (WDNR 2001), and historic topographic sheets (T-sheets). Features were digitized within ArcMap at a scale no larger than 1:3,000 using the field notes and visually interpolating the points shore-normal (perpendicular) to the shoreline. All shoretype mapping was snapped to the WDNR Shorezone shoreline (2001) and to the ends of each CGS shoretype segment. The final map products were produced at 1:24,000 scale, which has an accuracy standard of better than 67 ft for 90% of known points (United States National Map Accuracy Standards). The reported accuracy of the GPS unit while mapping in the field (with WAAS enabled) averaged 7.2 ft with a standard deviation of 2.8 ft. These field data were corrected with post processing +/- 1.5 ft, as stated above.

Parcel Processing

All CGS shoretype mapping was delineated and attributed with the San Juan County parcel data to allow for a spatial join of the two datasets to inform the San Juan County planners and resource managers. The parcel boundary shapefile dated 6/23/2009 was obtained from San Juan County GIS Data Download Library. The shoretype data did not overlap the parcels in many locations, so further processing was required to associate the non-overlapping shoretypes with the closest parcel. The ArcGIS Euclidean allocation tool was used to “extend” Parcel boundaries waterward by 100 ft. The resulting raster data were converted to polygons and then intersected with the shoretypes. This resulted in the shoretype segments being further split and associated with the nearest parcel.

Shoretype data at the parcel level can help managers and planners identify specific parcels encompassed within sensitive shoreforms, such as feeder bluffs and accretion shoreforms, within which development may be restricted or otherwise more closely considered.

Historic Conditions Mapping

The objective of the historic analysis portion of this study was to characterize the historic (pre-development) geomorphic character of marine shores of San Juan County. Two of the seven shoretypes used for the current conditions mapping (feeder bluff exceptional and feeder bluff) plus two additional shoretypes, *potential* feeder bluff and *not* feeder bluff, were used to classify the historic character of all currently modified shoreforms.

Because the biological assemblages and ecosystem structure of Puget Sound shorelines are largely dependent upon substrate size and quantity, understanding the historic nearshore geomorphic conditions (including sediment supply to drift cells) provides a valuable management tool. This is critical as considerable portions of the study area shores are modified. Comparing current and historic conditions elucidates the location and measured loss of sediment sources within each drift cell. This enables managers to prevent further degradation of nearshore sediment systems, while providing relevant historic data for prioritizing restoration aimed at reintroducing sediment into net shore-drift cells that are particularly “starved” of sediment as compared to their historic condition.

Due to limitations in documentation of pre-development data and imagery, a complete mapping of historic shoretypes was not possible with accuracy even close to current conditions mapping. Therefore, the current conditions mapping was used as a starting point for historic sediment source mapping. All areas characterized as modified in the current conditions mapping were analyzed in detail to determine their historic character. All other mapped current conditions segments were assumed to be the same in the pre-development period. A potential weakness of this assumption results from the fact that time lags often exist between erosion, transport and deposition of unconsolidated sediment (Brunsden 2001). Since current conditions mapping documents the present geomorphic character of the study area’s shores, and beaches are inherently dynamic features, it is possible for some shore segments to have changed geomorphic character during the period between pre-development and current conditions. An example of this may be that a former transport zone may have been gradually changed into a feeder bluff in the absence of continued natural sediment supply volumes. However, the chance that substantial reaches of the coast had changed geomorphic character is low in the relatively low wave-energy conditions of Puget Sound and data limitations preclude a more complete historic analysis.

Historic Sediment Source Index (HSSI)

Documented historic conditions are assumed to be close to pre-development conditions and represented by a range of time periods based on data availability (1885-1897). Historic Sediment Source Index (HSSI) methods were first developed for a study of the (current and) historic conditions of King County (Water Resource Inventory Areas 8 and 9) shores by Johannessen, MacLennan and McBride (2005). These methods rely heavily on concurrence between available data sets, Best Available Science, and previous work performed in portions of the present study area with similar objectives. Data used in the analysis are listed in Table 4. In an attempt to produce an analytical method that could be applied to the entire study area, datasets that included as much of the study area as possible were selected over those with only partial coverage.

Index Methods **–** Assessment of historic sediment sources in the study area was conducted by scoring each modified segment (or sub-segment) of shoreline from CGS current conditions mapping using an index developed by CGS, the HSSI requires investigation of reach topography, surface geology, known landslide history, landscape and net shore-drift context, historic topographic maps, and historic air photos.

Preliminary analysis of shoreline homogeneity within each modified shore segment was conducted to determine if delineation of smaller sub-segments was required or not. This process was particularly relevant where shoreline modifications extend across shores of contrasting historic character. US Geologic Survey (USGS) topographic maps, historic T-sheets and air photos, and the Washington State Department of Ecology shoreline oblique air photos were used to delineate sub-segments of consistent shore character and topography (high bluff, low bank, broad backshore) and the degree of development or modification dating as far back as possible within the segment.

Index questions for the HSSI were chosen based on beach and upland characteristics that are most indicative of nearshore sediment sources, as well as data availability. Index questions were largely based on the presence or absence of characteristics that indicate the likelihood of the segment being a sediment source; however, some questions required measured or categorical data. The maximum fetch (open water distance) of each segment was measured in miles using the GIS measurement tool. This feature was chosen since wave height and erosive power is controlled by fetch in inland waters (Nordstrom 1992). Typical bluff height was estimated using contours on USGS 7.5 minute topographic maps. Bluff height was chosen for the obvious reason that a higher bluff contributes a greater volume of sediment than lower bluffs with other factors equal. The dominant surficial geologic unit was recorded and valued based on its utility as beach sediment. Segments that were mapped as sedimentary deposits that were predominantly composed of coarse sand and/or gravel were considered more valuable than those with finer sediment such as silt or clay. The lithology of each geologic units exposed in the study area are found in Table 2. Historic vertical air photos from 1960 (1970 for parts of Waldron Island only) were georeferenced and assessed for visible indicators of erosion and mass wasting within segments. Erosional areas were identified by one or more of the following characteristics: fallen and jack-strawed trees over the intertidal, banks or bluffs largely free of vegetative cover, visible colluvium and/or toe erosion at the base of the bluff, bolder lag deposits, and a substantial change in the distance between the bank or bluff crest and the Shorezone shoreline.

Each segment was then scored using the HSSI, which produces a value conveying the relative likelihood of that shore segment as a source of substantial littoral sediment: “historic feeder bluff” (see Table 5, index score sheet). Segments with very low index scores were likely “not feeder bluffs”, or historic transport zones or accretion shoreforms. Segments with extraordinarily high scores were likely to be “feeder bluff exceptional” (see current conditions mapping in the *Methods* section for shoretype descriptions).

Segments were individually scored within a GIS using available data for analysis (Table 4). Source data covered nearly the entire study area with varying levels of inconsistency. Inconsistencies in data sets included only partial coverage of the study area in a 1960s vertical aerial photos.

Table 4. Available data for analysis of historic conditions of San Juan County.

Media	Year	Source	Coverage & Applicability, Misc.	
Vertical aerial photography				
	1960	San Juan Cty	Most of the study area, black and white, 1:12,000, georeferenced	
	1970	San Juan Cty	Waldron Is, black and white, 1:12,000, georeferenced	
	2008	San Juan Cty	All study area, six-inch pixel, orthorectified	
Oblique aerial photos				
	1977	WA Coastal Atlas	Department of Ecology Shoreline obliques online.	
	1995	WA Coastal Atlas	Department of Ecology Shoreline obliques online.	
	2002	WA Coastal Atlas	Department of Ecology Shoreline obliques online.	
	2006	WA Coastal Atlas	Department of Ecology Shoreline obliques online.	
Maps				
	1885-1897	USC&GS	T-sheets no: 2229, 2192, 1954, 2230, 1952, 1748, 2300, 2302, 2301, 2194, 1955, 1953, 1951, and 1870.	
Vector data	**Year**	**Source**	**Theme**	**Notes**
	2005	B. Collins and Sheikh T-sheet interp.	Cartographic symbol mapping	Mapped boulder lag deposits in intertidal
	2001	WADGER	Surface Geology	Mapped Qb, Qls
	1979	DOE-CZA	Slope stability	Recent landslides
	1979	DOE-CZA	Slope stability	Historic landslides
	2009/10	CGS	Shoretype	FBE, FB, TZ, AS, Mod
	2009/10	CGS	Recent landslides	In previous 2-3 yrs
	2009/10	CGS	Recent toe erosion	In previous 2-3 yrs

Table 5. Historic Sediment Source Index score sheet.

Score	Question	Answer		
0, 2, 4, 6	Measured Fetch (mi) 0=0<5, 2=5<10, 4=10<15, 6=15+			
0, 3, 5, 7, 9,12	Maximum bluff height. First contour must be within 100 ft of shorezone shoreline. 0=0ft, 3=20-40 ft 5=40-80, 7=80-120, 9=121-200, 10=200+.			
0, 2, 3, 5, 6	Geology: dominant unit in segment 6=Qva, 5=Qvrme; Qvrmo, 3=Ql; Qvrms, 2= Qvrmd, Qvt, Qvd,**			
10	Mapped as "eroding bank "or "bluff" in Tsheet interp. (Collins and Sheikh 2005).	Y	N	
15/0	1960/70 visual evidence of eroding bluff; including slides, slumping, scarps, trees in intertidal etc.	Y	N	
5	Older slides (Qls or Uos) within 500 ft of segment?	Y	N	
5	Recent slides within 500 ft of segment?	Y	N	
5	Landslide(s) mapped by CGS within 500 ft of segment?	Y	N	
2, 5	Adjacent to feeder bluff in CGS current conditions mapping; or historic feeder bluffs (score adjacent cells first) (2 pts for one adjacent FB)	FB 1	FB 2	N
2	Within 500 ft of divergent zone?	Y	N	
2	Within 1500 ft of divergent zone?	Y	N	
1	Absence of backshore	Y	N	

** Qva=Quaternary Vashon advance outwash, Qvrme=Quaternary Vashon emergence deposits (sand and gravel), Qvrmo=Quaternary Vashon marine outwash, Ql=Quaternary landslide deposits (Holocene), Qvrms=Quaternary Vashon marine subtidal deposits, Qvrmd=Quaternary Vashon marine diamicton, Qvt=Quaternary Vashon till, Qvd=Quaternary Vashon diamicton.

Scored Segments to Historic Shoretype - Following the scoring of each modified shore segment, segment scores were entered into a spreadsheet for analysis. The same shoretype unit delineations were used for the San Juan County shores as those applied to the other Puget Sound regional shores including those of WRIAs 8 and 9 and Bainbridge Island. Shores scoring 30-45 points were categorized as historic feeder bluffs, and segments scoring greater than 45 points were considered historic feeder bluff exceptional (Table 6). Segments that scored moderately (20-29 points) were categorized as *potential* feeder bluffs, to represent bluffs that have either some slide history or sediment input potential, but were neither contributing appreciable sediment into the nearshore nor completely lacking in erosion. When comparing *potential* feeder bluffs to shoretype mapping in current conditions, many of these areas were likely feeder bluffs, although sufficient evidence was not available to map them as such with confidence. *Not* feeder bluffs equate most directly with transport zones and heavily altered accretion shoreforms (such as filled marshlands), and represent currently modified shores that scored between 0-19 points. These areas exhibited less available sediment and apparent landsliding/erosion than *potential* feeder bluffs.

Scored segments were then spot-checked against existing data sets and historic air photos to assure appropriate assignment of pre-development shoretypes. Pre-development shoretypes were then brought into the GIS attribute table, which enabled spatial analysis of the pre-development sediment sources in the study area. Scored segments were then ranked for restoration and conservation prioritization.

Table 6. Historic shoretype delineations based on HSSI scores.

Score	HSSI Shoretype	Abbreviation	CGS shoretype
0 – 19	Not Feeder Bluff	NFB	HAS/HTZ
20 – 29	Potential Feeder Bluff	PFB	HTZ/HFB
30 – 45	Modified Feeder Bluff	HFB	HFB
46 +	Modified Feeder Bluff Exceptional	HFBE	HFBE

HAS = Historic Accretion Shoreform
HTZ = Historic Transport Zone
HFB = Historic Feeder Bluff
HFBE = Historic Feeder Bluff Exceptional

Restoration and Conservation Prioritization

Restoration and conservation prioritizations (based on sediment sources) were performed at both the unit and drift cell scale so as to enhance the usability of this analysis. In each case (modified) historic and current feeder bluff and feeder bluff exceptional unit HSSI scores were used to determine the relative value of each segment as a source of beach material.

Individual Unit Prioritization

The first step in prioritizing historic sediment sources for **restoration** was to identify the modified shore units with the highest HSSI scores. These highest scoring units were considered to be the greatest historic sources of sediment per linear foot of shore and therefore high restoration priorities. Units that scored higher than one standard deviation above the mean should be considered the highest restoration priority when assessing individual units regardless of their context within the drift cell. The top 3 scoring historic (modified) sediment sources in each drift cell were identified and can be used to select the restoration unit(s) of the highest priority within specific drift cells.

The first step in prioritizing currently intact sediment sources for **conservation** was to score all current feeder bluff and feeder bluff exceptional units using the HSSI. The resulting HSSI scores (for current feeder bluff; CFBs) were then ranked as a means of prioritizing bluffs for conservation. The same steps were taken and scoring methods were applied for these intact bluff units as the modified bluff units. Bluff units with high HSSI scores likely deliver more sediment to the nearshore than those with lower scores. Current sediment sources that scored higher than one standard deviation above the mean are of the greatest priority without regard for landscape context. For example, preserving these sediment sources will ensure the conservation of a sediment source that is contributing substantial sediment to the nearshore. The 3 top scoring currently intact sediment sources in each drift cell were identified so as to enable managers to select the highest priority bluff conservation unit(s) within a given drift cell.

Drift Cell Prioritization

The final step of the restoration and conservation prioritization was completed at the drift cell scale. The fundamental concept underlying this step was that drift cells that have lost the most high-quality (high scoring) feeder bluff units to modification (relative to their historic extent within the cell) are high priority restoration drift cells. High priority conservation drift cells are those with a large ratio of intact high-quality (high scoring) feeder bluffs, relative to their historic extent. Or alternatively, drift cells with the least percent of intact sediment sources relative to their historic extent, are in the greatest need of restoring modified bluff units. Drift cells that have a large percent of their historic sediment sources intact are the most optimal cells for conservation. Down-drift habitats or the occurrence of particular biological components were not considered in this analysis, as this analysis relied strictly on physical parameters.

Each drift cell was ranked for conservation using the following calculation. The first step (Step A) of the calculation was to multiply the HSSI score for each current feeder bluff (CFB) or current feeder bluff exceptional (CFBE) unit by the percent of the historic sediment sources within the drift cell that it encompassed. For example, a current segment of feeder bluff had and HSSI score of 42. That segment of feeder bluff represents 10% of the length of historic sediment sources within that drift cell. The length of the historic sediment sources is the sum of the lengths of all current and historic feeder bluff and feeder bluff exceptional units (potential feeder bluffs are not included). So the weighted score for this unit is 4.2 (42 (HSSI score) * 10%). This step produces a composite value that integrates the value of the sediment source with the length of the historic sediment supply that it represents (or represented). Next (Step B), the products of each composite value (or weighted CFB unit score) within the drift cell were then summed. This value was the numerator. To calculate the denominator (Step C), similar to the numerator, each CFB or CFBE score was multiplied by the percent of the historic sediment source that it encompassed. Then each historic feeder bluff (HFB) and historic feeder bluff exceptional (HFBE) unit score was multiplied by the percent of the total predevelopment sediment sources that it encompassed with in the subject drift cell. All unit products (for both CFBs and HFBs) were then summed (Step D), to produce the denominator of the prioritization score for a drift cell. The prioritization score is the quotient of the summed composite values.

Conservation prioritization score =

$$\frac{\text{(CFB score * \% of total pre-dev. sed source)}}{\text{(HFB score * \% HFB of total pre-dev. sed source) + (CFB score * \% of total pre-dev. sed source)}}$$

Where, CFB= Current Feeder Bluff, HFB=Historic Feeder Bluff).

The restoration prioritization calculation closely resembles the conservation equation with one slight deviation, in that the numerator is the summed products of each HFB score and the percent that the HFB unit represents of the historic or pre-development sediment sources mapped in the drift cell (see below).

Restoration prioritization score =

$$\frac{\text{(HFB score * \% of total pre-dev. sed source)}}{\text{(HFB score * \% HFB of total pre-dev. sed source) + (CFB score * \% of total pre-dev. sed source)}}$$

In general higher scores indicate higher restoration or conservation priority. These results enable managers to select the most optimal drift cell(s) for initiating restoration or conservation project(s). Drift cell rankings provide insight into the necessity of the restoration or conservation, as well as the quality of beach sediment being re-introduced into the cell from each bluff unit. The drift cell prioritization can be used in conjunction with the individual unit prioritization to select the optimal bluff units to restore and conserve throughout the study area.

RESULTS

The objective of this assessment was to research and map the current and historic coastal geomorphic conditions throughout the net shore-drift cells of San Juan County. Net shore-drift cells were the fundamental unit of analysis in this mapping effort. As previously mentioned, all geomorphic shoretype mapping took place *exclusively* within drift cells, and historic conditions were researched of modified shores within drift cells only. Therefore if no modified shores were mapped within a particular drift cell, then there was no need to research historic conditions.

Net shore-drift cells were originally mapped by Johannessen (1992) under contract with the Washington State Department of Ecology (WDOE). As mentioned in the *San Juan County Coastal Processes* section, the updated net shore-drift data set from this study now represents the most accurate mapping of the net shore-drift throughout San Juan County. Detailed descriptions of each of the changes applied to the digital version (digitized by Washington State Department of Ecology) of the original mapping are found in Appendix I. Descriptions of the location, length and direction of each net shore-drift cell are found in first table in each Island summary as well as being displayed in Maps 2-4.

Island Summaries of Current and Historic Coastal Geomorphic Mapping

The relative complexity of the shoreline, aspect, topography and exposure of islands, and geology are other factors of influence to the distribution of shoretypes among islands and throughout San Juan County (see Map 1, Table 2 for Geologic Setting). Current and historic conditions mapping of all fourteen islands (all those with net shore-drift cells) are presented in Maps and Tables as well as discussed in Island summaries below, followed by a larger summary of county-wide conditions. Ancillary data mapping of landslides and toe erosion are displayed separately from current conditions mapping. Please note that in this report “study area” refers only to the drift cells found within the respective islands, not the entire island or San Juan county shoreline. To better understand the distribution of shoretypes throughout the county at multiple scales, results are presented in several different ways including: the cumulative percent of each shoretype per island study area, the cumulative percent of each shoretype within each drift cell, and the average shoretype percent per island study area.

Orcas Island

As mentioned previously, shoretype mapping was exclusively conducted within net shore-drift cells, which on Orcas Island encompassed 17.6 miles of shoreline (Table 7a, Map 2). Sediment sources (feeder bluff and feeder bluff exceptional units) cumulatively made up 21% (3.6 miles) of the Orcas Island study area in current conditions (Table 7b, Maps 5-7). The average length of feeder bluff mapped within Orcas Island drift cells was 366 ft, while the average length of feeder bluff exceptional measured 478 ft. Feeder bluff exceptional segments were mapped on Orcas Island in Ship Bay and cumulatively measured 1,435 ft. The longest feeder bluff in the Orcas Island study area measured 1,870 ft and was found in cell OR-9, which is located along the bedrock-backed shores south of Judd Bay in East Sound. Four drift cells had no intact sediment sources, including cells OR-4, OR-6, OR-13a, and OR-15 (Table 7b). Drift cells without sediment sources were typically heavily modified and/or comprised of a larger percentage of transport zones, which can periodically deliver limited quantities of sediment to the nearshore in the form of toe erosion and infrequent landslides.

Feeder bluffs on Orcas were most abundant in Ship Harbor, Deer Harbor, Orcas Village, and at West Beach. Atypical feeder bluffs, which are partially bedrock, were mapped along northeastern Orcas and in East Sound near Judd Bay and Olga. Net shore-drift cells with the greatest percent of the cell length (20% or more) mapped as feeder bluff included cells OR-9 (56%), OR-7 (22% feeder bluff exceptional, 20% feeder bluff), OR-13 (41%), OR-16 (39%), OR-11 (33%), OR-2 (30%), OR-12 (28%), and OR-10 (23%) (Table 7b, Maps 5-7). Recent landslides and toe erosion were frequently co-located with feeder bluffs, and only occasionally occurred in transport zones (Maps 8 and 9).

