Puget Sound NOTES

Science news from the Puget Sound Action Team

Issue No. 47
September 2003

INSIDE THIS ISSUE:

Managing Puget Sound's shorelines—one drift cell at a time

Development along Puget Sound's shorelines has often proceeded without taking the dynamic nature of marine shorelines into consideration, leading to both lost private property and lost natural function of shoreline ecology. While scientists and others have long understood the dynamic nature of marine shorelines, unraveling the specific mechanisms of how the nearshore works requires observation across various spatial scales and over time.

The following articles will look at three aspects of the littoral **drift cell**—the currently accepted theory of shoreline dynamics**.** The writers explore, in both technical and practical terms, how shorelines are formed, how they are shaped through time and how human land-use changes affect natural resources.

The *2000 Puget Sound Water Quality Management Plan* directs local governments to protect natural sediment sources and the drift of sediments along shorelines through shoreline master programs and critical areas ordinances. This issue of *Puget Sound Notes* provides a better understanding of the Puget Sound's nearshore environment so that shoreline use can be accommodated while protecting natural resource functions.

• For more information about the Puget Sound Action Team's work with shorelines and the nearshore environment, contact **Doug Myers,** wetlands and habitat specialist, (360) 407-7322 or dmyers@psat.wa.gov.

PUGET SOUND DRIFT CELLS:

The importance of waves and wave climate

David Finlayson, School of Oceanography, University of Washington
Hugh Shipman, Washington Department of Ecology

Introduction

To better interpret the evolution and behavior of beaches and coastlines, geomorphologists developed the concept of a littoral cell (Davies 1974; Inman and Frautschy 1966; Zenkovich 1967). Just as watersheds delineate the boundary of a river system, littoral cells are landscape-scale units that delineate the boundary of a beach-sediment system. Like watersheds, littoral cells have inputs, throughputs, and outputs of energy and matter. Waves supply energy to the cell and the dissipation of wave energy drives the erosion and transport of beach material along the shoreline. When wave energy is insufficient to mobilize sediment further, deposition and accumulation occurs. Understanding how waves interact with sediment and, in particular, their influence on the long-term redistribution of sediment along the shoreline, is central to evaluating the operation of littoral cells.

The concept of a littoral cell is readily applicable to Puget Sound (Downing 1983; Schwartz *et al.* 1989; Terich 1987). Bauer (1974) mapped and described littoral cells, which he described as *drift sectors*. In Whatcom County, Dr. Maury Schwartz and students at Western Washington University mapped littoral cells, which they termed *net shore-drift cells*, and the direction of net shore-drift throughout Puget Sound (Schwartz *et al.* 1989). They delineated long-term patterns of littoral drift based on a suite of geomorphological criteria (Jacobsen and Schwartz, 1981) that includes the effect of local obstructions to drift, systematic changes in sediment size, bluff and beach morphology, and the shape of coastal landforms (spit orientation or stream mouth offsets, for example).

Although knowledge of wave conditions has informed these geomorphologic studies, there has been little systematic analysis of the role of waves in shaping littoral transport in Puget Sound. The only regional effort to infer drift directions and transport rates from wave data, the *Coastal Zone Atlas of Washington* (Youngmann 1977-1980), proved problematic. The Atlas applied hindcasting methods where historical wind data was used to model wave conditions and sediment transport directions. Unfortunately, the *Atlas* often resulted in transport directions contrary to those indicated by geomorphological evidence. This has been attributed to fact that wind conditions along the shoreline may not be represented adequately by the five upland wind stations that were employed and that short-term wind records were not a reliable basis for establishing long-term drift patterns (Jacobsen and Schwartz 1981; Schwartz *et al.* 1989).