Accretion shoreforms were scattered throughout the study area, cumulatively representing approximately 17% (2.9 miles) of the Orcas Island study area. The average length of accretion shoreform measured 430 ft. The longest accretion shoreform was in OR-1 along North Beach and measured 3,249 ft. The percent of accretion shoreform mapped within each drift cell ranged from 0 – 47% (Table 7b). Drift cells OR-2, OR-3, OR-8, OR-11, and OR-14 had no accretion shoreforms, but also contained modified lengths of shores that may have been accretion shoreforms historically. Large accretion shoreforms were found at North Beach, inside Deer Harbor, and in East Sound at Ship Harbor/Crescent Beach (Maps 5-7). Drift cells with a large percent (20% or more) of accretion shoreforms included: OR-1 (47%), OR-12 (36%), OR-4 (32%), OR-7 (28%), OR-13a (25%), and OR-15 (22 %).

Transport zones were mapped along approximately 47% (8.2 miles) of the Orcas Island study area and were the most prevalent shoretype mapped on the island. The average length of transport zones on Orcas Island measured 510 ft. A considerable portion of the Orcas Island shore is composed of bedrock overlain by Quaternary glacial deposits. Transport zones were commonly mapped in such areas which included drift cells in East Sound and along the north shore of the Island.

Modified shores were mapped along 0 to 73% of the Orcas Island drift cells (Table 7b). Drift cells along Orcas Island were 22% modified on average. Modifications most frequently consisted of residential shore armoring (Figure 1e), but boat ramps, piers, rock revetments and fill were also included in the data set. The average length of modified shores mapped in the Orcas Island study area was 244 ft. The maximum length of modified shore in a drift cell was 976 ft mapped in OR-2 along the exposed shores of northeast Orcas near Buckhorn. Modified shores cumulatively accounted for 16% (2.9 miles) of the Orcas Island study area. Three drift cells contained more than 50% of modified shore which included: OR-1a (73%) found at North Beach east of the airport, OR-4 (64%) which encompasses Obstruction Pass, and OR-11 (51%), which is found on south Orcas along the shores of Harney Channel. Table 7b and Maps 5-7 display detailed results of the current conditions shoretype mapping within the drift cells that represent the Orcas Island study area.

Results of historic analysis show that shoreline armoring has reduced the linear extent of functional feeder bluffs in most but not all of the drift cells found on Orcas Island (Table 7c, 7d). In total over 9,000 ft (9,012 ft, 1.7 miles) of historic feeder bluff are currently impounded behind shore armoring on Orcas Island. An additional 2,2720 feet of modified shore were mapped as potential feeder bluff, which represents shores that likely contributed a smaller volume of sediment less frequently than typical feeder bluffs. Potential feeder bluffs are often locally significant in drift cells with low sediment transport volumes, such as many of the drift cells found on Orcas Island. Drift cells with the most sediment impoundment included: OR-1a, OR-4, OR-6, OR-79, and OR-15 (Table 7c). The greatest linear extent of armored or historic feeder bluffs on Orcas Island occurred in cells: OR-1a (2,313 ft), OR-2 (1,649 ft) and OR-16 (1,686 ft). Approximately one-third of the modified shore mapped on Orcas Island was along shores that did not have a history of landsliding and were not likely sources of littoral sediment (*Not Feeder Bluff*, Table 7d). The remaining modified shore was comprised of historic sediment sources that delivered variable quantities of nearshore sediment. The historic shoretype of all currently modified shores on Orcas Island are buffered offshore of current conditions mapping in Maps 5-7.

Table 7a. Orcas Island drift cell descriptions.

Drift Cell Name	Drift Cell Direction	Drift Cell Length (ft)	Location Within Study Area
OR-1	Eastward	8,884	Orcas Island-North Beach
OR-1a	Westward	3,180	Orcas Island-North Beach east
OR-2	Northwestward	11,462	Northeast Orcas Island-Raccoon Point
OR-3	Northwestward	2,363	Southeast Orcas Island-Obstruction Pass
OR-4	Northeastward	1,975	Southeast Orcas Island-Obstruction Pass
OR-5	Northward	8,166	Southeast Orcas Island-Olga
OR-6	Northward	8,361	Orcas Island-Rosario
OR-7	Northwestward	6,550	Orcas Island-East Sound-Crescent Beach
OR-8	Westward	1,206	Orcas Island-East Sound-Judd Bay north
OR-9	Northwestward	4,033	Orcas Island-East Sound-Judd Bay south
OR-10	Northward	5,396	Orcas Island-East Sound-Sunderland Rd
OR-11	Southwestward	846	South Orcas Island-Harney Passage
OR-12	Southeastward	700	South Orcas Island-Harney Passage
OR-13	Eastward	1,881	South Orcas Island-Orcas Landing
OR-13a	Northward	869	Orcas Island-West Sound-Picnic Island
OR-14	Eastward	1,930	Orcas Island-West Sound-Haida Point
OR-15	Northwestward	4,659	Orcas Island-West Sound-Massacre Bay
OR-16	Northward	7,257	Orcas Island-Deer Harbor
OR-17	Northeastward	4,231	Orcas Island-West Beach
OR-18	Southwestward	9,006	Orcas Island-Point Doughty to Beach Haven

Table 7b. Current conditions mapping results of Orcas Island.
FBE = Feeder Bluff Exceptional; FB = Feeder Bluff; TZ = Transport Zone; AS = Accretion Shoreform; MOD = Modified; NAD = No Appreciable Drift; LS = Landslide; TE = Toe Erosion.

Drift Cell Name	Drift Cell Length (ft)	CGS Shoretypes (%)					LS	TE
		FBE	FB	TZ	AS	MOD		
OR-1	8,884	0	8	19	47	3	2	21
OR-1a	3,180	0	13	0	15	73	9	0
OR-2	11,462	0	30	55	0	15	7	10
OR-3	2,363	0	13	66	0	21	5	28
OR-4	1,975	0	0	4	32	63	0	0
OR-5	8,166	0	11	66	12	11	8	17
OR-6	8,361	0	0	84	6	10	5	1
OR-7	6,550	22	20	21	28	8	37	40
OR-8	1,206	0	15	81	0	4	0	15
OR-9	4,033	0	56	42	2	1	11	1
OR-10	5,396	0	23	69	8	0	1	5
OR-11	846	0	33	17	0	51	-	-
OR-12	700	0	28	36	36	0	-	-
OR-13	1,881	0	41	0	17	42	-	-
OR-13a	869	0	0	54	25	21	-	-
OR-14	1,930	0	4	55	0	42	-	-
OR-15	4,659	0	0	67	23	10	-	-
OR-16	7,257	0	39	22	12	27	9	46
OR-17	4,231	0	18	43	19	19	18	0
OR-18	9,006	0	19	50	17	13	3	24
All Drift Cells	**92,953**	**2**	**19**	**47**	**17**	**16**	**8**	**16**
Drift Cell Average	4,648	1	18	43	15	22	8	15

Table 7c. Historic versus current conditions of sediment sources of Orcas Island. This table includes drift cells with modified shores only.

Drift Cell Name	Drift Cell Length (ft)	% Pre-development Sed. Source	% Current Sed. Source	Sediment Source Lost (ft)	% Sediment Source Lost
OR-1	8,884	10	10	0	0
OR-1a	3,180	85	13	2,313	85
OR-2	11,462	44	30	1,650	33
OR-3	2,363	34	13	504	62
OR-4	1,975	14	0	277	100
OR-5	8,166	11	11	0	0
OR-6	8,361	3	0	261	100
OR-7	6,550	43	42	65	2
OR-8	1,206	15	15	0	0
OR-9	4,033	56	56	0	0
OR-11	846	33	33	0	0
OR-13	1,881	74	41	622	45
OR-13a	869	0	0	0	N/A
OR-14	1,930	19	4	286	79
OR-15	4,659	10	0	476	100
OR-16	7,257	63	39	1,686	37
OR-17	4,231	18	18	0	0
OR-18	9,006	29	19	871	33

Table 7d. Historic shoretypes of currently modified shores of Orcas Island.
This table includes drift cells with modified shores only. MOD = Modified, HFBE = Historic Feeder Bluff Exceptional, HFB = Historic Feeder Bluff, PFB = Potential Feeder Bluff, NFB = Not Feeder Bluff.

Drift Cell Name	Drift Cell Length (ft)	Modified Shores (ft)	Historic Shoretypes of Modified Shores (%)			
			%NFB	%PFB	%HFB	%HFBE
OB-2	1,403	32	100	0	0	0
OR-1	8,884	315	100	0	0	0
OR-11	846	429	75	25	0	0
OR-13	1,881	793	22	0	78	0
OR-13a	869	181	100	0	0	0
OR-14	1,930	802	12	52	36	0
OR-15	4,659	476	0	0	100	0
OR-16	7,257	1,972	14	0	86	0
OR-17	4,231	821	100	0	0	0
OR-18	9,006	1,144	9	15	76	0
OR-1a	3,180	2,313	0	0	79	21
OR-2	11,462	1,743	5	0	95	0
OR-3	2,363	504	0	0	100	0
OR-4	1,975	1,254	34	44	22	0
OR-5	8,166	894	88	12	0	0
OR-6	8,361	850	69	0	31	0
OR-7	6,550	545	88	0	0	12
OR-8	1,206	53	100	0	0	0
OR-9	4,033	30	100	0	0	0

Clark Island

A single net shore-drift cell is found on the southwest side of Clark Island (CL-1, Table 8a). This cell extends 1,820 ft and is entirely free of shore modifications. Feeder bluffs comprise 45% (825 ft) of the cell; while transport zones make up 33% (593 ft), and accretion shoreforms 22% (402 ft) as shown in Table 8a and Map 5. No armoring was observed within the Clark Island drift cell, so research into the historic condition of modified shores was not necessary.

Table 8a. Clark Island drift cell description.

Drift Cell Name	Drift Cell Direction	Drift Cell Length (ft)	Location Within Study Area
CL-1	Southward	1,820	Clark Island-southwest

Table 8b. Current conditions mapping results of Clark Island.

Drift Cell Name	Drift Cell Length (ft)	CGS Shoretypes (%)					LS	TE
		FBE	FB	TZ	AS	MOD		
CL-1	1,820	0	45	33	22	0	-	-

Obstruction Island

Net shore-drift cells encompass 3,758 ft of the north shore of Obstruction Island (Table 9a, Map 6). Sediment sources cumulatively made up 20% (748 ft) of the 3 drift cells of the Obstruction Island study area (Table 12, Map 6). The average percent of feeder bluff mapped within the three drift cells was 21% and the average length of feeder bluff mapped over the entire Obstruction Island study area was 374 ft. Drift cell OB-3 on the northwest side of the island had no intact sediment sources, but did have a larger percentage of transport zones accompanied by some toe erosion and landslide segments.

Two feeder bluff segments were mapped, one along the northeast side of Obstruction Island in OB-1 and one on the west side of the island in OB-2 just south of a divergence zone. Feeder bluffs made up 32% of OB-1 and 30% of OB-2 (Table 9b, Map 6). Recent landslides and toe erosion were mapped within feeder bluff segments, but a fair amount of toe erosion and two recent landslides were co-located with transport zones (Maps 8 and 9).

Accretion shoreforms on Obstruction Island occurred at the terminus of each of the three drift cells and cumulatively represented 13% (474 ft) of the study area. The average percent of accretion shoreform mapped within each drift cell was 12% and the average length was 158 ft. Transport zones were the dominant shoretype found within the Obstruction Island study area, and cumulatively represented 67% (2,505 ft) of the study area. The average length of transport zones was 626 ft.

Only one small shore modification was mapped within the Obstruction Island drift cells. The shore modification was apparently for beach access and was located along the southwest side of the island in drift cell OB-2. It measured 32 ft (1% of the cell) in length. Historic research showed that this section of modified shore was not a historic sediment source, so there has been no degradation to sediment supply in the Obstruction Island drift cells.

Table 9a. Obstruction Island drift cell descriptions.

Drift Cell Name	Drift Cell Direction	Drift Cell Length (ft)	Location Within Study Area
OB-1	Northwestward	1,016	Obstruction Island-east
OB-2	Southward	1,403	Obstruction Island-southwest
OB-3	Northward	1,339	Obstruction Island-northwest

Table 9b. Current conditions mapping results of Obstruction Island.

Drift Cell Name	Drift Cell Length (ft)	CGS Shoretypes (%)					LS	TE
		FBE	FB	TZ	AS	MOD		
OB-1	1,016	0	32	58	10	0	6	77
OB-2	1,403	0	30	55	13	2	9	0
OB-3	1,339	0	0	86	14	0	4	14
All Drift Cells	**3,758**	**0**	**20**	**67**	**13**	**1**	**6**	**26**
Drift Cell Average	1,253	0	21	66	12	1	6	30

Blakely Island

Net shore-drift cells occur along 5.3 miles Blakely Island (Table 10a, Map 3). Sediment sources (feeder bluffs) cumulatively made up 27% (1.4 miles) of the Blakely Island study area (Table 10b, Map 10). The average percent of feeder bluff mapped within Blakely Island drift cells was 28%. The average length of feeder bluff units on Blakely Island was 401 ft and the longest measured 1,239 ft, was located in cell BL-8 along the west side north of Bald Bluff. No feeder bluff exceptional units were mapped on Blakely Island. One drift cell had no intact sediment sources, BL-6, however it did contain a large percentage of transport zones and a relatively small proportion of modified shore.

Recent landslides and toe erosion were almost exclusively co-located with feeder bluffs in the Blakely study area (Maps 11 and 12). Toe erosion and landslides were mapped along 100% of cell BL-4, which is located at the southern tip of the island. Toe erosion commonly occurred within transport zones, and was considerably more abundant than landslides in Blakely Island drift cells.

Accretion shoreforms were frequently found at the terminus of the drift cells on Blakely Island. Accretion shoreforms cumulatively represented 20% (1.1 miles) of the Blakely Island study area. The average percent of accretion shoreforms mapped per drift cell was 20% and the average length of accretion shoreform over the study area was 425 ft. The longest accretion shoreform measured 1,300 ft and was mapped in BL-10 at the southwest end of Peavine Pass. Accretion shoreforms represented 3.5 - 56% of the drift cells on the Island (Table 10b). Large accretion shoreforms were found mainly on the north end of the island (Map 10).

Transport zones were mapped along 49% (2.6 miles) of the Blakely study area and were the most prevalent shoretype mapped on the island. The average percent of transport zones mapped within Blakely Island drift cell was 47% and the average length of transport zones mapped on the Blakely Island was 470 ft.

Modified shores ranged 0 – 17% in Blakely Island drift cells. Most modifications appeared to be residential bulkheads, but former industrial areas in Thatcher Bay and the marina at the northwest end of the island also had extensive fill and associated revetments. The average percent of modified shores mapped within drift cells was 5% and the average length of modified shores on Blakely Island was 110 ft. Drift cell BL-10 had the greatest extent of modified shore (297 ft), which was associated with the marina. Cumulatively 5% (1,321 ft) of the shores of the Blakely Island study area were modified.

Comparison between current and historic conditions mapping revealed that armoring of historic feeder bluffs has only occurred within two drift cells on the Island; BL-9 and BL-10. In addition, all of the armored shores within drift cell BL-5 were potential feeder bluffs, which represent shores that likely contributed a smaller volume of sediment to the nearshore with lesser frequency than typical feeder bluffs. The historic shoretype of all currently modified shores on Blakely Island are buffered offshore of current conditions mapping in Map 10. The cumulative loss of these historic feeder bluffs measured less than 175 ft, with an additional 334 ft of potential feeder bluffs. Results of historic analyses show that the majority of modified shores on Blakely Island were not feeder bluffs (54%, Table 10d). Approximately 16% of the modified shores were classified as historic feeder bluffs, and were mapped in drift cells BL-9 and BL-10, along the northwest shore of the Island (Map 4a). Potential feeder bluffs were found in BL-5 as well as BL-9 (Table 10d).

Table 10a. Blakely Island drift cell descriptions.

Drift Cell Name	Drift Cell Direction	Drift Cell Length (ft)	Location Within Study Area
BL-1	Northwestward	3,611	Blakely Island-northeast
BL-2	Northeastward	2,675	Blakely Island-southeast
BL-3	Southwestward	2,125	Blakely Island-southeast
BL-4	Westward	658	Blakely Island-south
BL-5	Southeastward	2,857	Blakely Island-south
BL-6	Northeastward	750	Blakely Island-Thatcher Bay
BL-7	Eastward	2,949	Blakely Island-Thatcher Bay
BL-8	Northward	5,136	Blakely Island-west
BL-9	Southward	5,013	Blakely Island-northwest
BL-10	Northeastward	2,314	Blakely Island-northwest

Table 10b. Current conditions mapping results of Blakely Island.

Drift Cell Name	Drift Cell Length (ft)	CGS Shoretypes (%)					LS	TE
		FBE	FB	TZ	AS	MOD		
BL-1	3,611	0	13	63	25	0	13	24
BL-2	2,675	0	10	87	4	0	1	0
BL-3	2,125	0	35	58	7	0	6	61
BL-4	658	0	86	0	14	0	100	100
BL-5	2,857	0	25	46	24	5	19	41
BL-6	750	0	0	71	25	4	0	0
BL-7	2,747	0	30	56	6	8	14	61
BL-8	5,136	0	64	32	4	1	13	81
BL-9	5,013	0	9	50	36	5	7	12
BL-10	2,314	0	14	12	56	17	4	14
All Drift Cells	**28,089**	**0**	**27**	**48**	**20**	**5**	**12**	**38**
Drift Cell Average	2,809	0	28	47	20	5	18	39

Table 10c. Historic versus current conditions of sediment sources of Blakely Island. This table includes drift cells with modified shores only.

Drift Cell Name	Drift Cell Length (ft)	% Pre-development Sed. Source	% Current Sed. Source	Sediment Source Lost (ft)	% Sediment Source Lost
BL-5	2,857	25	25	0	0
BL-6	750	0	0	0	N/A
BL-7	2,747	30	30	0	0
BL-8	5,136	64	64	0	0
BL-9	5,013	11	9	69	13
BL-10	2,314	19	14	106	25

Table 10d. Historic shoretypes of currently modified shores of Blakely Island.
This table includes drift cells with modified shores only. MOD = Modified, HFBE = Historic Feeder Bluff Exceptional, HFB = Historic Feeder Bluff, PFB = Potential Feeder Bluff, NFB = Not Feeder Bluff.

Drift Cell Name	Drift Cell Length (ft)	Modified Shores (ft)	Historic Shoretypes of Modified Shores (%)			
			%NFB	%PFB	%HFB	%HFBE
BL-5	2,857	153	0	100	0	0
BL-6	750	32	100	0	0	0
BL-7	2,747	225	100	0	0	0
BL-8	5,136	56	100	0	0	0
BL-9	5,013	250	0	72	28	0
BL-10	2,314	403	74	0	26	0

Decatur Island

Net shore-drift cells were mapped along 6.1 miles of Decatur Island (Table 11a). Sediment sources (feeder bluff and feeder bluff exceptional units) cumulatively comprised 35% (2.1 miles) of the Decatur Island study area (Table 11b, Map 13). The average percent of feeder bluff mapped within Decatur Island drift cells was 26%. The average length of feeder bluff mapped on Decatur Island was 1,050 ft. Feeder bluff exceptional segments were mapped only within cell DE-3, which accounted for 761 ft of that cell. The longest feeder bluff segment measured 2,987 ft and was located in DE-3 near White Cliff on the southeast side of the island. Drift cell DE-6 had no intact sediment sources, however, this cell was composed of over 50% transport zone with some toe erosion and a recent landslide, which likely delivers some sediment to the nearshore system. Toe erosion was mapped within almost all of the feeder bluff segments in the Decatur Island study area. Many recent landslides were also mapped within feeder bluff segments, especially within the feeder bluff exceptional shores along the southeast shore of the island (Maps 11 and 12).

Accretion shoreforms were abundant in the Decatur Island drift cells, cumulatively representing 27% (1.7 miles) of the study area. The average percent of accretion shoreform mapped within drift cells was 30%, averaging 439 ft. The longest accretion shoreform measured 1,608 ft, in drift cell DE-2, located on the south side of Decatur Head. The percent of accretion shoreform mapped within each drift cell ranged from 3.3 – 49% (Table 11b). All drift cells on Decatur Island contained accretion shoreforms. Large accretion shoreforms were found surrounding the Decatur Head lagoon, the marsh at Reads Bay (which is partially diked and filled due to an old road bed), and in Brigantine Bay (Map 13).

Transport zones were mapped along approximately 31% (1.9 miles) of the study area and were more commonly found along shores where bedrock was exposed. The northern, more bedrock dominated drift cells DE-1 and DE-6 were 63% and 51% transport zone, respectively. Transport zones on Decatur Island were typically co-located with toe erosion.

Decatur Island drift cells ranged 0 – 26% modified. Many of the modifications consisted of residential shoreline armoring, however, road revetments, an old roadbed and industrial areas in Reads Bay encompassed much of the modified shore. The average percent of modified shore mapped per drift cell was 5% and the average length of modified shore was 112 ft. Most cells had less than 2% modified shore, except DE-5, located in north Read's Bay, 26% of which was modified. Cumulatively, modified shores accounted for 7% (2,134 ft) of the Decatur Island study area. Drift cells DE-3 and DE-6 contained no modifications.

Historic analysis revealed that most of the drift cells on Decatur Island have not incurred declines in sediment supply due to shore modifications (Table 11c). Drift cell DE-5 had a decrease in the linear extent of sediment sources (a 21% loss of the historic sediment supply cumulatively measuring 627 ft). An additional 26% (15 ft) of the modified shore in drift cell DE-1 was classified as potential feeder bluff, which likely contribute smaller volumes of sediment to the nearshore than typical feeder bluffs. The historic conditions of most modified shores throughout the Island were classified as not feeder bluffs (Table 11d).

Table 11a. Decatur Island drift cell descriptions.

Drift Cell Name	Drift Cell Direction	Drift Cell Length (ft)	Location Within Study Area
DE-1	Southward	5,505	Decatur Island-north of Decatur Head
DE-2	Northeastward	7,730	Decatur Island-south of Decatur Head
DE-3	Southwestward	7,320	Decatur Island-southeast
DE-4	Northward	1,285	Decatur Island-south Reads Bay
DE-5	Southward	8,160	Decatur Island-Reads Bay
DE-6	Northwestward	2,345	Decatur Island-Brigantine Bay

Table 11b. Current conditions mapping results of Decatur Island.

Drift Cell Name	Drift Cell Length (ft)	CGS Shoretypes (%)					LS	TE
		FBE	FB	TZ	AS	MOD		
DE-1	5,505	0	11	63	24	1	6	22
DE-2	7,730	0	32	30	37	0	10	33
DE-3	7,320	10	71	15	3	0	53	66
DE-4	1,285	0	3	64	32	2	0	3
DE-5	8,160	0	29	11	34	25	0	30
DE-6	2,345	0	0	51	49	0	2	15
All Drift Cells	**32,099**	**2**	**33**	**31**	**27**	**7**	**16**	**35**
Drift Cell Average	5,350	2	24	39	30	5	12	28

Table 11c. Historic versus current conditions of sediment sources of Decatur Island. This table includes drift cells with modified shores only.

Drift Cell Name	Drift Cell Length (ft)	% Pre-development Sed. Source	% Current Sed. Source	Sediment Source Lost (ft)	% Sediment Source Lost
DE-1	5,505	11	11	0	0
DE-2	7,730	32	32	0	0
DE-4	1,285	3	3	0	0
DE-5	8,160	37	29	627	21

Table 11d. Historic shoretypes of currently modified shores of Decatur Island.
This table includes drift cells with modified shores only. MOD = Modified, HFBE = Historic Feeder Bluff Exceptional, HFB = Historic Feeder Bluff, PFB = Potential Feeder Bluff, NFB = Not Feeder Bluff.

Drift Cell Name	Drift Cell Length (ft)	Modified Shores (ft)	Historic Shoretypes of Modified Shores (%)			
			%NFB	%PFB	%HFB	%HFBE
DE-1	5,504.7	57.0	74	26	0	0
DE-2	7,729.8	20.2	100	0	0	0
DE-4	1,285.2	20.3	100	0	0	0
DE-5	8,160.0	2,036.3	69	0	31	0

Center Island

Center Island contains one drift cell, CE-1, which measures 2,519 ft along the southeast shore. Feeder bluffs comprise 39% (981 ft) of the drift cell, while transport zones make up 41% (1,031 ft, Map 13). Accretion shoreforms were mapped at the cell's terminus and represent a mere 2% (43 ft) of the drift cell. Modified shores represent 18% of the Center Island study area. Landslides and toe erosion on Center Island are shown in Maps 11 and 12. The majority of shore modifications were mapped at the south end (origin) of the drift cell and appeared to be for shore protection and beach access.

Research of the historic condition of modified shores on Center Island showed that most (91%) of the modified shores were historic feeder bluffs. Armoring of the sediment sources has reduced the historic extent of feeder bluffs by approximately 30% (or 423 ft) in the single drift cell. The historic shoretype of all currently modified shores on Center Island are buffered offshore of current conditions mapping in Map 13.

Table 12a. Center Island drift cell descriptions.

Drift Cell Name	Drift Cell Direction	Drift Cell Length (ft)	Location Within Study Area
CE-1	Northeastward	2,519	Center Island-southeast

Table 12b. Current conditions mapping results of Center Island.

Drift Cell Name	Drift Cell Length (ft)	CGS Shoretypes (%)					LS	TE
		FBE	FB	TZ	AS	MOD		
CE-1	2,519	0	39	41	2	18	7	39

Table 12c. Historic versus current conditions of sediment sources of Center Island. This table includes drift cells with modified shores only.

Drift Cell Name	Drift Cell Length (ft)	% Pre-development Sed. Source	% Current Sed. Source	Sediment Source Lost (ft)	% Sediment Source Lost
CE-1	2,519	56	39	423	30

Table 12d. Historic shoretypes of currently modified shores of Center Island.
This table includes drift cells with modified shores only. MOD = Modified, HFBE = Historic Feeder Bluff Exceptional, HFB = Historic Feeder Bluff, PFB = Potential Feeder Bluff, NFB = Not Feeder Bluff.

Drift Cell Name	Drift Cell Length (ft)	Modified Shores (ft)	Historic Shoretypes of Modified Shores (%)			
			%NFB	%PFB	%HFB	%HFBE
CE-1	2,519	463	9	0	91	0

Lopez Island

Net shore-drift and NAD cells mapped in this study are found along the 28.2 miles of the Lopez Island study area. Sediment sources (feeder bluff + feeder bluff exceptional units) cumulatively made up 25% (7.2 miles) of the island shores (Table 13a, 13b and Maps 14-16). The average length of feeder bluffs was 520 ft, while the average length of a feeder bluff exceptional segment was 380 ft. The longest feeder bluff mapped on Lopez was in cell LO-6, spanning 3,129 ft along east Lopez Island south of Spencer Spit (Map 14). The longest feeder bluff exceptional mapped measured 667 ft and was located in cell LO-14 on west Lopez south of Fisherman Bay (Map 16). Five drift cells on Lopez Island had no intact sediment sources, including cells LO-11, LO-12, LO-15, LO-16, and LO-19 (Table 13b, Maps 14-16). Three of these five drift cells contained transport zones with toe erosion and infrequent mass wasting events which, as stated above, may likely contribute small amounts of sediment to the drift cell.

Lopez Island contains many feeder bluffs (Map 14-16, Table 13b). These sediment sources were abundant along the east side of the island south of Spencer Spit, in southeast Mud Bay, southern Shoal Bight, south and north of Lopez Point, and between Flat Point and Upright Head. Net shore-drift cells with the greatest percent of the cell length (20% or more) mapped as feeder bluff included cells LO-1 (34%), LO-3 (26%), LO-4 (29%), LO-5 (27% feeder bluff, 4% feeder bluff exceptional), LO-6 (55% feeder bluff, 4% feeder bluff exceptional) LO-9 (42%), LO-13 (41%), LO-14 (19% feeder bluff, 7% feeder bluff exceptional) LO-20 (37%), LO-21 (31%), LO-22 (56%), LO-23 (56%) (Table 13b). Landslides frequently co-occurred frequently with feeder bluffs. Toe erosion was mapped throughout the study area, excluding the inner, protected shores of Fisherman Bay (Maps 11 and 12).

Accretion shoreforms were scattered throughout the study area, cumulatively representing approximately 22% (6.1 miles) of the Lopez Island shore. The average length of accretion shoreforms was 626 ft and the longest accretion shore was mapped in LO-14, (2,086 ft) at the north shore of Lopez Point at Fisherman Bay. The percent of accretion shoreform mapped within each drift cell ranged from 0 – 83% (Table 13b). All drift cells had intact accretion shoreforms mapped. Large accretion shoreforms were mapped in Swifts Bay, Spencer Spit, Mud Bay, Lopez Point, Fisherman Bay, and Flat Point (Maps 6-8). Drift cells with a large percent (20% or more) of accretion shoreforms included: LO-2 (22%), LO-3 (28%), LO-4 (25%), LO-5 (67%), LO-8 (41%), LO-9 (30%), LO-11 (69%), LO-12 (68%), LO-14 (24%), LO-15 (83%), LO-16 (75%), LO-18 (44%), LO-19 (24%), LO-22 (34%), LO-23 (30%).

Transport zones were mapped along approximately 19% (5.4 miles) of the study area shore. The average length of transport zones was 358 ft.

The drift cells that comprise the Lopez Island shore exhibited variable degrees of modification, ranging from 0 to 58% altered, by length. The average length of modified shore segments was 237 ft, and the longest modified shore spanned 3,326 ft along Bayshore Road (west shore of Fisherman Bay). Many of the modifications consisted of residential bulkheads which ranged from stacked angular rock rockeries to driftwood installations. Other shore modifications consisted of long road fills with riprap, marinas, and structures for pleasure craft (docks or boat ramps). Modified shores cumulatively accounted for 18% (5.2 miles) of the island. Three drift cells contained more than 50% of modified shore; LO-2 (50%) in Shoal Bay, and cells LO-18 (51%) and LO-19 (58%) within Fisherman Bay. The presence of marinas and roads strongly influenced the occurrence of modified shores in these areas. Detailed results of the shoretypes that comprise each drift cell, based on current conditions mapping, are in Table 13b and Maps 14-16.

Research of the historic condition of all modified shores showed that a large portion (44%) of the modified shore on Lopez Island were not feeder bluffs prior to being armored. Historic feeder bluffs and historic feeder bluff exceptional units together accounted for 32% of the modified shore. The historic shoretype of all currently modified shores on Lopez Island are buffered offshore of current conditions mapping in Maps 14-16. And an additional 24% of modified shores were classified as potential feeder bluffs; indicating that these areas likely contributed smaller volumes of sediment to the nearshore (Table 13d). Cumulatively the linear extent of feeder bluffs on Lopez Island has declined by 1.5 miles (8,083 ft) or by approximately 18%. Three drift cells have lost over 75% of the historic (linear) extent of sediment sources including cells LO-2, LO-7 and LO-10 (Table 13c). The extent of armored feeder bluff ranged among drift cells from less than 1 -100% and 68 – 1,450 ft.

Table 13a. Lopez Island drift cell descriptions.

Drift Cell Name	Drift Cell Direction	Drift Cell Length (ft)	Location Within Study Area
LO-1	Southeastward	3,236	Shoal Bay, North Lopez Island
LO-2	Southward	1,154	East side of Shoal Bay, North Lopez Island
LO-3	Southward	5,706	West side of Swifts Bay, North Lopez Island
LO-4	Westward	3,104	East side of Swifts Bay, North Lopez
LO-5	Southeastward	3,770	North end of Spencer Spit to the tip of Spencer Spit
LO-6	Northward	15,291	Lopez Sound to the tip of Spencer Spit, East Lopez Island
LO-7	Southward	2,673	Central Lopez Sound, East Lopez Island
LO-8	Southward	5,977	North side of Mud Bay to inner Mud Bay, East Lopez Island
LO-9	Southwestward	7,893	South side of Mud Bay to inner Mud Bay, East Lopez Island
LO-10	Northeastward	2,341	Southeast side of Mud Bay to lagoon, East Lopez Island
LO-11	Southeastward	1,503	Northeast Mud Bay to lagoon, East Lopez Island
LO-12	Northwestward	1,239	Northeast Mud Bay to east of Skull Island, East Lopez Island
LO-13	Northward	8,588	Shoal Bight, East Lopez Island
LO-14	Northward	22,891	Shark Reef to Fisherman Bay spit, West Lopez Island
LO-15	Southward	480	Northwest side of Fisherman Bay, West Lopez Island
LO-16	Northward	2,064	Northwest side of Fisherman Bay, West Lopez Island
LO-17	Southward	4,095	West side of Fisherman Bay to lagoon, West Lopez Island
LO-18	Westward	4,429	Central east Fisherman Bay to lagoon, West Lopez Island
LO-19	Northward	5,833	Central east Fisherman Bay to lagoon, West Lopez Island
LO-20	Southward	4,856	San Juan Channel to Fisherman Bay, West Lopez Island
LO-21	Northward	7,347	San Juan Channel to Flat Point, West Lopez Island
LO-22	Westward	5,922	Upright Channel to Flat Point, North Lopez Island
LO-23	Northeastward	2,979	Upright Channel to Odlin County Park, North Lopez Island

Table 13b. Current conditions mapping results of Lopez Island.

Drift Cell Name	Drift Cell Length (ft)	CGS Shoretypes (%)					LS	TE
		FBE	FB	TZ	AS	MOD		
LO-1	3,236	0	34	31	12	22	0	0
LO-2	1,154	0	7	21	22	50	0	0
LO-3	5,706	0	26	10	28	36	0	0
LO-4	3,104	0	29	18	25	29	0	0
LO-5	3,770	4	27	2	67	0	0	0
LO-6	15,291	4	55	16	12	13	4	20
LO-7	2,673	0	11	36	13	40	8	9
LO-8	5,977	0	18	26	41	15	4	8
LO-9	7,893	0	42	18	30	11	11	35
LO-10	2,341	0	18	18	17	47	10	16
LO-11	1,503	0	0	31	69	0	0	12
LO-12	1,239	0	0	32	68	0	0	15
LO-13	8,588	0	41	31	10	18	18	53
LO-14	22,891	7	19	32	24	18	11	26
LO-15	480	0	0	17	83	0	0	0
LO-16	2,064	0	0	12	75	13	0	12
LO-17	4,095	0	6	57	17	20	0	0
LO-18	4,429	0	1	5	44	50	0	1
LO-19	5,833	0	0	18	24	58	0	0
LO-20	4,856	0	37	3	14	47	2	37
LO-21	7,347	5	31	43	18	4	14	39
LO-22	5,922	0	56	10	33	0	19	56
LO-23	2,979	0	56	10	30	4	20	66
All Drift Cells	**123,370**	**2**	**29**	**23**	**26**	**20**	**7**	**23**
Drift Cell Average	**5,364**	1	22	21	34	22	5	18

Table 13c. Historic versus current conditions of sediment sources of Lopez Island. This table includes drift cells with modified shores only.

Drift Cell Name	Drift Cell Length (ft)	% Pre-development Sed. Source	% Current Sed. Source	Sediment Source Lost (ft)	% Sediment Source Lost
LO-1	3,236	36	34	68	6
LO-2	1,154	57	7	581	88
LO-3	5,706	46	26	1,137	43
LO-4	3,104	43	29	432	33
LO-6	15,291	69	59	1,450	14
LO-7	2,673	49	11	1,013	77
LO-8	5,977	24	18	311	22
LO-9	7,893	49	42	558	15
LO-10	2,341	19	0	443	100
LO-13	8,588	41	41	0	0
LO-14	22,891	28	26	451	7
LO-16	2,064	0	0	0	N/A
LO-17	4,095	11	6	212	46
LO-18	4,429	1	1	0	0
LO-19	5,833	0	0	0	N/A
LO-20	4,856	58	37	1,054	37
LO-21	7,347	40	36	297	10
LO-22	5,922	57	56	20	1
LO-23	2,979	58	56	57	3

Table 13d. Historic shoretypes of currently modified shores of Lopez Island.
This table includes drift cells with modified shores only. MOD = Modified, HFBE = Historic Feeder Bluff Exceptional, HFB = Historic Feeder Bluff, PFB = Potential Feeder Bluff, NFB = Not Feeder Bluff.

Drift Cell Name	Drift Cell Length (ft)	Modified Shores (ft)	Historic Shoretypes of Modified Shores (%)			
			%NFB	%PFB	%HFB	%HFBE
LO-1	3,236	719	11	79	9	0
LO-13	8,588	1,557	100	0	0	0
LO-14	22,891	4,077	89	0	10	1
LO-16	2,064	260	100	0	0	0
LO-17	4,095	826	74	0	26	0
LO-18	4,429	2,235	9	91	0	0
LO-19	5,833	3,361	11	89	0	0
LO-2	1,154	581	0	0	100	0
LO-20	4,856	2,273	54	0	40	7
LO-21	7,347	297	0	0	83	17
LO-22	5,922	20	0	0	100	0
LO-23	2,979	106	47	0	53	0
LO-3	5,706	2,047	38	6	56	0
LO-4	3,104	888	51	0	49	0
LO-6	15,291	1,947	0	26	74	0
LO-7	2,673	1,068	0	5	95	0
LO-8	5,977	878	56	9	35	0
LO-9	7,893	864	35	0	65	0

Shaw Island

Net shore-drift cells comprise 2.6 miles Shaw Island (Table 14a). Within that study area, sediment sources (feeder bluff and feeder bluff exceptional units) cumulatively made up 20% (2,732 ft) of the shore (Table 14b, Map 17). The average percent of feeder bluff mapped within drift cells on Shaw Island was 14.6% and the average length of feeder bluff mapped along the Shaw Island study area was 324 ft. A single feeder bluff exceptional segment was mapped on Shaw Island in Indian Cove (SH-5), which measured 143 ft in length. The longest feeder bluff measured 1,424 ft, also in Indian Cove. Drift cell SH-3 had no intact sediment sources; however transport zones with toe erosion were mapped in the cell, as well as a considerable amount of modified shore.

Accretion shoreforms were found intermittently throughout the study area, cumulatively representing 16% (2,174 ft) of the Shaw Island study area. The average percent of accretion shoreform mapped within Shaw Island drift cells was 10%. The average length of accretion shoreform mapped along the Shaw Island study area was 272 ft. The largest unmodified accretion shoreform measured 538 ft and was located in Indian Cove (Figure 1d). The percent of accretion shoreforms mapped within each drift cell ranged from 0 – 39% (Table 14b). Drift cells SH-1 and SH-3 had no accretion shoreforms, and also contained modified lengths of shores that may have been accretion shoreforms historically.

Transport zones were mapped along approximately 25% (3,458 ft) of the Shaw Island study area and appeared to be the most abundant shoretype within the study area (Figure 1c). All five drift cells of Shaw Island exhibited a moderate to high degree of modification; ranging from 18% to 66%. These modifications typically consisted of residential bulkheads as well as road revetments such as those found in Blind Bay. The average percent of modified shore mapped per drift cell was 45%. The average modified length of shore was 195 ft. Modified shores cumulatively accounted for 40% (1 mile) of the Shaw Island study area.

Results of historic research on Shaw Island revealed that (cumulatively) 2,064 ft of historic feeder bluffs are not longer functioning due to shore armoring. The historic shoretype of all currently modified shores on Shaw Island are buffered offshore of current conditions mapping in Map 17. The greatest decline in the linear extent of feeder bluffs (relative to their historic extent) occurred within drift cells SH-1 (671 ft) and SH-4 (1,285 ft, Table 14c). Historic conditions mapping documented that 38% of the modified shores on Shaw Island were historically feeder bluffs. An additional 34% of modified shores were mapped as potential feeder bluffs, indicating that these shores were likely contributing smaller volumes of sediment to the nearshore (Table 14d).

Table 14a. Shaw Island drift cell descriptions.

Drift Cell Name	Drift Cell Direction	Drift Cell Length (ft)	Location Within Study Area
SH-1	Northward	1,403	Shaw Island-Broken Point
SH-2	Northward	2,378	Shaw Island-Blind Bay
SH-3	Southward	1,933	Shaw Island-Blind Bay
SH-4	Southward	3,476	Shaw Island-Blind Bay
SH-5	Eastward	4,639	Shaw Island-Indian Cove

Table 14b. Current conditions mapping results of Shaw Island.

Drift Cell Name	Drift Cell Length (ft)	CGS Shoretypes (%)					LS	TE
		FBE	FB	TZ	AS	MOD		
SH-1	1,403	0	9	30	0	61	6	14
SH-2	2,378	0	6	53	9	33	0	34
SH-3	1,933	0	0	34	0	66	0	12
SH-4	3,476	0	20	26	5	49	3	27
SH-5	4,639	3	35	5	39	18	23	47
All Drift Cells	**13,829**	**1**	**19**	**25**	**16**	**40**	**9**	**32**
Drift Cell Average	2,766	1	14	29	10	45	6	27

Table 14c. Historic versus current conditions of sediment sources of Shaw Island. This table includes drift cells with modified shores only.