Wind and waves

Puget Sound, inland of the Strait of Juan de Fuca, is largely isolated from the influences of ocean swell and, as a result, any significant wave action must be generated by local winds. Winds within the Puget Lowland blow dominantly north or south, channeled by both regional (the Olympic and Cascade Mountains) and local (the major basins of Puget Sound) topography. During the winter, winds blow primarily from the south while during summer, gentle northerly breezes blow across most of the Sound (Harris 1954). Average wind speeds recorded between November and March at the West Point lighthouse, Seattle, between 1994 and 2001 are about 5 m/s; sustained winds of 15 m/s occur annually with peak gusts exceeding 25 m/s during some storms (NDBC, 2003). Strong wind events are infrequent. For example, Downing (1983) reports that winds greater than 8 m/s were recorded only eight days per month during the winter and that the frequency dropped to only four days per month during the summer.

Wind, blowing across the water, generates waves. Strong and sustained winds form stronger, more energetic waves. On smaller bodies of water, there is insufficient open water space or fetch to allow the wind to build waves to their maximum height before they break on the downwind shoreline. These systems are referred to as **fetch-limited** (CERC 1984; Demirbilek and Vincent 2002). The limited fetch of Puget Sound constrains waves, even during major storms, to less than 2% of the energy found on open coasts during similar conditions (Downing 1983; Heavner 1981).

Wave climate describes the long-term pattern of wave conditions for an area. It combines the effects on waves of both frequently occurring **prevailing** winds and stronger, but less frequent **predominant** winds. Whereas prevailing winds may affect short-term sediment movement, predominant winds may play a greater role in defining shoreline evolution, long-term transport, and the formation of littoral cells. Gauging is the most reliable method of estimating wave climate (Vincent *et al.* 2002), but few direct measurements of waves in Puget Sound are sufficiently long-term to distinguish prevailing from predominant conditions.

To illustrate how even a simple model for wave generation shows tremendous complexity in the wave climate of a confined water body, we have performed a hindcast of the waves of Hood Canal for the month of January. A 6-year record of January wind speeds and directions (more than 26,000 measurements) from the West Point lighthouse, Seattle (NDBC 2003) was assumed to be representative of winds in Hood Canal. A 30-degree clockwise rotation was added to each wind measurement to simulate the alignment of the winds with the axis of the Hood Canal trough. Winds were grouped into 16 direction bins, then a mean 4-hour maximum sustained wind speed and direction (after rotation) was calculated for each of the 16 compass directions. These 16 mean values for wind speed and direction were converted to wave heights on a GIS raster of fetches using the JONSWAP spectral estimate method (Hasselmann *et al.* 1976). Finally, a wave climate raster was calculated by taking the mean of the 16-directional grids weighted by the percentage of wind observations in each direction bin.

The resulting wave climate field is presented in Figure 1. The total wave height estimates are probably conservative (too large), which is expected from these techniques (Vincent *et al.* 2002). The pattern accounts for winds blowing in **all** directions over the 6-year record of January winds. It is an estimate of the wave climate, not the waves on any particular day. Note how the mean wave height varies along the shoreline, how some beaches are sheltered from wave attack by topography and how others experience rapid changes in incident wave energy over short distances. This model is greatly simplified and does not show the full complexity we expect occurs in Hood Canal, yet it is sufficient to demonstrate the wide range of wave characteristics that drive littoral transport in Puget Sound.

Waves and Sediment

Waves drive longshore sediment transport. The interaction between waves and sediment at the shoreface leads to complex fluid and particle dynamics, particularly in environments such as Puget Sound that exhibit:

1. Episodic low-energy waves.
2. Mixed sand and gravel sediment.
3. A large tidal range.

These factors are not typically found on open coasts where most beach research has concentrated over the past 150 years (Komar 1998). As a result, many of the fundamental geomorphic tenets of coastal research must be used with caution in Puget Sound (Jackson *et al.* 2002; Mason and Coates 2001; Nordstrom, 1992).

The typical Puget Sound beach exhibits distinctly different nearshore processes than seen on open coasts, mainly due to the relatively small wave-height-to-water-depth ratio (Jackson *et al.* 2002; Nordstrom 1992), but also due to their typical mixed sand and gravel composition (Mason and Coates 2001). Small waves do not break until very close to the shoreface. This has the dual effect of eliminating wave dissipation in the surf zone and limiting the amount of refraction that the waves experience prior to breaking. These factors concentrate wave energy in the **swash zone** (the area where the waves break onto the shore) and lend the swash a significant longshore velocity component.