Drift Cell Name	Drift Cell Length (ft)	% Pre-development Sed. Source	% Current Sed. Source	Sediment Source Lost (ft)	% Sediment Source Lost
SH-1	1,403	57	9	671	84
SH-2	2,378	10	6	108	45
SH-3	1,933	0	0	0	N/A
SH-4	3,476	57	20	1,285	65
SH-5	4,639	38	38	0	0

Table 14d. Historic shoretypes of currently modified shores of Shaw Island.
This table includes drift cells with modified shores only. MOD = Modified, HFBE = Historic Feeder Bluff Exceptional, HFB = Historic Feeder Bluff, PFB = Potential Feeder Bluff, NFB = Not Feeder Bluff.

Drift Cell Name	Drift Cell Length (ft)	Modified Shores (ft)	Historic Shoretypes of Modified Shores (%)			
			%NFB	%PFB	%HFB	%HFBE
SH-1	1,403	850	21	0	79	0
SH-2	2,378	783	43	43	14	0
SH-3	1,933	1,279	0	100	0	0
SH-4	3,476	1,697	9	16	76	0
SH-5	4,639	857	100	0	0	0

Turn Island

Two net shore-drift cells occur along the south and west sides of Turn Island, which together represent 2,734 ft of shore (Table 15a). Sediment sources (feeder bluffs) cumulatively made up 27% (741 ft) of the Turn Island study area (Table 15b, Map 17). However, all of the feeder bluffs were mapped in cell TU-1 (54%). No feeder bluffs were mapped in drift cell TU-2, which had considerable lengths of transport zones with toe erosion. The inequality of feeder bluffs among the two drift cells may be attributed to the southeastern exposure of TU-1, from which prevailing and predominant winds originate. TU-2 on the other hand is more protected and is only exposed to San Juan Channel from the northwest. Both drift cells contained toe erosion and TU-1 contained landslides that were typically co-located with feeder bluff segments (Maps 18 and 19).

Accretion shoreforms comprised 39% (1,071 ft) of the Turn Island study area. TU-1 contained 21% (291 ft) accretion shoreform, while TU-2 contained considerably more accretion shoreform with 58% (780 ft). Transport zones on Turn Island comprise 34% (923 ft) of the study area, cumulatively. No modifications were mapped; therefore no historic research was necessary.

Table 15a. Turn Island drift cell descriptions.

Drift Cell Name	Drift Cell Direction	Drift Cell Length (ft)	Location Within Study Area
TU-1	Southwestward	1,380	Turn Island-south
TU-2	Southwestward	1,354	Turn Island-west

Table 15b. Current conditions mapping results of Turn Island.

Drift Cell Name	Drift Cell Length (ft)	CGS Shoretypes (%)					LS	TE
		FBE	FB	TZ	AS	MOD		
TU-1	1,380	0	54	25	21	0	12	54
TU-2	1,354	0	0	42	58	0	0	24
All Drift Cells	**2,734**	**0**	**27**	**34**	**39**	**0**	**6**	**39**
Drift Cell Average	1,367	0	27	34	39	0	6	39

Brown Island

Similar to Turn Island, Brown Island is a small island near Friday Harbor that contains two drift cells. Drift cell BR-1 is located on the southwest side of the island and BR-2 is found on the southeast (Map 4). Together these cells comprise 3,590 ft of shoreline (Table 16a). Cumulatively, feeder bluffs were mapped along 22% (798 ft) of the Brown Island study area (Table 16b, Map 17). Feeder bluffs represented 20% (546 ft) of BR-1, while 32% (252 ft) of cell BR-2 was mapped as feeder bluff. Transport zones cumulatively represented 57% (3,458 ft) of the Brown Island study area and were much more abundant in cell BR-1. Transport zones represented 66% (1,831 ft) of BR-1 and 26% (203 ft) of BR-2 (Table 16b, Map 17). Landslides and toe erosion were mapped exclusively with feeder bluffs on Brown Island (Maps 18 and 19).

Very few accretion shoreforms were mapped on Brown Island (1.4%, 49 ft). Drift cell BR-1 was comprised of 1.7% (49 ft) of accretion shoreform, while none were mapped in BR-2. This may be attributed to the rocky nature and limited glacial deposits of the island, as well as the large proportion of modifications along BR-2. Modifications were mapped along 13% (371 ft) of BR-1 and 43% (338 ft) of BR-2, consisting of residential bulkheads, groins, dock armoring and a boat ramp (Table 16b, Map 17).

Results of historic conditions mapping showed that each of the Brown Island drift cells has incurred considerable declines in the linear extent of sediment sources (Table 16c). Historic conditions mapping is shown in Map 17, buffered offshore of current conditions. Drift cell BR-2 incurred the greatest percent loss (57%), though cell BR-1 had a greater loss of linear footage (371 ft). All of the modified shore within both drift cells were historic feeder bluffs (Table 16d, Map 17).

Table 16a. Brown Island drift cell descriptions.

Drift Cell Name	Drift Cell Direction	Drift Cell Length (ft)	Location Within Study Area
BR-1	Westward	2,797	Brown Island-southwest
BR-2	Westward	793	Brown Island-southeast

Table 16b. Current conditions mapping results of Brown Island.

Drift Cell Name	Drift Cell Length (ft)	CGS Shoretypes (%)					LS	TE
		FBE	FB	TZ	AS	MOD		
BR-1	2,797	0	20	65	2	13	1	20
BR-2	793	0	32	26	0	43	19	19
All Drift Cells	**3,590**	**0**	**22**	**57**	**1**	**20**	**5**	**19**
Drift Cell Average	1,795	0	26	46	1	28	10	19

Table 16c. Historic versus current conditions of sediment sources of Brown Island. This table includes drift cells with modified shores only.

Drift Cell Name	Drift Cell Length (ft)	% Pre-development Sed. Source	% Current Sed. Source	Sediment Source Lost (ft)	% Sediment Source Lost
BR-1	2,797	33	20	371	40
BR-2	793	74	32	338	57

Table 16d. Historic shoretypes of currently modified shores of Brown Island.
This table includes drift cells with modified shores only. MOD = Modified, HFBE = Historic Feeder Bluff Exceptional, HFB = Historic Feeder Bluff, PFB = Potential Feeder Bluff, NFB = Not Feeder Bluff.

Drift Cell Name	Drift Cell Length (ft)	Modified Shores (ft)	Historic Shoretypes of Modified Shores (%)			
			%NFB	%PFB	%HFB	%HFBE
BR-1	2,797.4	371.2	0	0	100	0
BR-2	792.5	338.1	0	0	100	0

San Juan Island

Net shore-drift cells are found along approximately 18 miles of San Juan Island (Table 17a, Map 4). Sediment sources (feeder bluff + feeder bluff exceptional units) cumulatively made up 18% (3.2 miles) of the San Juan Island study area in current conditions (Maps 20 and 21). The average length of feeder bluff within a drift cell was 265 ft. A single feeder bluff exceptional segment was mapped on San Juan Island near Cattle Point, which measured 4,765 ft. Ten drift cells had no intact sediment sources, including cells SJ-3, SJ-6, SJ-14, SJ-15, SJ-16, SJ-17, SJ-19, SJ-20, SJ-21a, and SJ-23. Drift cells without considerable sediment sources were typically comprised of a larger percentage of transport zones, which can periodically deliver limited quantities of sediment to the nearshore in the form of toe erosion and infrequent landslides.

Feeder bluffs were most abundant along southern Griffin Bay, the southeast shore on the Strait of Juan de Fuca, and within False Bay (Maps 20 and 21). Along the southern San Juan Island shore a lengthy feeder bluff exceptional, adjacent to a shorter length of feeder bluff was mapped southeast to Cattle Point. Shorter and less frequent segments of feeder bluff were mapped on the north part of the island in rocky embayments. Net shore-drift cells with the greatest percent of the cell length (20% or more) mapped as feeder bluff included cells SJ-4 (37%), SJ-5 (33%), SJ-8 (22%), SJ-10 (3% feeder bluff, 37% feeder bluff exceptional), SJ-11 (41%), SJ-12 (36%), SJ-13 (36%), and SJ-22 (44%) (Table 17b, Maps 20 and 21). Recent landslides and toe erosion frequently occurred where feeder bluffs were mapped (Maps 18 and 19). Toe erosion was also mapped within many transport zones, and was more widespread than mapped landslides. Both landslides and toe erosion shores were mapped mainly in southern San Juan Island, including southern Griffin Bay, at the southeastern shore along the Strait of Juan de Fuca, and in False Bay where glacial deposits were more abundant (Map 1, Table 2).

Accretion shoreforms were scattered throughout the island, cumulatively representing approximately 27% (4.8 miles) of the length of the San Juan Island study area shore. The average length of accretion shoreform was 571 ft. The percent of accretion shoreform mapped within each drift cell ranged from 0 – 80% (Table 17b). Drift cells SJ-3, SJ-5, SJ-14, SJ-15, SJ-16, and SJ-26 had no accretion shoreforms, but also contained modified lengths of shores that may have been accretion shoreforms historically. Large accretion shoreforms were found south of Davison Head, in Griffin Bay, and at the southeast shore along the Strait of Juan de Fuca (Maps 20 and 21). Drift cells with a large percent (20% or more) of accretion shoreforms included: SJ-1 (22%), SJ-2 (45%), SJ-3 (80%), SJ-6 (28%), SJ-7 (41%), SJ-8 (58%), SJ-9 (49%), SJ-10 (45%), SJ-17 (28%), SJ-19 (23%), SJ-20 (21%), SJ-21a (39%), and SJ-28 (54%).

Transport zones were mapped along approximately 42% (7.6 miles) of the San Juan Island study area. This is attributed to their prevalence in longer drift cells in the south and shorter drift cells in the north of the island. Fundamentally transport zones were so common due to the unique character of drift cells in the San Juan Islands, where limited glacial drift deposits are present and moderately low wave energy is typical.

San Juan Island drift cells exhibited variable degrees of modification, ranging from 0 to 91%, by length (Table 17b). These modifications typically consisted of residential bulkheads, but former industrial areas and urban areas also had extensive fill and/or seawalls. The average length of modified shores mapped per drift cell was 150 ft. The maximum length of modified shore was 1,579 ft mapped in SJ-26 along White Point Rd road in north Westcott Bay. On San Juan Island modified shores cumulatively accounted for 13% (2.3 miles). Three drift cells contained more than 50% of modified shore; SJ-2b near Turn Island (56%), SJ-26 in (outer) north Westcott Bay (56%) and SJ-14 in (southwest) Mitchell Bay (91%).

Results of historic conditions analysis showed that shore armoring has reduced the linear extent of sediment sources throughout many drift cells on San Juan Island. The historic shoretype of all currently modified shores on San Juan Island are buffered offshore of current conditions mapping in Maps 20 and 21. The drift cells with the greatest linear loss of feeder bluff (measuring 400 ft or more) were found in cells SJ-5, SJ-7, SJ-11, SJ-24 and SJ-28 (Table 17c). Drift cells that had incurred the greatest percent loss (50% or more) of their historic sediment supply include cells SJ-1, SJ-20, SJ-24, SJ-25, and SJ-28 (Table 17c). Results also showed that the armored shores within several drift cells were exclusively not feeder bluffs including cells: SJ-2b, SJ-3, SJ-6, SJ-14, SJ-15, SJ-16, SJ-17, SJ-19 and SJ-21a (Table 17d). These shores therefore do not realistically require armoring, which likely functions more as a landscaping feature than erosion control, in general. Armored shores in drift cells SJ-3, SJ-17 and SJ-18 were exclusively comprised of potential feeder bluffs, which represent historic sediment sources that contribute smaller volumes of sediment or erode with less frequency than typical feeder bluffs. In contrast all of the armored shore in drift cells SJ-5, SJ-11 and SJ-27 were along historic feeder bluffs. Each of these drift cells did not have any feeder bluffs mapped in them in current conditions mapping, therefore these armored shores represent the only sediment sources in the drift cells. Nine drift cells on San Juan Island did not encompass any feeder bluffs in neither historic nor current conditions mapping. These drift cells were typically comprised of low gradient, very sheltered shoreline where very little sediment transport is likely to occur.

Table 17a. San Juan Island drift cell descriptions.

Drift Cell Name	Drift Cell Direction	Drift Cell Length (ft)	Location Within Study Area
SJ-1	Westward	2,009	Southeast Davison Head to the lagoon, N San Juan Island
SJ-2	Southeastward	2,598	Lagoon to shore across Davison Head, N San Juan Island
SJ-2a	Southward	1,176	West Turn Bay, eastern central San Juan Island
SJ-2b	Northwestward	1,237	East Turn Bay, eastern central San Juan Island
SJ-3	Westward	2,351	Jackson Beach, South San Juan Island
SJ-4	Northward	2,383	Argyle to Jackson Beach Lagoon, South San Juan Island
SJ-5	Northward	2,989	Dinner Island to Argyle, South San Juan Island
SJ-6	Southward	2,424	Jensen Bay, South San Juan Island
SJ-7	Northwestward	13,242	South Griffin Bay to Low Point, South San Juan Island
SJ-8	Eastward	2,780	South Griffin Bay to marina, South San Juan Island
SJ-9	Northward	3,804	Goose Island, South San Juan Island
SJ-10	Eastward	12,813	San Juan National Historical Park, South San Juan Island
SJ-11	Northward	5,006	East side of False Bay, West San Juan Island
SJ-12	Northeastward	2,237	Northeast side of False Bay, West San Juan Island
SJ-13	Northward	2,194	South east side of False Bay, West San Juan Island
SJ-14	Eastward	531	Southwest end of Mitchell Bay, North San Juan Island
SJ-15	Westward	1,143	Central south side of Mitchell Bay, North San Juan Island
SJ-16	Eastward	1,424	Elbow of Mitchell Bay, North San Juan Island
SJ-17	Southward	982	Elbow of Mitchell Bay, North San Juan Island
SJ-18	Northward	1,795	East side of inner Mithcell Bay, North San Juan Island
SJ-19	Northward	3,181	West side of inner Mithcell Bay, North San Juan Island
SJ-20	Southward	1,258	Northwest end of Mitchell Bay, North San Juan Island
SJ-21a	Southward	3,202	Inner Garrison Bay, North San Juan Island
SJ-21b	Northward	2,007	Garrison Bay to Bell Point, North San Juan Island
SJ-22	Westward	1,005	Southwest Westcott Bay to Bell Point, N San Juan Island
SJ-23	Eastward	1,129	South side of Westcott Bay to estuary, North San Juan Island
SJ-24	Northeastward	5,976	Westcott to inner Westcott Bay, North San Juan Island
SJ-25	Northeastward	3,578	North side of inner Westcott Bay, North San Juan Island
SJ-26	Eastward	3,534	White Point to inner Westcott Bay, North San Juan Island
SJ-27	Northward	2,258	Mosquito Pass at White Point, North San Juan Island
SJ-28	Southward	2,507	Pearl Island to Davison Head, North San Juan Island

Table 17b. Current conditions mapping results for San Juan Island.

Drift Cell Name	Drift Cell Length (ft)	CGS Shoretypes (%)					LS	TE
		FBE	FB	TZ	AS	MOD		
SJ-1	2,009	0	3	53	22	22	0	0
SJ-2	2,598	0	5	40	44	11	5	5
SJ-2a	1,176	0	9	17	0	74	0	0
SJ-2b	1,237	0	0	31	13	56	0	0
SJ-3	2,351	0	0	0	80	20	0	0
SJ-4	2,383	0	36	55	0	9	6	36
SJ-5	2,989	0	32	54	0	14	3	21
SJ-6	2,424	0	0	53	28	19	0	40
SJ-7	13,242	0	19	37	41	4	6	35
SJ-8	2,780	0	22	20	58	0	20	22
SJ-9	3,804	0	10	41	49	0	0	17
SJ-10	12,813	37	3	14	45	0	38	41
SJ-11	5,006	0	41	35	1	23	13	64
SJ-12	2,237	0	36	58	6	0	0	15
SJ-13	2,194	0	34	60	6	0	22	0
SJ-14	531	0	0	9	0	91	0	0
SJ-15	1,143	0	0	85	0	15	0	0
SJ-16	1,424	0	0	93	0	7	0	0
SJ-17	982	0	0	60	28	13	0	0
SJ-18	1,795	0	10	86	2	1	0	0
SJ-19	3,181	0	0	65	23	12	0	0
SJ-20	1,258	0	0	61	21	18	0	0
SJ-21a	3,202	0	0	60	39	1	0	0
SJ-21b	2,007	0	9	76	15	0	0	0
SJ-22	1,005	0	44	47	9	0	0	0
SJ-23	1,129	0	0	88	12	0	0	0
SJ-24	5,976	0	6	52	12	30	0	3
SJ-25	3,578	0	6	66	12	16	2	4
SJ-26	3,534	0	19	25	0	56	3	19
SJ-27	2,258	0	20	44	17	18	5	29
SJ-28	2,507	0	4	18	54	24	0	0
All Drift Cells	94,751	5	13	42	27	13	9	20
Drift Cell Average (ft)	3,056	1	12	48	21	18	4	11

Table 17c. Historic versus current conditions of sediment sources of San Juan Island. This table includes drift cells with modified shores only.

Drift Cell Name	Drift Cell Length (ft)	% Pre-development Sed. Source	% Current Sed. Source	Sediment Source Lost (ft)	% Sediment Source Lost
SJ-1	2,009	14	3	218	79
SJ-2	2,598	10	5	122	48
SJ-2a	1,176	9	9	0	0
SJ-2b	1,237	0	0	0	N/A
SJ-3	2,351	0	0	0	N/A
SJ-4	2,383	44	36	185	18
SJ-5	2,989	46	32	416	30
SJ-6	2,424	0	0	0	N/A
SJ-7	13,242	22	19	491	17
SJ-11	5,006	64	41	1,141	36
SJ-14	531	0	0	0	N/A
SJ-15	1,143	0	0	0	N/A
SJ-16	1,424	0	0	0	N/A
SJ-17	982	0	0	0	N/A
SJ-18	1,795	10	10	0	0
SJ-19	3,181	0	0	0	N/A
SJ-20	1,258	2	0	20	100
SJ-21a	3,202	0	0	0	N/A
SJ-24	5,976	15	6	575	62
SJ-25	3,578	17	6	365	61
SJ-26	3,534	27	19	263	28
SJ-27	2,258	39	20	414	47
SJ-28	2,507	9	4	133	59

Table 17d. Historic shoretypes of currently modified shores of San Juan Island.
This table includes drift cells with modified shores only. MOD = Modified, HFBE = Historic Feeder Bluff Exceptional, HFB = Historic Feeder Bluff, PFB = Potential Feeder Bluff, NFB = Not Feeder Bluff.

Drift Cell Name	Drift Cell Length (ft)	Modified Shores (ft)	Historic Shoretypes of Modified Shores (%)			
			%NFB	%PFB	%HFB	%HFBE
SJ-1	2,009	437	0	50	50	0
SJ-2	2,598	279	0	56	44	0
SJ-2a	1,176	869	43	57	0	0
SJ-2b	1,237	696	27	73	0	0
SJ-3	2,351	480	0	100	0	0
SJ-4	2,383	206	0	10	90	0
SJ-5	2,989	416	0	0	100	0
SJ-6	2,424	456	100	0	0	0
SJ-7	13,242	525	7	0	93	0
SJ-11	5,006	1,141	0	0	100	0
SJ-14	531	484	100	0	0	0
SJ-15	1,143	168	100	0	0	0
SJ-16	1,424	102	100	0	0	0
SJ-17	982	124	0	100	0	0
SJ-18	1,795	17	0	100	0	0
SJ-19	3,181	377	100	0	0	0
SJ-20	1,258	222	91	0	9	0
SJ-21a	3,202	25	100	0	0	0
SJ-24	5,976	1,813	19	49	32	0
SJ-25	3,578	584	21	16	63	0
SJ-26	3,534	1,976	87	0	13	0
SJ-27	2,258	414	0	0	100	0
SJ-28	2,507	589	77	0	23	0

Pearl Island

Pearl Island, north of Roche Harbor, contains a single drift cell (PE-1) that extends 1,435 ft along the north shore of the island (Table 18a). No feeder bluffs were mapped along this drift cell (Table 18b, Map 21). Transport zones represented 39% (557 ft) of the cell and were the most abundant shoretype in the Pearl study area. Accretion shoreforms comprised 22% (589 ft) of the drift cell and were primarily located in the central portion of the drift cell. Modified shores accounted for 20% (289 ft) of the drift cell which were predominantly residential shoreline armoring structures. Toe erosion was mapped along a modified segment of shore as the bulkhead was being undermined (Map 18).