Most of the sediment found on the upper foreshore of a typical Puget Sound beach is too large to be suspended in nearshore currents directly; rather, the sediment is mobilized as bedload in the swash zone, making its way along the beach a little bit with each successive wave. The narrow swash zone sweeps up and down the beach with the tides so that no one elevation of the beach face is under attack for long. When the tides are especially low and wave energy can shoal on the low-tide terraces fringing many of our shores, a true surf zone may develop briefly among the sea grasses and sands of the lower intertidal, though the effect of this on longshore sediment transport is not understood (Nordstrom 1992).

Puget Sound Littoral Cells

Longshore variability in the wave field, combined with the irregular shape of the Puget Sound shoreline, results in the compartmentalization of the coast into many hundreds of discrete littoral cells (Figure 2), ranging from a few tens of meters in length to a few tens of kilometers (Wallace 1988; Youngmann 1977-1980). Within each cell, variations in wave energy and the resulting flux of longshore sediment transport often lead to localized zones of accretion and erosion. As a result, littoral cells on Puget Sound typically do not have just a single source and sink for sediment, but rather develop a mosaic of eroding bluffs and accretional shoreforms along their length (Figure 3). Additional complexity in longshore sediment movement occurs on shorelines where winds and waves approach from different directions. Over the short term, this may simply lead to seasonal reversals in transport direction, but over the long term, it may influence the evolution of coastal features and the distribution of sediment types along the shoreline. Schwartz *et al.* (1989) and Johannessen (1993) have noted locations where prevailing winds and resulting waves moved sand-size material in one direction, yet more powerful, but less frequent, predominant winds and waves moved coarser material in the opposite direction. A common example on the Sound are locations where drift may be northwards during the winter, reflecting the dominance of southerly wave action, yet southwards in the summer, when northerlies are more prevalent (Schwartz *et al.* 1989; Wallace 1988). Such variability can lead to ambiguity in interpreting transport patterns.

Conclusions

Our understanding of littoral cells in Puget Sound is far from ideal. Short-term wind and wave measurements are generally acknowledged to be poor indicators of long-term coastal transport and therefore, geomorphologic indicators have been employed to assess net shore-drift (Jacobsen and Schwartz 1981) and to define boundaries of drift cells. Within these cells, however, we have difficulty evaluating the relative importance of different sediment sources and we recognize that pathways for different sediment sizes may not be the same. While currently mapped cells may describe the ultimate boundaries of sediment movement over the late Holocene, it is possible that modern sediment movement may be restricted to smaller sub-cells, at least over decades or centuries.

To date, research on coastal geomorphology on Puget Sound has focused on observations of landforms and landscape-scale interpretations of longshore sediment movement. Little is understood of the first-order processes (how waves move particles of different sizes along the beach) that would inform the construction of useful models. It is with beach modeling in mind that we have begun focused studies on the west side of Camano Island (Finlayson *et al.*, in press). This irregular shoreline consists of both eroding bluffs and small accretional points, making it an ideal location to examine the complex wave-beach interactions described in this paper. The beaches themselves exhibit the high spatial variability in substrate, morphology, and biology typical of Puget Sound. Accurate elevation information and continuous wind and wave data will feed models and regular surveys are being conducted to observe changes in the form and position of the beach. In time, we hope to strengthen our conceptual model of shoreline processes and littoral cells on Puget Sound.

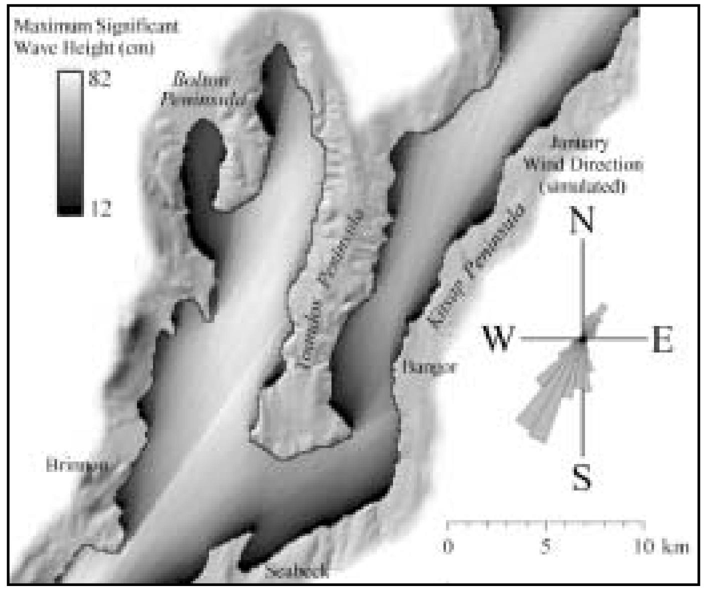

Figure 1. Simulated wave climate for the month of January (1996–2002), Dabob Bay, Hood Canal. The compass rose is a directional histogram of model wind directions. Dark areas represent relatively low wave heights, while lighter areas represent higher wave heights.

Acknowledgements

Research funding for D. Finlayson provided by Washington Sea Grant R/ES-43.

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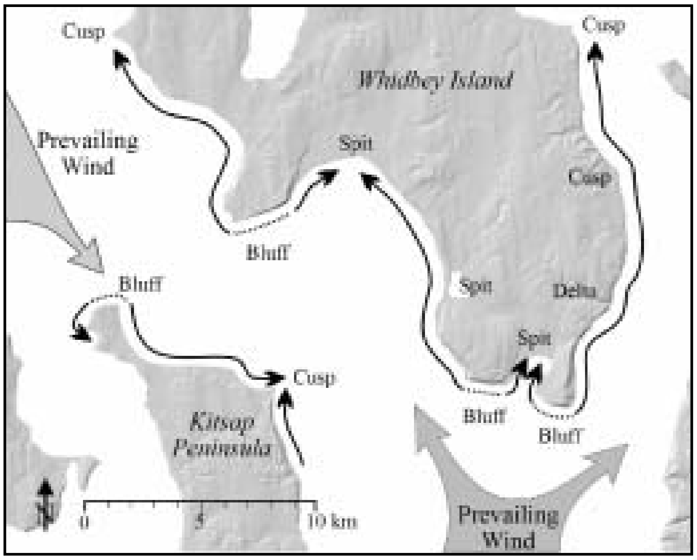

Figure 2. Patterns of long-term net shore-drift along the southern portion of Admiralty Inlet, between the Hansville Peninsula and southern Whidbey Island. Dashed lines represent zones of drift divergence, where sediment derived from bluff erosion may be carried in either direction. Each arrow, from its origins at a sediment source to its downdrift terminus, represents a littoral, or net shore-drift, cell [drift mapping from Keuler (1988), and Johannessen (1993)].

Figure 3. Aerial view of western Camano Island. Rapidly changing orientation of the shoreline leads to significant variation in the character of wave action at any given location, both in the level of wave energy reaching the beach and in the direction of wave action. The geomorphology of the shoreline is characterized by a mosaic of erosional bluffs and small accretional landforms.

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Shoreline changes and the human footprint: Lessons from Hood Canal

Ted Labbe, Habitat Biologist
Port Gamble S'Klallam Tribe

A recent field survey of shoreline modifications and natural geomorphology in Hood Canal and the eastern Strait of Juan de Fuca reveals complex interactions between human development patterns and shoreline erosional processes (Hirschi *et al.* 2003a). As the western arm of Puget Sound with 600 km of shoreline, over 120 distinct drift cells, and a variety of human development levels, Hood Canal and the eastern Strait offer unique insights into land-use / drift-cell dynamics that can inform shoreline management decisions. When we scale up, across larger spatial and temporal scales, we can begin to measure and understand the numerous and varied human influences on drift cells.