Historic conditions analyses of the modified shore on Pearl Island showed that 56% of the 289 feet of armoring was historic feeder bluff (Table 18d). The remaining shore was not feeder bluff. The historic feeder bluff segment was the only sediment source historically found within the drift cell resulting in a 100% loss of sediment supply (Table 18c). The historic shoretype of currently modified shores on Pearl Island are buffered offshore of current conditions mapping in Map 21.

Table 18a. Pearl Island drift cell description.

Drift Cell Name	Drift Cell Direction	Drift Cell Length (ft)	Location Within Study Area
PE-1	Westward	1,435	Pearl Island-north

Table 18b. Current conditions mapping results of Pearl Island.

Drift Cell Name	Drift Cell Length (ft)	CGS Shoretypes (%)					LS	TE
		FBE	FB	TZ	AS	MOD		
PE-1	1,435	0	0	39	41	20	0	7

Table 18c. Historic versus current conditions of sediment sources of Pearl Island. This table includes drift cells with modified shores only.

Drift Cell Name	Drift Cell Length (ft)	% Pre-development Sed. Source	% Current Sed. Source	Sediment Source Lost (ft)	% Sediment Source Lost
PE-1	1,435	11	0	163	100

Table 18d. Historic shoretypes of currently modified shores of Pearl Island.
This table includes drift cells with modified shores only. MOD = Modified, HFBE = Historic Feeder Bluff Exceptional, HFB = Historic Feeder Bluff, PFB = Potential Feeder Bluff, NFB = Not Feeder Bluff.

Drift Cell Name	Drift Cell Length (ft)	Modified Shores (ft)	Historic Shoretypes of Modified Shores (%)			
			%NFB	%PFB	%HFB	%HFBE
PE-1	1,434.9	288.5	44	0	56	0

Henry Island

Henry Island contains 8 net shore-drift cells, which together represent the 3.3 miles of the Henry Island study area. Sediment sources (feeder bluff units) cumulatively represent 21% (3,755 ft) of the study area (Table 19b, Map 21). On average, drift cells contained 16% feeder bluff. The average length of feeder bluff mapped along the Henry Island study area was 375 ft. The longest feeder bluff segment mapped on Henry Island measured 1,767 ft and was mapped on HE-8 on the more exposed, northwest side of the island. Four drift cells had no intact sediment sources, including cells HE-1, HE-3, HE-6, and HE-7. Drift cells without considerable sediment sources were typically comprised of a larger percentage of transport zones, which can periodically deliver limited quantities of sediment to the nearshore. Considerable lengths of modified shore were mapped in several of the drift cells with no intact sediment sources.

Accretion shoreforms were prevalent throughout the Henry Island drift cells, cumulatively representing approximately 37% (1.2 miles) of the Henry Island study area. The average percent of accretion shoreform mapped within drift cells was 48% and the average length of accretion shoreform mapped throughout the study area was 432 ft. The longest accretion shoreform mapped in the Henry Island study area measured 1,009 ft and was found in HE-5 along Mosquito Pass (Map 21). Transport zones were mapped along approximately 36% (1.2 miles) of the study area, were most abundant in Nelson Bay in HE-1 and HE-2.

The drift cells that comprise the Henry Island study area were modified from 0 to 21% (Table 19b). Modifications typically consisted of residential bulkheads and dock footings. The average percent of modified shores mapped within drift cells was 4%. The average length of modified shore across the Henry Island study area was 75 ft. The maximum length of modified shore was 147 ft mapped in HE-2 and appeared to be for shore protection and dock footings at the Seattle Yacht Club facility near the northeast point of the island. Modified shores cumulatively accounted for 6% (1,046 ft) of the Henry Island study area.

Armoring was mapped in only 3 drift cells on Henry Island, which were the target of the historic condition analyses. None of the armored shore in drift cell HE-1 were found to be historic feeder bluff, however 64% was classified as potential feeder bluff indicating that some sediment was likely supplied to the nearshore, though less frequently, and in smaller volumes than a typical feeder bluff (Table 19d). Cell HE-2 incurred the greatest decline in sediment supply of 57%; with 81% of the armored shore in the cell mapped as historic feeder bluffs (523 ft, Table 19c and 19d). Cell HE-4 had a lesser decline in the extent of feeder bluffs (91 ft, or 7%), however the sediment sources included both historic feeder bluffs and historic feeder bluff exceptional segments. The historic shoretype of all currently modified shores on Henry Island are buffered offshore of current conditions mapping in Map 21.

Table 19a. Henry Island drift cell descriptions.

Drift Cell Name	Drift Cell Direction	Drift Cell Length (ft)	Location Within Study Area
HE-1	Southward	3,222	Henry Island-west Nelson Bay
HE-2	Southwestward	2,989	Henry Island-east Nelson Bay
HE-3	Southeastward	747	Henry Island-Pole Island
HE-4	Northeastward	2,337	Henry Island-north Mosquito Pass
HE-5	Southwestward	1,738	Henry Island-central Mosquito Pass
HE-6	Northwestward	1,116	Henry Island-central Mosquito Pass
HE-7	Southward	1,494	Henry Island-south Mosquito Pass
HE-8	Northward	3,893	Henry Island-northwest

Table 19b. Current conditions mapping results of Henry Island.

Drift Cell Name	Drift Cell Length (ft)	CGS Shoretypes (%)					LS	TE
		FBE	FB	TZ	AS	MOD		
HE-1	3,222	0	0	48	43	9	0	35
HE-2	2,989	0	13	55	11	21	3	41
HE-3	747	0	0	42	58	0	0	0
HE-4	2,337	0	50	30	15	5	0	61
HE-5	1,738	0	18	24	58	0	0	42
HE-6	1,116	0	0	21	79	0	0	0
HE-7	1,494	0	0	23	77	0	0	0
HE-8	3,893	0	48	27	24	0	36	53
Study Area Total	17,535	**0**	**21**	**36**	**37**	**6**	**8**	**38**
Drift Cell Average	2,192	0	16	34	46	4	5	29

Table 19c. Historic versus current conditions of sediment sources of Henry Island. This table includes drift cells with modified shores only.

Drift Cell Name	Drift Cell Length (ft)	% Pre-development Sed. Source	% Current Sed. Source	Sediment Source Lost (ft)	% Sediment Source Lost
HE-1	3,222	0	0	0	N/A
HE-2	2,989	30	13	523	57
HE-4	2,337	54	50	91	7

Table 19d. Historic shoretypes of currently modified shores of Henry Island. This table includes drift cells with modified shores only. MOD = Modified, HFBE = Historic Feeder Bluff Exceptional, HFB = Historic Feeder Bluff, PFB = Potential Feeder Bluff, NFB = Not Feeder Bluff.

Drift Cell Name	Drift Cell Length (ft)	Modified Shores (ft)	Historic Shoretypes of Modified Shores (%)			
			%NFB	%PFB	%HFB	%HFBE
HE-1	3,222	289	36	64	0	0
HE-2	2,989	643	19	0	81	0
HE-4	2,337	116	21	0	67	12

Stuart Island

Net shore-drift cells occur along 2.4 miles of Stuart Island shore (Table 20a). Sediment sources (feeder bluffs) cumulatively made up 13% (1,572 ft) the Stuart Island study area (Table 20b, Map 22). The average percent of feeder bluff mapped within Stuart Island drift cells was 14%. The average length of feeder bluff mapped across the Stuart Island drift cells was 262 ft. The longest feeder bluff mapped was 413 ft in ST-4 near the west side of the landing strip. Three drift cells had no intact sediment sources, including cells ST-6, ST-7, and ST-8.

Accretion shoreforms were prevalent throughout the study area, cumulatively representing 33% (4,136 ft) of the Stuart Island study area. The average percent of accretion shoreform per drift cell was 36% and the average length was 318 ft. The longest accretion shoreform measured 1,430 ft and was located near Johns Pass. The percent of accretion shoreform mapped within each drift cell ranged from 0 – 95% (Table 20b). Large accretion shoreforms were found near Johns Pass, inside Reid Harbor, and intermittently near the west side of the landing strip and in western Prevost Harbor (Map 22). Transport zones were cumulatively mapped along approximately 50% (1.2 miles) of the study area and were the most abundant shoretype on Stuart Island.

Modified shores among Stuart Island drift cells ranged 0 to 22% and averaged 6 percent (Table 20b, Map 22). Modifications typically consisted of residential bulkheads. The average length of modified shores mapped was a mere 78 ft. The maximum length of modified shore was 157 ft mapped in ST-1 in western Prevost Harbor and appeared to be shore protection with an associated dock footing. On Stuart Island modified shores cumulatively accounted for 4% (544 ft) of the study area. It should be noted however that many more modifications were observed along the shores of Stuart Island outside of drift cells during field mapping.

The historic condition of all armored shores within drift cells were analyzed and mapped. The historic shoretype of all currently modified shores on Stuart are buffered offshore of current conditions mapping in Map 22. Results showed that all of the armored shores within the two drift cells were historic feeder bluffs (Table 20d). Comparison of current and historic conditions reveals that drift cell ST-6 has incurred a 100% loss of sediment supply – which cumulatively measured only 73 ft (Table 20c). Cell ST-2 had a 17% reduction in sediment supply or 99 ft (Table 20c). Within both drift cells all armoring occurred along historic feeder bluffs (Table 20d).

Table 20a. Stuart Island drift cell descriptions.

Drift Cell Name	Drift Cell Direction	Drift Cell Length (ft)	Location Within Study Area
ST-1	Northwestward	972	Stuart Island-northwest Prevost Harbor
ST-2	Westward	1,330	Stuart Island-southwest Prevost Harbor
ST-3	Westward	3,977	Stuart Island-northeast
ST-4	Eastward	1,314	Stuart Island-northeast
ST-5	Southeastward	563	Stuart Island-northeast
ST-6	Northeastward	1,503	Stuart Island-Johns Pass
ST-7	Southwestward	977	Stuart Island-north Reid Harbor
ST-8	Northwestward	1,801	Stuart Island-south Reid Harbor

Table 20b. Current conditions mapping results of Stuart Island.

Drift Cell Name	Drift Cell Length (ft)	CGS Shoretypes (%)					LS	TE
		FBE	FB	TZ	AS	MOD		
ST-1	972	0	28	11	39	22	0	25
ST-2	1,330	0	37	56	0	7	4	56
ST-3	3,977	0	9	68	23	0	-	-
ST-4	1,314	0	31	24	34	10	-	-
ST-5	563	0	6	50	43	2	-	-
ST-6	1,503	0	0	0	95	5	-	-
ST-7	977	0	0	67	33	0	-	-
ST-8	1,801	0	0	77	22	1	-	-
Study Area Total	**12,436**	**0**	**13**	**50**	**33**	**4**	**0**	**8**
Drift Cell Average	1,555	0	14	44	36	6	2	41

Table 20c. Historic versus current conditions of sediment sources of Stuart Island. This table includes drift cells with modified shores only.

Drift Cell Name	Drift Cell Length (ft)	% Pre-development Sed. Source	% Current Sed. Source	Sediment Source Lost (ft)	% Sediment Source Lost
ST-1	972	28	28	0	0
ST-2	1,330	44	37	98	17
ST-4	1,314	31	31	0	0
ST-5	563	6	6	0	0
ST-6	1,503	5	0	72	100
ST-8	1,801	0	0	0	0

Table 20d. Historic shoretypes of currently modified shores of Stuart Island.
This table includes drift cells with modified shores only. MOD = Modified, HFBE = Historic Feeder Bluff Exceptional, HFB = Historic Feeder Bluff, PFB = Potential Feeder Bluff, NFB = Not Feeder Bluff.

Drift Cell Name	Drift Cell Length (ft)	Modified Shores (ft)	Historic Shoretypes of Modified Shores (%)			
			%NFB	%PFB	%HFB	%HFBE
ST-1	972	211	100	0	0	0
ST-2	1,330	99	0	0	100	0
ST-4	1,314	135	100	0	0	0
ST-5	563	10	100	0	0	0
ST-6	1,503	73	0	0	100	0
ST-8	1,801	17	100	0	0	0

Johns Island

A single net shore-drift cell extends eastward 3,732 ft along the south shore of Johns Island (JN-1, Map 4). Cumulatively feeder bluffs represented 42% (1,555 ft) of the Johns Island drift cell (Table 21b, Map 21). The longest of which extended 911 ft, and was located near the drift cell origin. Toe erosion was co-located with most of the feeder bluff segments (Maps 18 and 19). Accretion shoreforms comprised 15% (557 ft) of JN-1. One large accretion shoreform was mapped at the east end (terminus) of the drift cell that measured 557 ft long. Transport zones comprised the majority of the drift cell with 43% (1,600 ft). Only one 20 ft segment of modified shore was mapped in JN-1, which appeared to be associated with a beach access. This modified segment contained a groin and historic research shows that it was likely a historic feeder bluff prior to modification (Table 21c and 21d). Modification reduced historic sediment supply in the John's Island drift cell by 1% (Table 21c).

Table 21a. Johns Island drift cell description.

Drift Cell Name	Drift Cell Direction	Drift Cell Length (ft)	Location Within Study Area
JN-1	Southeastward	3,732	Johns Island-south

Table 21b. Current conditions field mapping results of Johns Island.

Drift Cell Name	Drift Cell Length (ft)	CGS Shoretypes (%)					LS	TE
		FBE	FB	TZ	AS	MOD		
JN-1	3,732	0	42	43	15	1	0	44

Table 21c. Historic versus current conditions of sediment sources on Johns Island. This table includes drift cells with modified shores only.

Drift Cell Name	Drift Cell Length (ft)	% Pre-development Sed. Source	% Current Sed. Source	Sediment Source Lost (ft)	% Sediment Source Lost
JN-1	3,732	42	42	20	1

Table 21d. Historic shoretypes of currently modified shores of Johns Island.
This table includes drift cells with modified shores only. MOD = Modified, HFBE = Historic Feeder Bluff Exceptional, HFB = Historic Feeder Bluff, PFB = Potential Feeder Bluff, NFB = Not Feeder Bluff.

Drift Cell Name	Drift Cell Length (ft)	Modified Shores (ft)	Historic Shoretypes of Modified Shores (%)			
			%NFB	%PFB	%HFB	%HFBE
JN-1	3,732	20	0	0	100	0

Waldron Island

Net shore-drift cells on Waldron Island comprise 7.2 miles of the Waldron Island study area (Table 22a, Map 2). Waldron Island offers some of the most stunning examples of feeder bluff and feeder bluff exceptional units of the entire San Juan Islands. Sediment sources (feeder bluff and feeder bluff exceptional units) cumulatively made up 27% (2.0 miles) of the Waldron Island study area (Table 22b, Map 23). Each drift cell had intact sediment sources. The average percent of sediment sources per drift cell was 35%. The average length of feeder bluff and feeder bluff exceptional mapped was 940 ft across the Waldron Island study area. The most extensive feeder bluffs were mapped in cells WL-3 and WL-4, located on the northwest side of the island (Map 23). Recent landslides and toe erosion frequently occurred where feeder bluff and feeder bluff exceptional units were mapped (Maps 8 and 9). Toe erosion was also mapped within a few transport zones, and was more widespread than mapped landslides.

Accretion shoreforms were also abundant throughout Waldron Island, cumulatively representing approximately 38% (2.8 miles) of the study area (Table 22b). The average percent of accretion shoreform mapped per drift cell was 35% and ranged from 22 to 49% (Table 22b). The average length of accretion shoreform mapped across the Waldron Island study area was 1,131 ft. The longest accretion shoreform mapped in the Waldron Island study area measured 4,688 ft and extended from Fishery Point into North Bay on the northwest side of the island (Map 23). Transport zones were mapped intermittently throughout the study area and cumulatively represented 34% (2.4 miles) of the Waldron Island drift cells. Transport zones were frequently mapped where bedrock outcrops occurred alongshore in drift cells, especially in the south end of Cowlitz Bay.

Modified shores were less abundant in the Waldron study area and were only mapped in Cowlitz Bay (WL-3) and comprised 3% of that drift cell. Cumulatively the modifications comprised only 1% (351 ft) of the Waldron study area. The modifications in Cowlitz Bay consisted of two spans of large rock used for shore protection near Sandy Point and another span of rocked shore associated with the wharf at the south end of Cowlitz Bay. Research of the historic condition of these modified shores revealed that approximately 111 ft of the 350 ft of modified shore were historic feeder bluffs (32%, Tables 22c and d). Map 23 also shows the historic condition of modified shores buffered offshore of current conditions mapping. The remaining 68% of modified shore on Waldron Island was classified as a potential feeder bluff indicating that smaller volumes of sediment are likely eroded and supplied to the nearshore however with less frequency than a typical feeder bluff (Table 22c). Comparison of the extent of historic and current sediment sources reveals only a 3% decline in sediment supply in WL-3 (Table 22d).

Table 22a. Waldron Island drift cell descriptions.

Drift Cell Name	Drift Cell Direction	Drift Cell Length (ft)	Location Within Study Area
WL-1	Northward	1,275	Waldron Island-northeast to Point Hammond
WL-2	Southward	5,300	Waldron Island-northeast
WL-3	Northwestward	12,851	Waldron Island-Cowlitz Bay
WL-4	Southwestward	18,757	Waldron Island- Point Hammond to Sandy Point

Table 22b. Current conditions mapping results of Waldron Island.

Drift Cell Name	Drift Cell Length (ft)	CGS Shoretypes (%)					LS	TE
		FBE	FB	TZ	AS	MOD		
WL-1	1,275	59	0	17	24	0	59	59
WL-2	5,300	20	12	26	43	0	16	32
WL-3	12,851	5	19	50	22	3	14	28
WL-4	18,757	10	15	25	49	0	16	23
Study Area Total	**38,183**	**12**	**15**	**34**	**38**	**1**	**17**	**27**
Drift Cell Average	9,546	24	11	30	35	1	26	36

Table 22c. Historic versus current conditions of sediment sources of Waldron Island. This table includes drift cells with modified shores only.

Drift Cell Name	Drift Cell Length (ft)	% Pre-development Sed. Source	% Current Sed. Source	Sediment Source Lost (ft)	% Sediment Source Lost
WL-3	12,851	25	25	111	3

Table 22d. Historic shoretypes of currently modified shores of Waldron Island.
This table includes drift cells with modified shores only. MOD =Modified, HFBE = Historic Feeder Bluff Exceptional, HFB = Historic Feeder Bluff, PFB = Potential Feeder Bluff, NFB = Not Feeder Bluff.

Drift Cell Name	Drift Cell Length (ft)	Modified Shores (ft)	Historic Shoretypes of Modified Shores (%)			
			%NFB	%PFB	%HFB	%HFBE
WL-3	12,851	351	0	68	32	0

Summary of Countywide Current and Historic Coastal Geomorphic Mapping

This mapping effort encompassed all of the drift cells found in San Juan County, cumulatively measuring approximately 90 miles (89.6 mi), within 126 (updated) net shore-drift cells, and across 16 Islands. Geology, shore orientation, topography and exposure influence the abundance of shoretypes, such as feeder bluffs and accretion shoreforms. This patterns is evident when one compares the relative distribution of shoretypes among the islands located in the southeast portion of the study area (along Rosario Strait), where the exposure is high and the geology is typically glacially derived, versus the more protected bedrock conditions observed in the northern or central part of the County. This is precisely the case with the distribution of feeder bluffs; which are most abundant on Lopez Island (Table 23). Other patterns that are likely associated with the pressure from shoreline development are visible when comparing the extent of shore modifications on islands with ferry service versus the more remote islands, such as on Waldron, Turn, Obstruction, Henry or Blakely. Shaw Island had the greatest percentage (40%) of modified shores (within drift cells) due to extensive roads along the shoreline of Blind Bay.

Countywide, current conditions mapping documented sediment sources, which included both feeder bluffs and feeder bluff exceptional units, along 25% or approximately 22 miles of the 90 mile study area (Table 23). Accretion shoreforms accounted for 25% of the County's shoreline. Transport zones, which are characteristically neither actively eroding nor accreting, were the most abundant shoreform in the County, cumulatively accounting 37% and almost 33 miles of shoreline. Shore modifications were mapped along 14% of the study area, or slightly more than 12 miles.

Table 23. Distribution of current conditions geomorphic shoretypes within San Juan County.