With support from the Bureau of Indian Affairs, scientists from Point No Point Treaty Council mapped shoreline modifications like bulkheads, docks, and launch ramps in relation to natural shoreline features like feeder bluffs and accretion beaches. A global positioning system (GPS) and geographic information system (GIS) were used to compile and summarize information by drift cells and larger management units. Shoreline features were mapped from a boat, then interactively "snapped" to a map of the shoreline using GIS. For analysis purposes, contiguous drift cells that feed a common depositional landform (e.g. a spit, embayment, or point) were clustered together. The location and frequency of armoring, other human modifications, and backshore geomorphic types were summarized for each drift cell and drift-cell cluster. Because both shoreline modifications and natural geomorphology were spatially referenced, each could be examined in relation to the other.

The results demonstrate striking variations in human development patterns among drift cells. While certain shoreline areas were almost completely armored and continuously lined with docks and other modifications, other areas were remarkably pristine with healthy riparian cover and relatively unaltered shoreline erosional processes that nourish and sustain nearshore-marine food webs. Notably, along developed drift cells intertidal fill and the built environment often entirely obscured natural shoreline geomorphology, confounding efforts to understand interactions between development and drift cell erosion and deposition processes. A review of older navigation charts for select drift cells showed a dramatic loss of depositional features such as sand spit-enclosing pocket estuaries as a result of fill for development and interruptions to littoral drift. The loss of these pocket estuaries or "habitat complexes" is biologically significant, due to their important role as feeding and stopover sites for migrating juvenile salmon, shorebirds, and waterfowl.

To interpret complex changes, a series of case studies of specific drift cells or drift-cell clusters were used to examine how the location and type of shoreline modification influences shoreline evolution and change.

Lower Hood Canal

Lower Hood Canal encompasses the north and south shores of the southern hook of Hood Canal, near Belfair in Mason County. Shorelines within this region of Hood Canal are among the most highly modified in the study area. Overall, 53% of the shoreline is armored but this figure obscures even higher rates of shoreline modification along individual drift cells. Nearly half of the drift cells (14 of 30) exhibit armoring rates of 70 to 100%. And much of the bulkhead construction lies below the ordinary high water line, resulting in the loss of productive upper intertidal beach habitat (Figure 1). Moreover, road construction, development, and shoreline armoring have isolated all but one feeder bluff from the shoreline, cutting off critical sediment recruitment sources that sustain nearshore-marine ecosystems.

As a result of lost sediment recruitment sources and highly modified littoral drift processes, 35 of 41 (85%) "habitat complexes" formed behind or in association with accretion features (e.g. sand spits, lagoons) mapped in an 1884 nautical chart survey have been lost or severely degraded (Figure 1). These habitat complexes include highly productive salt marsh and tidal channel networks that are important hotspots in marine food webs. Persistent water quality problems resulting in seasonal dissolved oxygen limitations in lower Hood Canal are not an unrelated problem; most shoreline homes rely on aging septic systems that drain directly to marine waters and contribute to eutrophication.

Southpoint/Bridgehaven

In contrast to conditions in lower Hood Canal, many other drift cells in Hood Canal and the eastern Strait retain much of their natural erosional and ecosystem dynamics. One of the largest and most pristine drift cells originates on the east shore of the Toandos Peninsula and terminates near Shine, just west of the Hood Canal Bridge. High bluffs with a healthy riparian overstory line the east shore of the Toandos Peninsula, feeding sediment, organic detritus, and large wood to numerous accretion shoreforms to the north and east. Among these are Brown and Green points, and sand spits enclosing salt marshes at Thorndyke Bay and Bridgehaven. In the context of highly modified shorelines typical across Puget Sound, areas such as this represent important reference sites that help us understand how natural processes maintain habitat, and enable us to better evaluate the emerging science of beach restoration. There is also a pressing need to permanently protect these sites from encroachment by development through the acquisition of title or deed restrictions.

Though shoreline modifications are limited in overall extent, this drift cell is not without the imprint of human influence. Historical nautical charts reveal that the sandspit at Bridgehaven was formerly more extensive, projecting northwards to twice its present length and enclosing a once much larger lagoon/salt

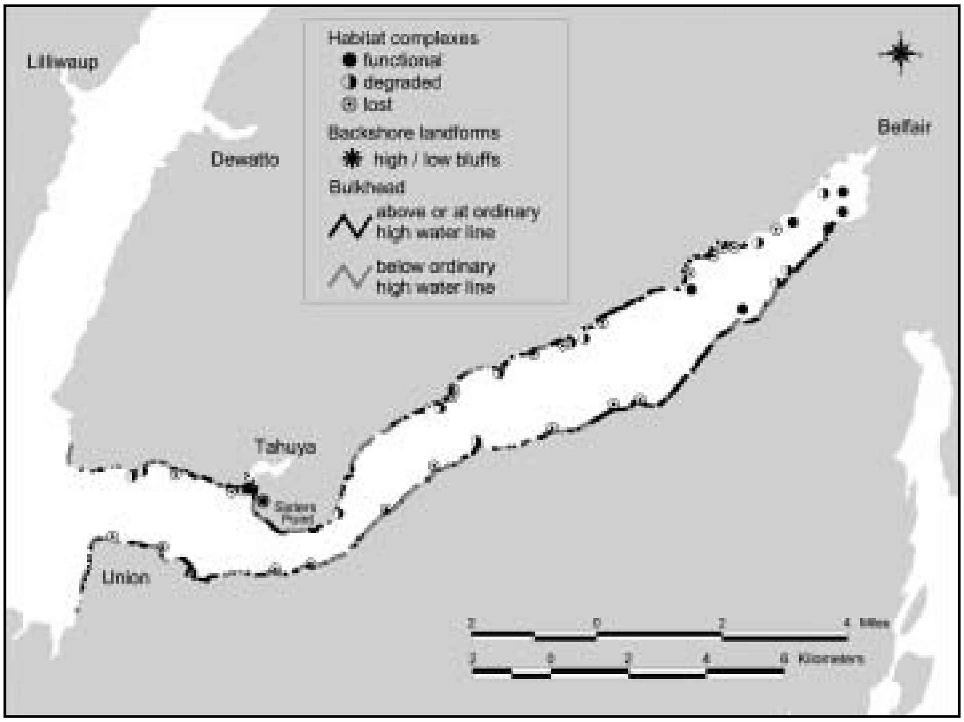

Figure 1. Map of lower Hood Canal showing bulkheads (at/above OHWL vs. below OHWL), habitat complexes (functional, degraded, or lost), and high/low bluffs (mapped as a star). This is a combination of figures 8 and 10 from Hirschi *et al.* 2003a.

marsh complex. Though sand spits and other accretion shoreforms are often dynamic and ephemeral, the dramatic loss of the Bridgehaven spit is at least in part due to the cumulative effects of construction of the former Lofall-Southpoint ferry terminal, seawalls for residential homes, and a jetty/boat navigation channel which truncated sediment delivery processes to the spit. Within the lagoon, the dredging of a boat channel and filling for home and road construction has led to the loss of productive shallow-water salt marsh-tidal channel habitats. What little salt marsh remains now lies disconnected from Hood Canal behind a roadbed and fish-blocking culvert. Though relatively isolated from the principal salmon spawning and rearing streams, we know these fringing lagoon/salt marsh environments are a critical landscape element for out-migrating juvenile salmon in Hood Canal and Puget Sound (Hirschi *et al.* 2003b; Beamer *et al.* 2003). In Skagit Bay, juvenile chinook fry migrants are 10-100 times more abundant in these independent "pocket estuaries," as compared to adjacent nearshore and offshore environments, likely due to their habitat value as a refuge from predators and as sites of abundant food production (Beamer *et al.* 2003).