Island	Drift Cell Length (ft)	Feeder Bluff Exceptional		Feeder Bluff		Transport Zone		Accretion Shoreform		Modified	
		Ft	%	Ft	%	Ft	%	Ft	%	Ft	%
Orcas	92,953	1,435	2	17,558	19	43,346	47	15,494	17	15,120	16
Clark	1,820	0	0	825	45	593	33	402	22	0	0
Obstruction	3,758	0	0	748	20	2,505	67	474	13	32	1
Blakely	28,089	0	0	7,628	27	13,617	48	5,523	20	1,321	5
Decatur	32,099	761	2	10,499	33	9,918	31	8,787	27	2,134	7
Center	2,519	0	0	981	39	1,031	41	43	2	463	18
Lopez	123,370	2,659	2	35,406	29	28,375	23	31,941	26	24,674	20
Shaw	13,829	143	1	2,589	19	3,458	25	2,174	16	5,466	40
Turn	2,734	0	0	741	27	923	34	1,071	39	0	0
Brown	3,590	0	0	798	22	2,034	57	49	1	709	20
San Juan	94,751	4,765	5	12,286	13	40,037	42	25,263	27	12,400	13
Pearl	1,435	0	0	0	0	557	39	589	41	288	20
Henry	17,535	0	0	3,754	21	6,256	36	6,478	37	1,047	6
Stuart	12,436	0	0	1,572	13	6,185	50	4,136	33	544	4
Johns	3,732	0	0	1,555	42	1,600	43	557	15	20	1
Waldron	38,183	4,421	12	5,916	15	12,797	34	14,699	38	351	1
Countywide Total	**472,834**	**14,184**	**3**	**102,856**	**22**	**173,231**	**37**	**117,680**	**25**	**64,569**	**14**

Feeder Bluffs

Countywide, the most feeder bluffs (feeder bluffs and feeder bluff exceptional units) were mapped on Lopez Island in both current and historic conditions (current: 33% 7.2 miles, historic 32%, Figures 2 and 3). Orcas and San Juan Islands had roughly half of the linear extent of feeder bluffs as Lopez Island, followed by Decatur, Waldron and Blakely Islands (Figure 2, Table 23). The historic distribution of sediment sources was very similar to current conditions – with the greatest ratio of feeder bluffs found within the major Islands such as Lopez, Orcas, and Shaw islands, although historically Orcas Island encompassed 19% of the feeder bluffs, while currently it encompasses 16% (Figures 2 and 3). The decrease in percent from historic to current conditions is due the extent of armored historic feeder bluffs on Orcas Island. Decreased ratios in the distribution of feeder bluffs from historic to current conditions were also observed on Center, Shaw, Brown, San Juan, and Pearl Islands. In contrast, Lopez Island had an increase in the percent of feeder bluffs (32% historic versus 33% current conditions mapping) due to there being more intact sediment sources on Lopez than elsewhere in the County, despite the fact that many feeder bluffs on Lopez also incurred considerable armoring. Similarly, Waldron, Blakely and Decatur islands each had a small decrease in the percentage of feeder bluffs from historic to current conditions, which is generally a relict of the countywide distribution calculation – rather than representing an increase in sediment sources. Because feeder bluffs occurrence was historically more widespread than it is currently; the relative distribution of the resource has increased among these islands that maintain considerable lengths of intact feeder bluff.

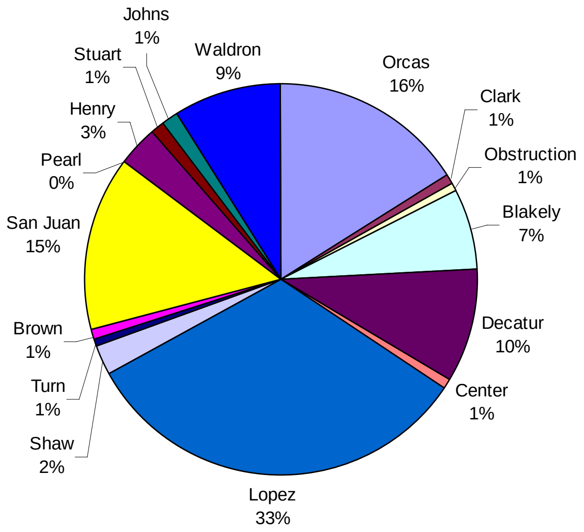

Figure 2. Percent of San Juan County current feeder bluffs found on each Island.

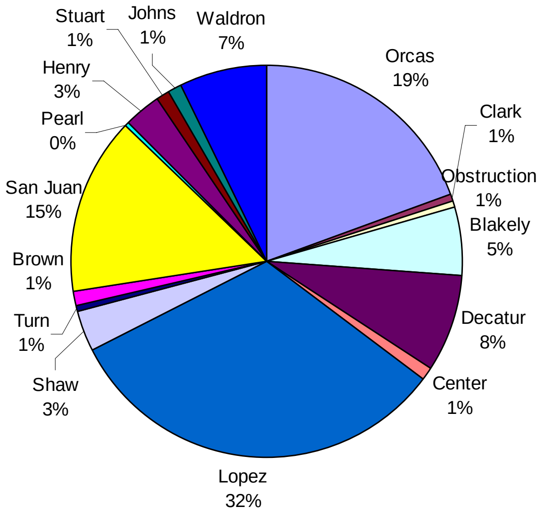

Figure 3. Percent of San Juan County historic feeder bluffs found on each Island.

Throughout San Juan County over 5 miles of sediment sources (historic feeder bluff or historic feeder bluff exceptional units) have been armored or modified to the degree that they no longer supply sediment to the nearshore (Tables 24 and 25). An additional 2.5 miles of drift cell shore was classified as potential feeder bluff, which likely represents shores that prior to being armored, were slowly eroding and contributing smaller volumes of sediment to the nearshore with less frequency than a typical Puget Sound feeder bluff. The distribution of the historic feeder bluffs is shown in Figure 4. Islands that did not incur any loss of sediment supply were not included in the figure.

Thirty-four percent of the historic feeder bluffs in the county were mapped on Orcas Island (Figure 4, Table 24). Shaw Island sediment sources exhibited a similar pattern of a reduced occurrence of feeder bluff by from historic to current conditions (1%), and a considerably higher ratio of the armored sediment sources (43%, Figure 4, Table 25). Armored feeder bluffs were most frequently mapped on Orcas Island (34%; 9,012 ft), followed by Lopez Island (31%; 8,083 ft). Sixteen percent of the (4,341 ft) of the armored feeder bluffs in San Juan County were mapped on San Juan Island. The islands that incurred the greatest loss of sediment supply included: Pearl (100%), Shaw (43%), Orcas (32%), Center and Brown (30%), and Lopez (18%).

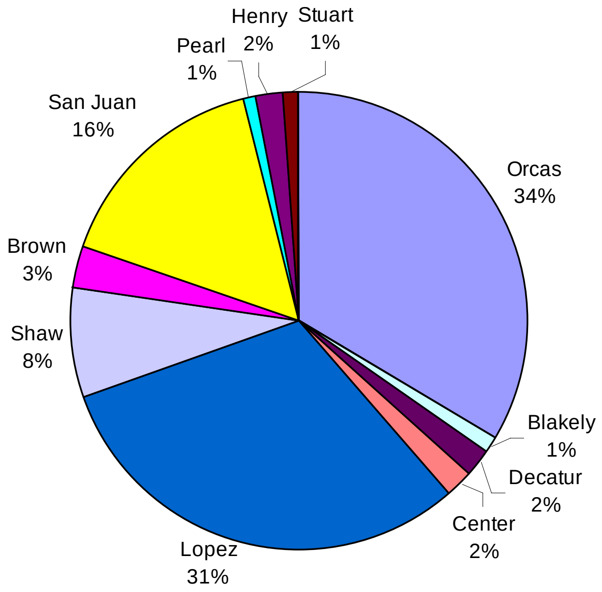

Figure 4. Percent of San Juan County historic (armored) feeder bluffs found on each Island.

The percent of lost sediment sources on each island was calculated to highlight which islands have incurred the greatest decline in sediment supply relative to the historic extent (Figures 5 and 6). Many small islands have small lengths of armored feeder bluffs, which can mistakenly appear to cause minimal impact. By comparing the current and the historic extent of feeder bluffs in a given drift cell one can attain a more accurate measure of the impact to sediment supply (Figure 6). For example, many small islands often have naturally low-volume sediment budgets, in which 200 ft of armoring can have a much greater impact in a drift cell with only 300 ft of (historic) feeder bluff compared to a drift cell with 4000 ft of (historic) feeder bluff. In these cases, feeder bluffs are already in low supply and therefore adequate conservation or restoration is necessary. Additionally, there are often fewer drift cells on many smaller islands, and the habitats associated with feeder bluffs and down-drift accretion shoreforms are unique and often the only habitats of that kind for many miles of shoreline. The rarity of these shoreforms emphasizes their value as conservation priorities in the marine landscape. Such is the case with Brown and Center Islands, in which armored feeder bluffs account for 20% and 17% (respectively) of the Islands' net shore-drift cell shoreline (not including potential feeder bluffs, Figure 6).

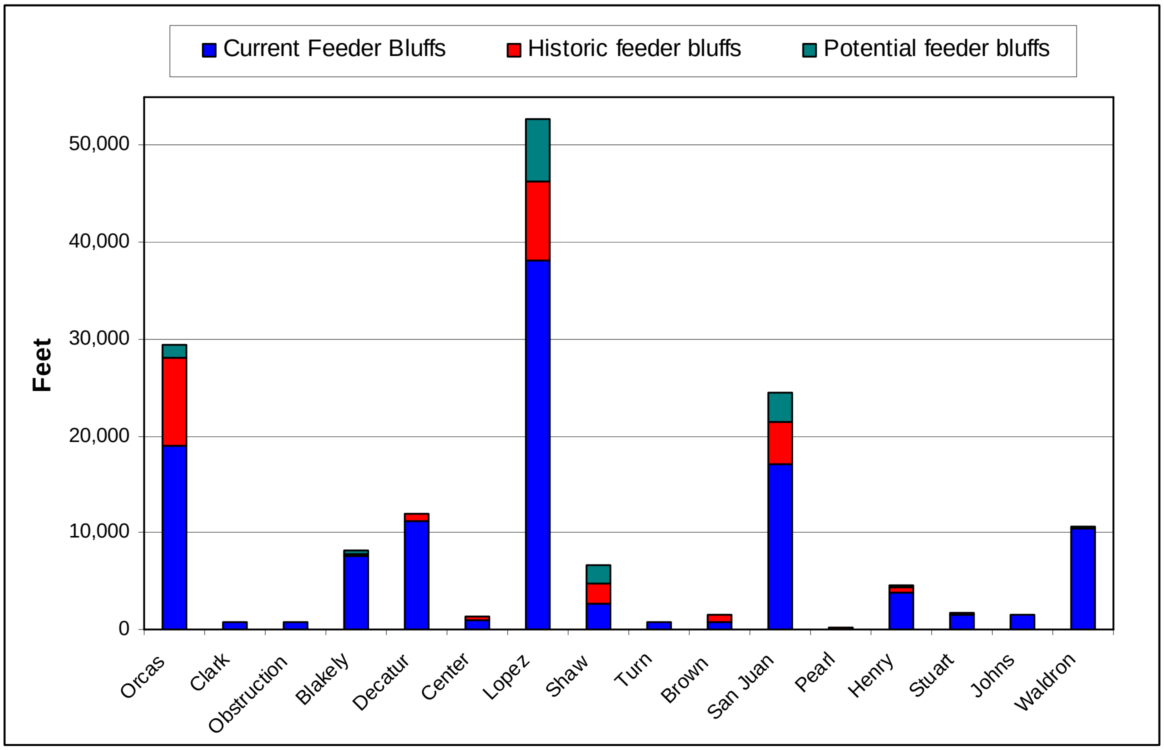

Figure 5. The linear extent of current, historic and potential feeder bluffs in San Juan County.

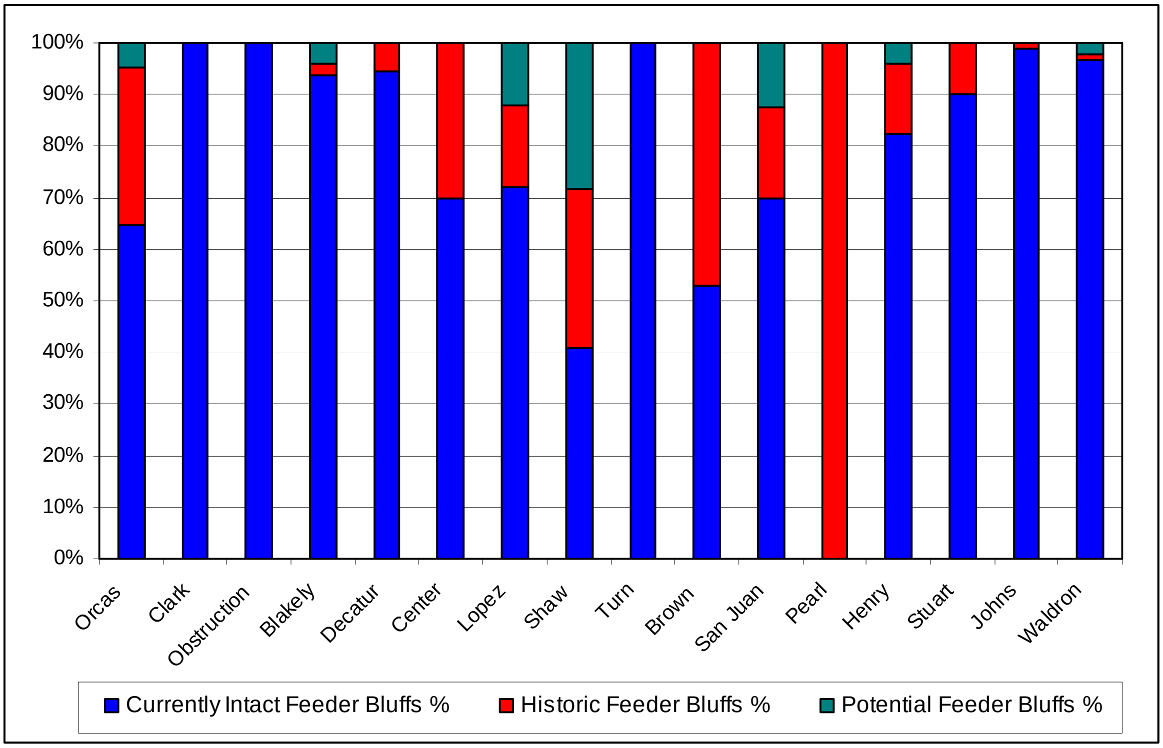

Figure 6. Ratio of currently intact feeder bluffs versus historic feeder bluffs and potential feeder bluffs in San Juan County.

Table 24. Historic shoretypes of modified shores within each island in San Juan County. This table includes drift cells with modified shores only. HFB = Historic Feeder Bluff, PFB = Potential Feeder Bluff, NFB = Not Feeder Bluff.

Island	Modified Shores (ft)	Drift Cell Length (ft)	Historic Conditions (% of Mod Shores)		
			HFB %	PFB %	NFB %
Orcas	15,120	92,953	60	9	31
Clark	0	1,820	NA	NA	NA
Obstruction	32	3,758	0	0	100
Blakely	1,321	28,089	13	25	61
Decatur	2,134	32,099	29	1	70
Center	463	2,519	91	0	9
Lopez	24,674	123,370	34	26	41
Shaw	5,466	13,829	38	34	28
Turn	0	2,734	NA	NA	NA
Brown	709	3,590	100	0	0
San Juan	12,400	94,751	35	24	41
Pearl	288	1,435	56	0	44
Henry	1,047	17,535	59	18	24
Stuart	544	12,436	31	0	69
Johns	20	3,732	100	0	0
Waldron	351	38,183	32	68	0
Total	**64,569**	**472,834**	**41**	**21**	**38**

Table 25. Distribution of current, historic, and lost sediment sources in San Juan County.

Island	Drift Cell Length (ft)	Current Sed Sources (Ft, %)		Historic Sed Sources (Ft, %)		Lost Sed Sources (Ft, %)	
Orcas	92,953	18,994	16	28,006	19	9,012	34
Clark	1,820	825	1	825	1	0	0
Obstruction	3,758	748	1	748	1	0	0
Blakely	28,089	7,628	7	7,803	5	175	1
Decatur	32,099	11,260	10	11,887	8	627	2
Center	2,519	981	1	1,404	1	423	2
Lopez	123,370	38,066	33	46,364	32	8,298	31
Shaw	13,829	2,732	2	4,796	3	2,064	8
Turn	2,734	741	1	741	1	0	0
Brown	3,590	798	1	1,507	1	709	3
San Juan	94,751	17,051	15	21,393	15	4,341	16
Pearl	1,435	0	0	163	0	163	1
Henry	17,535	3,754	3	4,368	3	614	2
Stuart	12,436	1,572	1	1,742	1	171	1
Johns	3,732	1,555	1	1,575	1	20	0
Waldron	38,183	10,337	9	10,447	7	111	0
Total	**472,834**	117,040	100	143,768	100	26,728	100

Between the 16 islands and 126 drift cells mapped in this study, a total of 27 drift cells had no feeder bluffs. As reported in the individual island summaries, most of these drift cells were short and located in very protected areas, with very low sediment budgets. It is likely that the functioning sediment sources within these cells are more characteristically transport zones that intermittently contribute sediment to the cell via toe erosion and infrequent landslides. Seven drift cells had no *intact* sediment sources (no feeder bluffs in current conditions, only historic conditions mapping) and had incurred a 100% loss of sediment supply. Three of these drift cells were located on Orcas Island, and single cells on San Juan, Lopez, Pearl and Stuart islands. In contrast, 45 drift cells had not incurred any decline in the linear extent of sediment sources.

Accretion Shoreforms

Accretion shoreforms were scattered throughout the study area, cumulatively representing approximately 25% (22 miles) of the length of the entire study area shore (in current conditions, Table 23, Figure 7). Analysis of the distribution of accretion shoreform throughout the entire study area showed that 27% of them were mapped along Lopez Island, followed by San Juan (21%), Orcas (13%) and Waldron (12%) islands. These features are typically associated with coastal wetlands (salt marshes) and valuable habitats for many species, particularly juvenile salmonids. The average length of accretion shoreforms over the entire study was 462 ft. Pearl Island had the most cumulative accretion shoreform percentage per island study area with 41%. However, Waldron Island, with a study area almost 27 times that of Pearl Island, consisted of 38% accretion shoreform (Table 23). Restoration and conservation planning associated with accretion shoreforms should address the condition of up-drift sediment sources that sustain these important habitats.

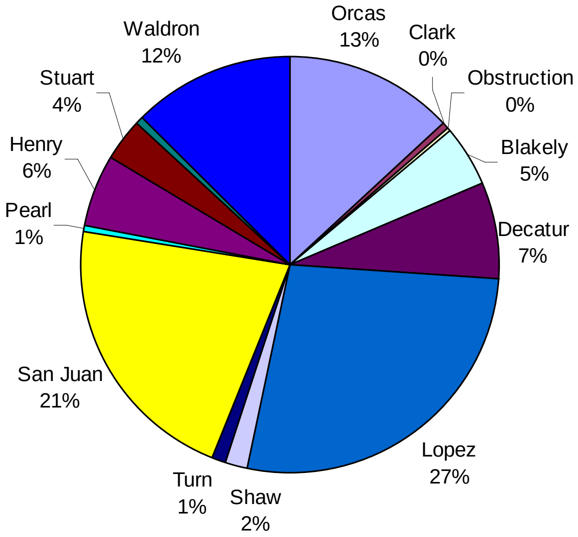

Figure 7. Percent of San Juan County accretion shoreforms found on each Island.

Transport Zones

Transport zones were mapped along approximately 37% (33 miles) of the study area shore. As to be expected the largest islands encompassed the greatest ratio of shoreline mapped as transport zone including: Orcas (25%), San Juan (23%) and Lopez (16%) islands (Table 23, Figure 8). Over 50% of the shorelines on some islands, including Obstruction and Brown Islands, were mapped as transport zone. Transport zones were mapped in many areas where bedrock outcropped above the beach but contiguous littoral drift was maintained waterward of the bedrock. Due to the abundant bedrock in San Juan County, this occurred frequently and transport zones occurred more frequently than in other counties where this mapping typology has been applied.