As with watersheds, each drift cell possesses a unique environmental setting and complement of human influences. Yet in many cases, these dynamic natural shoreline units behave in a predictable fashion in response to human modifications that alter riparian and littoral drift processes (bluff erosion, sediment matter recruitment, and deposition) and ultimately modify nearshore-marine ecosystem food webs that humans can readily see and appreciate. As shoreline managers we are tasked with telling the stories of our shorelines and re-connecting people with the critical landscape processes. Shoreline inventories of present-day conditions are currently popular in Puget Sound, but they are really just the first step to understanding and properly managing our shorelines. We need to recover historical charts and other archival materials to better characterize the often dramatic human-mediated changes to our shorelines. Land-use patterns, nearshore habitat structure, and historical maps can be used to assess cause and effect relationships between human development and drift cell dynamics, build understanding about littoral drift processes, and inform shoreline planning and regulatory processes. Such an approach is just beginning in Lower Hood Canal where innovative rehabilitation strategies are attempting to replace or mimic lost habitat-forming processes.

To be more effective, our future shoreline management will need to consider not just localized impacts from shoreline modifications, but also drift-cell-wide impacts. And we will need to consider management approaches that link new development plans with restoration of natural littoral drift processes.

Acknowledgements

A. Carter-Mortimer and Steve Todd (Point No Point Treaty Council), as well as R. Brocksmith (Hood Canal Coordinating Council) provided helpful feedback and assistance with graphics.

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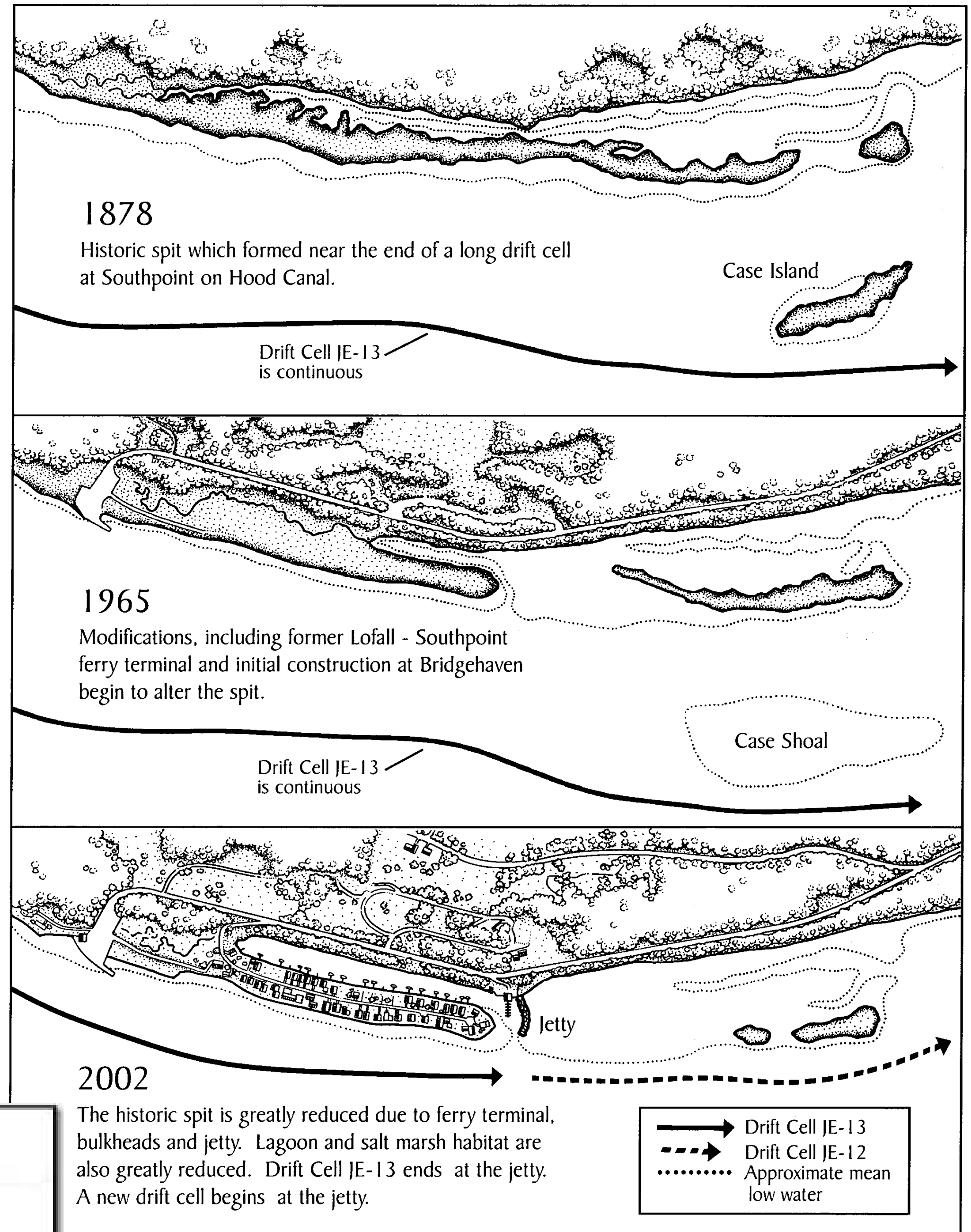
Figure 2. Oblique time series drawings of Southpoint—figure 15 in Hirschi *et al.* 2003a.