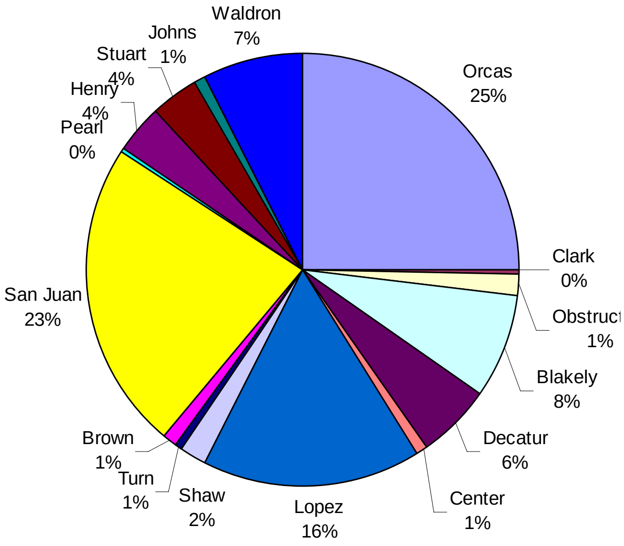

Figure 8. Percent of San Juan County accretion shoreforms found on each Island.

Shore Modifications

Shore modifications were mapped along 14% (12.2 miles) of San Juan County drift cells (Table 23). The largest ratio (38%) and linear extent (4.7 miles, 24,674 ft) of shore modifications were found on Lopez Island. Historic analyses showed that most of the modified shores were historic feeder bluffs (41%) with an additional 21% of potential feeder bluff (Table 24). Twenty-three percent of the modified shores were located within drift cells on Orcas Island (Figure 9). San Juan Island drift cell shores encompassed 19% of the modifications mapped in the San Juan County study area (Figure 9). Much of the remaining modified shore was mapped within drift cells on Decatur, Henry and Brown Island(s) (Tables 23). When comparing the extent of modified shores within each Island study area, Shaw Island had the greatest (cumulative) ratio of modified shore (40%) followed by Lopez and Brown Islands (20%, Table 23). Other islands with a larger ratio of modified shore included Center, Orcas, Pearl and San Juan Islands. Modifications predominantly consisted of residential bulkheads and docks. However, larger infrequent segments of modified shore were formed by marinas, road revetments and miscellaneous industrial infrastructure.

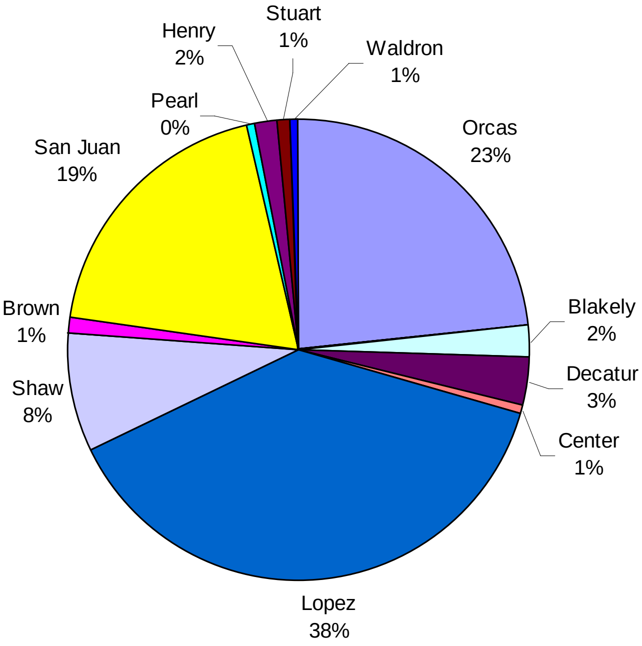

Figure 9. Percent of San Juan County shoreline modifications found on each Island.

RESTORATION AND CONSERVATION PRIORITIZATION

Restoration and conservation planners may benefit from understanding the overall distribution of each shoretype among the different islands. The geology and coastal geomorphology varies moderately throughout the county. The habitats associated with each shoreform type are unique and dependent on intact processes that form and sustain them. Restoration and conservation efforts aimed at sustaining and ameliorating impacts to specific shoreforms target where they are currently and were historically most abundant.

The proposed restoration/conservation actions that make up this prioritization entail restoring coastal processes impounded nearshore sediment sources (historic feeder bluffs) and preserving intact nearshore sediment sources (mapped feeder bluff or feeder bluff exceptional in current conditions mapping). Results of this 3-phase mapping project were compiled and synthesized to determine where the greatest and the least change has occurred for restoration and conservation prioritizations. Bluff restoration priorities were identified based on their relative quality as nearshore sediment sources throughout the study area, within each individual drift cell and across drift cells.

Drift cells that had incurred large losses of sediment supply were considered to be a greater restoration priority over those drift cells that had incurred little reduction in sediment supply. Drift cells with little to no decrease in (the linear extent) of sediment supply when comparing current and historic conditions were considered to be high conservation priorities. The highest scoring intact feeder bluffs were also considered to be conservation priorities as they likely represent the greatest sources of beach sediment.

Restoration Bluffs

Forty-four bluff units had HSSI scores higher than one standard deviation above the mean and were considered to be bluffs of the highest restoration priority. This approach for determining restoration priorities for modified bluff segments was first developed for similar work in WRIAs 8 and 9 (Johannessen et al. 2005). These high priority bluffs for restoration are displayed in Table 26 and Maps 24-26. The top scoring modified bluff units include units 205, 173, 8, 204, 203 and 4. Each of these units scored 40 points or more in the HSSI, and are listed in Table 26. The largest portion of top ranking conservation bluffs were located on Lopez Island (17 units), followed by Orcas (12) and then San Juan (8).

The top 3 scoring modified bluff units within each drift cell are identified and displayed in Table 27 and Maps 27-39. Where multiple units had the same unit score, thereby tying in rank, the unit of greater length was selected as the higher restoration priority. If the highest scoring units in a drift cell were not high enough to score as HFBs or even PFBs there were not considered restoration priorities.

Table 26. **Highest priority bluffs for restoration in San Juan County. Maps 24-26.**

Bluff Unit	Length	Drift cell	Area of County	HSSI Score
173	27	LO-14	Shark Reef to Lopez Spit, West Lopez	51
205	50	LO-21	San Juan Channel to Flat Point, West Lopez Island	51
8	370	OR-1a	Orcas Island-North Beach	49
4	120	OR-1a	Orcas Island-North Beach	47
203	46	LO-20	San Juan Channel to Fisherman Bay, West Lopez	47
204	104	LO-20	San Juan Channel to Fisherman Bay, West Lopez	47
27	41	OR-7	Orcas Island-East Sound-Cresent Beach	46
28	25	OR-7	Orcas Island-East Sound-Cresent Beach	46
344	14	HE-4	Henry Island-north Mosquito Pass	46
11	461	OR-2	Northeast Orcas Island-Raccoon Point	45
24	249	OR-6	Orcas Island-Rosario	45
170	67	LO-14	Shark Reef to Lopez Spit, West Lopez	43
5	583	OR-1a	Orcas Island-North Beach	42
6	228	OR-1a	Orcas Island-North Beach	42
7	529	OR-1a	Orcas Island-North Beach	42
174	84	LO-14	Shark Reef to Lopez Spit, West Lopez	42
279	39	SJ-7	S Griffin Bay to Low Point, S San Juan Is	42
278	71	SJ-7	S Griffin Bay to Low Point, S San Juan Is	42
285	576	SJ-11	East side of False Bay, West San Juan Island	42
286	565	SJ-11	East side of False Bay, West San Juan Island	42
343	78	HE-4	Henry Island-north Mosquito Pass	42
96	71	CE-1	Center Island	41
97	203	CE-1	Center Island	41
98	73	CE-1	Center Island	41
148	43	LO-6	Lopez Sound to the tip of Spencer Spit, E Lopez	41
149	34	LO-6	Lopez Sound to the tip of Spencer Spit, E Lopez	41
152	29	LO-8	North side of Mud Bay to inner Mud Bay, East Lopez	41
153	46	LO-8	North side of Mud Bay to inner Mud Bay, East Lopez	41
161	221	LO-9	South side of Mud Bay to inner Mud Bay, East Lopez	41
162	142	LO-9	South side of Mud Bay to inner Mud Bay, East Lopez	41
338	110	HE-2	Henry Island-east Nelson Bay	41
11	516	OR-2	Northeast Orcas Island-Raccoon Point	40
25	12	OR-6	Orcas Island-Rosario	40
58	167	OR-18	Orcas Island-Point Doughty to Beach Haven	40
150	1013	LO-7	Central Lopez Sound, East Lopez Island	40
175	66	LO-14	Shark Reef to Lopez Spit, West Lopez	40
200	444	LO-20	San Juan Channel to Fisherman Bay, West Lopez	40
201	336	LO-20	San Juan Channel to Fisherman Bay, West Lopez	40
202	123	LO-20	San Juan Channel to Fisherman Bay, West Lopez	40
272	34	SJ-5	Dinner Island to Argyle, S San Juan Is	40
273	24	SJ-5	Dinner Island to Argyle, S San Juan Is	40
318	365	SJ-25	N side of inner Westcott Bay, N San Juan Is	40
319	227	SJ-26	White Point to inner Westcott Bay, N San Juan Is	40
352	20	JN-1	Johns Island-south	40

Table 27. Top 3 scoring historic feeder bluffs (sediment sources) for restoration within each drift cell. Maps 27-39.

Restoration	1st Priority		2nd Priority		3rd Priority	
Drift Cell Name	**Unit ID**	**Unit Score**	**Unit ID**	**Unit Score**	**Unit ID**	**Unit Score**
OR-1a	8	49	4a	47	5	42
OR-2	11a	45	11b	40	12	37
OR-3	14	35	13	34	16	33
OR-4	17a	30	17b	23	--	--
OR-5	22	29	--	--	--	--
OR-6	24	45	25	40	--	--
OR-7	27	46	28	46	--	--
OR-11	33a	27	--	--	--	--
OR-13	35	33	--	--	--	--
OR-14	41b	31	421a	28	--	--
OR-15	42	31	43	31	44	31
OR-16	45	39	47	36	49	34
OR-18	58	40	62	36	59	32
BL-5	64	28	--	--	--	--
BL-9	71	36	70	34	68	27
BL-10	72	39	73	39	--	--
DE-1	76	25	--	--	--	--
DE-5	90	33	--	--	--	--
CE-1	97	41	98	41	96	41
LO-1	101	38	99	26	100	24
LO-2	109	37	110	37	108	37
LO-3	123	36	121	36	117	36
LO-4	128	36	127	34	--	--
LO-6	148	41	149	41	131	39
LO-7	150	40	151	28	--	--
LO-8	153	41	152	41	157	30
LO-9	161	41	162	41	160	39
LO-10	163	37	164	37	165	32
LO-14	173	51	170	43	174	42
LO-17	183	32				
LO-18	189	28	191	26	188	23
LO-19	192	26	193	21	--	--
LO-20	204	47	203	47	200	40
LO-21	205	51	207	39	208	33
LO-22	209	37	--	--	--	--
LO-23	211	31	--	--	--	--
SH-1	212b	35	213	33	--	--
SH-2	214	36	215	30	216	28
SH-3	227	29	223	26	225	26
SH-4	232	35	234	30	228	29
BR-1	245	38	246	38	244	33
BR-2	241	36	242	34	240	34
SJ-1	248	31	249	31	254	31

Table 27 Continued. Top 3 scoring historic feeder bluffs (sediment sources) for restoration within each drift cell. Maps 27-39.

Restoration	1st Priority		2nd Priority		3rd Priority	
Drift Cell Name	Unit ID	Unit Score	Unit ID	Unit Score	Unit ID	Unit Score
SJ-2	257	31	258	31	259	28
SJ-2a	261	29	262	29		
SJ-2b	265	26	267	26	266	26
SJ-3	268	22	--	--	--	--
SJ-4	270	30	269	25	--	--
SJ-5	272	40	273	40	275	38
SJ-7	278	42	279	42	280	37
SJ-11	285	42	286	42	--	--
SJ-17	295	29	294	25	--	--
SJ-18	296	29	--	--	--	--
SJ-20	303	30	--	--	--	--
SJ-24	307	33	306	33	305	33
SJ-25	318	40	315	29	--	--
SJ-26	319	40	323	34	--	--
SJ-27	325	35	324	35	--	--
SJ-28	326a	32	--	--	--	--
PE-1	328	32	327	32	--	--
HE-1	331	28	334	28		
HE-2	338	41	335	33	337	31
HE-4	344	46	343	42		
ST-2	347	33	--	--	--	--
ST-6	350	32	--	--	--	--
JN-1	352	40	--	--	--	--
WL-3	355	33	354	30	353	27

Restoration Drift Cells

The highest priority drift cells have incurred the greatest loss of sediment input based on the results of the current and historic conditions mapping and analyses. Drift cells that would benefit most from restoring impounded sediment sources include cells OR-4, OR-6, OR-15, PE-1, SJ -20, ST-6, and LO-2 (Table 28, Maps 40-42). Each of these cells has lost over 88% (linear extent) of historic sediment sources. Table 28 displays the only highest ranking drift cells for restoration in San Juan County; an expanded version of this same table that includes many lower priority drift cells is found in Appendix II. Drift cells of moderately high restoration priority include cells OR-1a, SH-1, LO-7, OR-14 and San Juan-1. Each of these cells has lost 79% or more of their historic sediment sources.

Table 28. Drift cells prioritized for restoration in San Juan County. See Maps 40-42.
SedSrc = Feeder Bluffs/Bluff Sediment Sources.

Drift Cell Name	Drift Cell length	Historic SedSrc %	Current SedSrc %	SedSrc Loss (ft)	SedSrc loss %	Restoration Priority	Restoration Priority
OR-4	1975	14	0	277	100	1.00	Highest Priority
OR-6	8361	3	0	261	100	1.00	
OR-15	4659	10	0	476	100	1.00	
PE-1	1435	11	0	163	100	1.00	
SJ-20	1258	2	0	20	100	1.00	
ST-6	1503	5	0	72	100	1.00	
LO-2	1154	57	7	581	88	0.90	
OR-1a	3180	85	13	2313	85	0.86	Moderately High Priority
SH-1	1403	57	9	671	84	0.84	
LO-7	2673	49	11	1013	77	0.83	
OR-14	1930	19	4	286	79	0.81	
SJ-1	2009	14	3	218	79	0.80	
SJ-24	5976	15	6	575	62	0.67	Moderate Priority
SH-4	3476	57	20	1285	65	0.67	
SJ-25	3578	17	6	365	61	0.66	
OR-3	2363	34	13	504	62	0.64	
SJ-28	2507	9	4	133	59	0.61	
BR-2	793	74	32	338	57	0.57	
HE-2	2989	30	13	523	57	0.55	
BR-1	2797	33	20	371	40	0.51	
SJ-2	2598	10	5	122	48	0.51	
LO-10	2341	19	0	443	100	0.50	
SJ-27	2258	39	20	414	47	0.47	Priority
SH-2	2378	10	6	108	45	0.47	
OR-13	1881	74	41	622	45	0.46	
LO-3	5706	46	26	1137	43	0.46	
LO-17	4095	11	6	212	46	0.46	
SJ-11	5006	64	41	1141	36	0.40	
OR-16	7257	63	39	1686	37	0.37	
OR-18	9006	29	19	871	33	0.35	
LO-20	4856	58	37	1054	37	0.33	
SJ-26	3534	27	19	263	28	0.30	

Conservation Bluffs

Fifty-seven bluff units scored higher than one standard deviation above the mean (mean HSSI score for HFBs, HFBEs), and were therefore highlighted as optimal bluffs for conservation in San Juan County. These high priority conservation bluffs are listed in Table 29 and displayed in Maps 43-45. The most number of conservation bluffs were mapped on Lopez Island (24 bluff units) followed by Orcas (10 bluffs), Decatur (7) and Waldron (6) Islands. Drift cell LO-14, which extends from Shark Reef to Lopez Point, and maintains the spit bounding that embays Fisherman's Bay, on West Lopez, encompassed more conservation bluffs than any other drift cell in the County.

The 3 highest scoring intact sediment sources were identified as conservation priorities within each drift cell. These conservation priorities are listed in Table 30 and displayed in Maps 27-39. Where bluff unit scores were tied, the longest unit was considered the greatest conservation priority as more sediment volume is likely to be delivered by bluff units of greater length. Drift cells that did not have any intact sediment sources were excluded from this prioritization as there were no mapped sediment sources to conserve.

Table 29. Current feeder bluffs of the highest priority for conservation. See Maps 43-45.

Unit No.	Shoretype	Unit length	Drift cell	Area of County	HSSI Score
78	FB	610	DE-3	Decatur Island-southeast	65
79	FBE	459	DE-3	Decatur Island-southeast	65
80	FB	739	DE-3	Decatur Island-southeast	61
81	FBE	302	DE-3	Decatur Island-southeast	61
251	FBE	1,060	WL-2	Waldron Island-northeast	55
145	FB	374	LO-14	Shark Reef to Lopez Spit, West Lopez	55
82	FB	1,536	DE-3	Decatur Island-southeast	54
198	FBE	4,765	SJ-10	San Juan National Historical Park, S San Juan Is	53
199	FB	442	SJ-10	San Juan National Historical Park, S San Juan Is	53
146	FB	1,272	LO-14	Shark Reef to Lopez Spit, West Lopez	53
149	FB	967	LO-14	Shark Reef to Lopez Spit, West Lopez	52
196	FB	615	SJ-8	South Griffin Bay to marina, S San Juan Is	51
195	FB	758	SJ-7	S Griffin Bay to Low Point, S San Juan Is	51
158	FB	673	LO-21	San Juan Channel to Flat Point, West Lopez Island	51
159	FB	944	LO-21	San Juan Channel to Flat Point, West Lopez Island	51
160	FBE	347	LO-21	San Juan Channel to Flat Point, West Lopez Island	51
157	FB	1,125	LO-20	San Juan Channel to Fisherman Bay, West Lopez	51
61	FB	360	BL-3	Blakely Island-southeast	51
163	FB	1,150	LO-22	Upright Channel to Flat Point, North Lopez Island	50
164	FB	716	LO-22	Upright Channel to Flat Point, North Lopez Island	50
161	FB	327	LO-21	San Juan Channel to Flat Point, West Lopez Island	50
77	FB	857	DE-3	Decatur Island-southeast	50
9	FB	272	OR-2	Northeast Orcas Island-Raccoon Point	49
10	FB	1,097	OR-2	Northeast Orcas Island-Raccoon Point	49
11	FB	188	OR-2	Northeast Orcas Island-Raccoon Point	49
12	FB	1,230	OR-2	Northeast Orcas Island-Raccoon Point	49
164	FB	897	LO-22	Upright Channel to Flat Point, North Lopez Island	49
141	FBE	667	LO-14	Shark Reef to Lopez Spit, West Lopez	49
76	FB	2,503	DE-2	Decatur Island-south of Decatur Head	49

Table 29 Continued. Current feeder bluffs of the highest priority for conservation. See Maps 43-45.

Unit No.	Shoretype	Unit length	Drift cell	Area of County	HSSI Score
259	FBE	1,933	WL-4	Waldron Island-Hammond Point to Sandy Point	48
252	FB	385	WL-2	Waldron Island-northeast	48
165	FB	1,660	LO-23	Upright Channel to Odlin County Park, North Lopez	48
163	FB	563	LO-22	Upright Channel to Flat Point, North Lopez Island	48
147	FB	405	LO-14	Shark Reef to Lopez Spit, West Lopez	48
155	FB	216	LO-20	San Juan Channel to Fisherman Bay, West Lopez	47
156	FB	183	LO-20	San Juan Channel to Fisherman Bay, West Lopez	47
67	FB	1,249	BL-8	Blakely Island-west	47
258	FB	273	WL-4	Waldron Island-Hammond Point to Sandy Point	46
250	FB	233	WL-2	Waldron Island-northeast	46
249	FBE	751	WL-1	Waldron Island-northeast to Point Hammond	46
172	FB	1,424	SH-5	Shaw Island-Indian Cove	46
173	FBE	143	SH-5	Shaw Island-Indian Cove	46
174	FB	200	SH-5	Shaw Island-Indian Cove	46
19	FB	187	OR-7	Orcas Island-East Sound-Cresent Beach	46
20	FB	37	OR-7	Orcas Island-East Sound-Cresent Beach	46
21	FBE	204	OR-7	Orcas Island-East Sound-Cresent Beach	46
22	FB	110	OR-7	Orcas Island-East Sound-Cresent Beach	46
23	FBE	374	OR-7	Orcas Island-East Sound-Cresent Beach	46
24	FBE	857	OR-7	Orcas Island-East Sound-Cresent Beach	46
105	FB	607	LO-5	North Spencer Spit SP to the tip of Spencer Spit	46
106	FBE	149	LO-5	North Spencer Spit SP to the tip of Spencer Spit	46
107	FB	421	LO-5	North Spencer Spit SP to the tip of Spencer Spit	46
104	FB	787	LO-4	East side of Swifts Bay, North Lopez	46
162	FB	325	LO-21	San Juan Channel to Flat Point, West Lopez Island	46
140	FB	988	LO-14	Shark Reef to Lopez Spit, West Lopez	46
144	FBE	505	LO-14	Shark Reef to Lopez Spit, West Lopez	46
234	FB	430	HE-4	Henry Island-north Mosquito Pass	46

Table 30. Top 3 scoring intact sediment sources within each drift cell. See Maps 27-39.

Conservation	1st Priority		2nd Priority		3rd Priority	
Drift Cell Name	Unit ID	Unit Score	Unit ID	Unit Score	Unit ID	Unit Score
OR-1	1	44	2	44	--	--
OR-1a	5	42	6	42	3	40
OR-2	12	49	10	49	9	49
OR-3	14	35	13	30	15	25
OR-5	18b	44	16	37	17	36
OR-7	24	46	23	46	21	46
OR-8	26	31	--	--	--	--
OR-9	29	42	28b	40	28a	30
OR-10	34	42	33	42	32	38
OR-11	35	33	--	--	--	--
OR-12	36	33	--	--	--	--
OR-13	37	31	--	--	--	--

Table 30 Continued. Top 3 scoring intact sediment sources within each drift cell. See Maps 27-39.

Conservation	1st Priority		2nd Priority		3rd Priority	
Drift Cell Name	**Unit ID**	**Unit Score**	**Unit ID**	**Unit Score**	**Unit ID**	**Unit Score**
OR-14	38	28	--	--	--	--
OR-16	44	38	43	36	39	35
OR-17	46	36	--	--	--	--
OR-18	47	42	48	42	51	33
CL-1	52	31	--	--	--	--
OB-1	53	30	--	--	--	--
OB-2	54	32	--	--	--	--
BL-1	55	44	57	34	56	34
BL-2	58	39	59	36	--	--
BL-3	61	51	60	43	--	--
BL-4	63	34	62	32	--	--
BL-5	64	34	65	34	--	--
BL-6	--	--	--	--	--	--
BL-7	66	45	--	--	--	--
BL-8	67	47	69	37	68	37
BL-9	71	36	--	--	--	--
BL-10	72	39	73	36	--	--
DE-1	74	37	75	30	--	--
DE-2	76	49	--	--	--	--
DE-3	79	65	78	65	80	61
DE-5	86	37	84	35	85	27
CE-1	88	43	89	43	87	38
LO-1	91	36	92	36	94	35
LO-2	95	31	--	--	--	--
LO-3	99	36	100	36	101	36
LO-4	104	46	103	34	--	
LO-5	105	46	107	46	106	46
LO-6	115	42	108	41	110	39
LO-7	121	28	122	28	--	--
LO-8	123	41	124	41	125	28
LO-9	131	43	132	41	133	41
LO-10	134	41	135	37	136	34
LO-13	138	42	139	40	138	32
LO-14	145	55	146	53	149	52
LO-17	150	33	151	33	--	--
LO-18	152	26	--	--	--	--
LO-20	157	51	155	47	156	47
LO-21	159	51	158	51	160	51
LO-22	163a	50	164a	2	164b	49
LO-23	165	48	--	--	--	--
SH-1	166	35	--	--	--	--
SH-2	167	31	168	28	--	--
SH-4	169	33	170	28	171	28

Table 30 Continued. Top 3 scoring intact sediment sources within each drift cell. See Maps 27-39.

Conservation	1st Priority		2nd Priority		3rd Priority	
Drift Cell Name	**Unit ID**	**Unit Score**	**Unit ID**	**Unit Score**	**Unit ID**	**Unit Score**
SH-5	172	46	174	46	173	46
TU-1	175	34	176	34	--	--
BR-1	179	31	--	--	--	--
BR-2	178	36	177	34	--	--
SJ-1	181	29	--	--	--	--
SJ-2	182	28	--	--	--	--
SJ-2a	183	32	--	--	--	--
SJ-4	184	38	185	38	186	31
SJ-5	188	43	187	43	189	40
SJ-7	195	51	194	40	193	40
SJ-8	196	51	--	--	--	--
SJ-9	197	31	--	--	--	--
SJ-10	198	53	199	53	--	--
SJ-11	203	45	204	45	200a	39
SJ-12	208	40	206	38	207	30
SJ-13	209	37	211	37	210	37
SJ-18	213	27	--	--	--	--
SJ-21a	214	35	--	--	--	--
SJ-22	215	33	--	--	--	--
SJ-24	217	31	218	31	216	21
SJ-25	219	40	221	30	220	30
SJ-26	222	40	223	33	224	31
SJ-27	226	38	225	33	--	--
SJ-28	227	35	228	26	--	--
HE-2	231	38	230	38	229	31
HE-4	234	46	235	43	233	39
HE-5	236	43	--	--	--	--
HE-8	237	44	238	42	--	--
ST-1	239	37	--	--	--	--
ST-2	240	40	241	31	--	--
ST-3	242	39	--	--	--	--
ST-4	243	39	--	--	--	--
ST-5	244	31	--	--	--	--
JN-1	246	37	247	37	248	37
WL-1	249	46	--	--	--	--
WL-2	251	55	252	48	250	46
WL-3	255	42	254	45	253	42
WL-4	259	48	258	46	257	44

Conservation Drift Cells

Due to the pristine condition of many areas of San Juan County, 50 drift cells were ranked as being of the highest conservation priority. All but 5 of these drift cells had 100% of the historic sediment supply intact. Further prioritization could be applied to these highest ranked priority drift cells that could include pairing these results with the presence of priority habitats or willing land-owners. The highest priority drift cells were mapped on Blakely, Clark, Decatur, Lopez, Orcas, San Juan, Stuart, Turn and Waldron Islands (Table 31, Maps 46-48). Refer to Table 30 and Maps 27-39 to determine the top bluffs within each drift cell to conserve.

Table 31. Drift cells prioritized for conservation throughout San Juan County. See Map 46-48.

Drift Cell Name	Drift Cell length	Historic SedSrc %	Current SedSrc %	SedSrc Intact %	Conservation Quotient	Conservation Priority
BL-1	3611	13	13	100	1.0	Highest Priority
BL-2	2675	10	10	100	1.0	
BL-3	2125	35	35	100	1.0	
BL-4	658	86	86	100	1.0	
BL-5	2857	25	25	100	1.0	
BL-7	2747	30	30	100	1.0	
BL-8	5136	64	64	100	1.0	
CL-1	1820	45	45	100	1.0	
DE-1	5505	11	11	100	1.0	
DE-2	7730	32	32	100	1.0	
DE-3	7320	81	81	100	1.0	
DE-4	1285	3	3	100	1.0	
HE-5	1738	18	18	100	1.0	
HE-8	3893	48	48	100	1.0	
LO-5	3770	31	31	100	1.0	
LO-13	8588	41	41	100	1.0	
LO-18	4429	1	1	100	1.0	
OB-1	1016	32	32	100	1.0	
OB-2	1403	30	30	100	1.0	
OR-1	8884	10	10	100	1.0	
OR-5	8166	11	11	100	1.0	
OR-8	1206	15	15	100	1.0	
OR-9	4033	56	56	100	1.0	
OR-10	5396	23	23	100	1.0	
OR-11	846	33	33	100	1.0	
OR-12	700	28	28	100	1.0	
OR-17	4231	18	18	100	1.0	
SH-5	4639	38	38	100	1.0	
SJ-2a	1176	9	9	100	1.0	
SJ-8	2780	22	22	100	1.0	
SJ-9	3804	10	10	100	1.0	
SJ-10	12813	41	41	100	1.0	
SJ-12	2237	36	36	100	1.0	
SJ-13	2194	34	34	100	1.0	
SJ-18	1795	10	10	100	1.0	

Table 31(cont'd). Drift cells prioritized for conservation throughout San Juan County. See Map 46-48.

Drift Cell Name	Drift Cell length	Historic SedSrc %	Current SedSrc %	SedSrc Intact %	Conservation Quotient	Conservation Priority
SJ-21b	2007	9	9	100	1.0	Highest Priority
SJ-22	1005	44	44	100	1.0	
ST-1	972	28	28	100	1.0	
ST-3	3977	9	9	100	1.0	
ST-4	1314	31	31	100	1.0	
ST-5	563	6	6	100	1.0	
TU-1	1380	54	54	100	1.0	
WL-1	1275	59	59	100	1.0	
WL-2	5300	32	32	100	1.0	
WL-4	18757	25	25	100	1.0	
LO-22	5922	57	56	99	1.0	
JN-1	3732	42	42	99	1.0	
LO-23	2979	58	56	97	1.0	
OR-7	6550	43	42	98	1.0	
WL-3	12851	25	25	97	1.0	
LO-14	22891	28	26	93	0.9	Moderately High
LO-1	3236	36	34	94	0.9	
HE-4	2337	54	50	93	0.9	
LO-21	7347	40	36	90	0.9	
BL-9	5013	11	9	87	0.9	
LO-6	15291	69	59	86	0.9	
SJ-7	13242	22	19	83	0.9	
SJ-4	2383	44	36	82	0.9	
ST-2	1330	44	37	83	0.8	
DE-5	8160	37	29	79	0.8	
LO-8	5977	24	18	78	0.8	Moderate
BL-10	2314	19	14	75	0.7	
LO-9	7893	49	42	85	0.7	
LO-4	3104	43	29	67	0.7	
SJ-5	2989	46	32	70	0.7	
CE-1	2519	56	39	70	0.7	
OR-2	11462	44	30	67	0.7	
SJ-26	3534	27	19	72	0.7	
LO-20	4856	58	37	63	0.7	
OR-18	9006	29	19	67	0.6	
OR-16	7257	63	39	63	0.6	
SJ-11	5006	64	41	64	0.6	
LO-17	4095	11	6	54	0.5	Priority
LO-3	5706	46	26	57	0.5	
OR-13	1881	74	41	55	0.5	
SH-2	2378	10	6	55	0.5	
SJ-27	2258	39	20	53	0.5	
LO-10	2341	19	0	0	0.5	

CONCLUSIONS

Phase I feeder bluff mapping of San Juan County consisted of mapping the current geomorphic conditions within drift cells of San Juan and Lopez Islands. That effort was completed in the spring of 2009. Phase II included mapping the current geomorphic conditions within the remaining drift cells found across the county. This final phase (Phase III) entailed researching and mapping the historic condition of all modified shores in drift cells in San Juan County and performing a restoration and conservation prioritization based on the syntheses of all mapping results. Following completion of each mapping effort all data was segmented at the parcel unit scale and attributed with parcel number data, to allow resource managers to connect geomorphic data with the parcel database. This will allow resource managers to better understand the current and historic geomorphic shoretypes found within each parcel and target education and outreach efforts to specific property owners that encompass high priority restoration and conservation areas. Prioritization data can also be paired with habitat data to assure that conservation and restoration measures are adequately addressing nearshore species that are in the greatest need or under the greatest threat.

References

Beamer, E.M., A. McBride, R. Henderson, and K. Wolf, 2003. The importance of non-natal pocket estuaries in Skagit Bay to wild Chinook salmon: an emerging priority for restoration, Skagit River Systems Cooperative, La Conner, Washington, 9p. http://www.skagitcoop.org/EB1579_Beamer%20et%20al%202003.pdf

Brandon, M.T., Cowan, D.S. and Vance, J.A., 1988, The Late Cretaceous San Juan thrust system: Geological Society of America special paper 221, 81 p., 1 map.

Bruun, P., 1962. Sea-level rise as a cause of shore erosion. *Journal Waterways and Harbors Division,* vol. 88, (1-3)**,** 117.

Cooper, N.J., 2003. The use of 'managed retreat' in coastal engineering. *Engineering Sustainability*, vol. 156, June 2003, Issue ES2, p. 101-110.

Downing, J., 1983. The Coast of Puget Sound: Its Processes and Development, University of Washington Press, Seattle, 126 p.

Fletcher, C.H., R.A. Mullane, B.M. Richmond, 1997. Beach loss along armored shoreline on Oahu, Hawaiian Islands, *Journal of Coastal Research*, vol. 13, no. 1, p. 209-215.

Griggs, G.B., 2005. The impacts of coastal armoring. *Shore and Beach*, vol. 73, no. 1, Winter, p. 13-22.

Hosking, A. and R. McInnes, 2002. Preparing for the Impacts of climate change on the Central Southeast of England: A framework for future risk management. *Journal of Coastal Research,* Special Issue 36, p. 381-389.

Intergovernmental Panel on Climate Change (IPCC), 2001. Climate change 2001: impacts, adaptation, and vulnerability. Edited by: J.J. McCarthy, O.F. Canziani, N.A. Leary, D.D. Dokken, and K.S. White. http://www.grida.no/climate/ipcc_tar/wg2/index.htm.

Jacobsen, E.E and M.L. Schwartz, 1981. The use of geomorphic indicators to determine the direction of net shore-drift: *Shore and Beach*, vol. 49, p. 38-42.

Johannessen, J.W., 1992. Net shore-drift in San Juan County and parts of Jefferson, Island, and Snohomish counties, Washington: final report. Western Washington University, for Shorelands and Coastal Zone Management Program, Washington Department of Ecology, Olympia, 58 p., 25 maps.

Johannessen, J.W., 1993. Net shore-drift in San Juan County and parts of Jefferson, Island, and Snohomish counties, WA. Unpublished master's thesis, W. Washington U., Bellingham, 175 p.

Johannessen, J.W. and M.A. Chase, 2005. Island County feeder bluff and accretion shoreform mapping. Prepared for Island County Marine Resources Committee.

Johannessen, J.W., A.J. MacLennan, and A. McBride, 2005. Inventory and assessment of current and historic beach feeding sources/erosion and accretion areas for the marine shorelines of water resource inventory areas 8 & 9. Prepared by Coastal Geologic Services, for King County Department of Natural Resources and Parks, Seattle, WA.

Johannessen, J. and A.J. MacLennan, 2007. Beaches and bluffs of Puget Sound. Puget Sound Nearshore Partnership Report No. 2007-04. Published by Seattle District, US Army Corps of Engineers, Seattle, Washington.

Keuler, R.F., 1988. Map showing coastal erosion, sediment supply, and longshore transport in the Port Townsend 30- by 60-minute quadrangle, Puget Sound region, Washington: U.S. Geologic Survey Miscellaneous Investigations Map I-1198-E, scale 1:100,000.

MacDonald, K., D. Simpson, B. Paulsen, J. Cox, and J. Gendron, 1994. Shoreline armoring effects on physical coastal processes in Puget Sound, Washington: Coastal Erosion Management Studies, vol. 5, Shorelands Program, Washington Dept. of Ecology, Olympia, DOE Report 94-78.

MacLennan, A. J. and J. W. Johannessen, 2008. Net Shore-drift QA/QC Methods for Puget Sound and the Northwest Straits, Prepared for the USACE and Puget Sound Nearshore Partnership under contract to Anchor Environmental LLC for integration in to the Puget Sound Change Analysis Geodatabase. 6p.

MacLennan, A.J. and J.W. Johannessen, 2008. San Juan Initiative protection assessment nearshore case study area characterization. Prepared by Coastal Geologic Services, for Puget Sound Partnership, Olympia, WA.

MacLennan, A.J., J.W. Johannessen and S.A. Williams, 2009. Current Geomorphic Shoretype (Feeder Bluff) mapping of San Juan and Lopez Islands, WA. Prepared by Coastal Geologic Services, for Puget Sound Partnership through the Surfrider Foundation, Olympia, WA.

Maekawa, T., and E.H. Brown, 1991, Kinematic analysis of the San Juan thrust system, Washington: Geological Society of America Bulletin, v. 103, p. 1007-1016.

McGroder, M.F., 1991, Reconciliation of two-sided thrusting, burial metamorphism, and diachronous uplift in the Cascades of Washington and British Columbia: Geological Society of America Bulletin, v. 103, n. 2, p. 189-209.

Miles, J.R., P.E. Russell, and D.A. Huntley, 2001. Field measurements of sediment dynamics in front of a seawall, *Journal of Coastal Research*, v. 17, no. 1, p. 195-206.

Nordstrom, K.F., 1992. Estuarine Beaches: Elsevier, New York, 225 p.

Penttila, D.E., 1978. Studies of surf smelt (*Hypomesus pretiosus*) in Puget Sound, WA, Dept. of Fisheries, Technical Report no. 42, 47 p.

Penttila, D., 1995. Investigations of the spawning habitat of the Pacific Sand Lance, Ammodytes hexapterus, in the Puget Sound, Puget Sound Research 1995 Proceedings, January 12-14, 1995, Volume 2, Session 8C. p 855-859.

Penttila, D., 2000. Documented Spawning Seasons of Populations of the Surf Smelt, Hypomesus in the Puget Sound Basin, Washington State Department Of Fish and Wildlife Briefing Report. 32p

Penttila, D., 2007. Marine forage fishes in Puget Sound. Puget Sound Nearshore Partnership Report No. 2007-03. Published by Seattle District, US Army Corps of Engineers, Seattle, Washington.

Pethick, J., 2001. Coastal management and sea-level rise. *Catena,* 42, p. 307-322.

Pierre, G. and P. Lahousse, 2006. The role of groundwater in cliff instability: an example at Cape Blanc-Nez (Pas-de-Calais, France). *Earth Surfaces Processes and Landforms,* vol. 31, 31-45.

Pilkey, O.H and H. L. Wright, 1988. Seawalls versus beaches, In: N.C. Kraus and O.H. Pilkey (Editors) The effects of seawalls on the beach, *Journal of Coastal Research*, SI 4, p. 41-64.

Puget Sound Action Team, 2003. 2003 Puget Sound update, Olympia, WA, 127 p.

Redman, S. and K. Fresh, 2005. Regional nearshore and marine aspects of salmon recovery, Puget Sound Action Team and NOAA Fisheries, Olympia/Seattle.

San Juan County Marine Resources Committee, 2007. San Juan County Marine Stewardship Area Plan. Edited By Kristen evans and Jody Kennedy. 154p. http://www.sjcmrc.org/programs/msaplan_files/MSA%20plan%2002-Jul-2007%20Final.pdf

Schwartz, M.L. et al. , 1991. Net shore-drift in Washington State: shorelands and Coastal Zone Management Program, Washington Department of Ecology, Olympia, WA.

Simenstad, C.A., M. Ramirez, J. Burke, M. Logsdon, H. Shipman, C. Tanner, C. Davis, J. Fung, P. Bloch, K. Fresh, D. Myers, E. Iverson, A. Bailey, P. Schlenger, C. Kiblinger, P. Myre, W. Gerstel, and A. MacLennan. 2009. Historic Change of Puget Sound Shorelines: Puget Sound Nearshore Ecosystem Project Change Analysis. Puget Sound Nearshore Report No. 2009-XX. Published by Washington Department of Fish and Wildlife, Olympia, Washington, and U.S. Army Corps of Engineers, Seattle, Washington.

Shipman, H., 2004. Coastal bluffs and sea cliffs on Puget Sound, Washington, In: M.A. Hampton and G.B. Griggs, eds., Formation, evolution, and stability of coastal cliffs-status and trends, Professional Paper No. 1693, US Department of the Interior, U.S. Geological Survey, Denver, CO., 123 p.

Thom, R.M., D.K. Shreffler, and K. MacDonald, 1994. Shoreline armoring effects on coastal ecology and biological resources in Puget Sound, Washington. Coastal Erosion Management Studies, Volume 7. Shorelands and Water Resources Program, Washington Department of Ecology, Olympia, WA.

Tubbs, D.W., 1974.Causes, Mechanisms and Prediction of Landsliding in Seattle. Unpublished dissertation, University of Washington, November 1975.

US Geologic Survey, in press. Shoreline Armoring on Puget Sound, US Geologic Survey Special Paper.

Washington Department of Ecology, 1979. Coastal Zone Atlas of Washington, Volume 3, San Juan County. Olympia, WA.

Washington State Department of Natural Resources, 2001. Washington State ShoreZone inventory. Nearshore Habitat Program, Olympia, WA.

Washington State Department of Natural Resources – Division of Geology and Earth Resources, 2001. Digital geologic maps of the 1:100,000 quadrangles of Washington. Olympia, WA. http://www.dnr.wa.gov/geology/dig100k.htm