Shoreline Management Areas: A Tool for shoreline ecosystem management

Peter Namtvedt Best, Planner
City of Bainbridge Island

The City of Bainbridge Island manages approximately 53 miles of shoreline and has been working on updating its shoreline management program, including the use of shoreline management areas as the basis for ecosystem management. Bainbridge Island shorelines border the main body of central Puget Sound, a large protected embayment, two high-current passages, and contains numerous inlets and lagoons. Bainbridge Island also exhibits rocky, high bluff, low bluff, spit/barrier/backshore, marsh/lagoon, and significantly modified coastal geomorphologies (Williams *et al.* in prep). Perhaps the only coastal geomorphology found in central Puget Sound that is not exhibited on Bainbridge Island is that of a large river delta.

Bainbridge Island shorelines have been significantly developed, with 82% of shoreline lots currently in residential, recreational, commercial, or industrial use. Along with a development pattern dominated by single-family residences, the island's shorelines host two State Parks and many local parks, a fish-pen aquaculture operation, ferry terminal, ferry maintenance and repair facility, marinas, mixed-use development, and a Superfund site (a former creosote wood treatment plant). An inventory conducted by the city in 2001 shows, among other results, that 48.5% of the island's shorelines are armored and only 27.1% of the island's shorelines have overhanging riparian vegetation. Additionally, there are 152 structures (i.e. groins, boat ramps) documented to intercept long-shore sediment drift. (Best in prep.)

Throughout this article the term "shoreline" is used to maintain consistency with existing management terminology within Washington State. As a practical matter, however, shoreline management is principally focused on activities that occur in what is better described as the "nearshore," which includes the riparian, backshore, intertidal, and shallow subtidal zones (Williams and Thom 2001). Therefore, the term "shoreline," as used here, is largely interchangeable with the term "nearshore."

Shoreline Management Program

The City of Bainbridge Island regulates land use, development, and activities along the shoreline through our local Shoreline Management Master Program as required by the Washington State Shoreline Management Act of 1971. Master programs are comprehensive planning documents intended to provide a long-term vision for environmental protection and shoreline development while also regulating uses on a daily basis through permitting and enforcement. Master programs are required to be developed based on sound and up-to-date science, inventories of shoreline uses and resources, assessments of impacts and benefits, prioritization of uses, and geographic designations. While this picture of shoreline management may appear comprehensive and up-to-date, the reality is not usually so progressive.

Master programs have typically been developed or updated infrequently because, in part, they are controversial and broad in scope, therefore requiring a long period of time and significant resources to develop. Master programs, including the city's, typically lack the mechanisms necessary for ongoing adaptation to new science, changing environmental conditions, or development trends. Local jurisdictions often lack the financial resources and staff to regularly assess and monitor the shoreline and update their shoreline management programs to changing conditions and new scientific information. This situation often results in the review of site-specific shoreline development proposals using dated regulations and environmental information. And, since there is a general absence of ongoing monitoring and assessment or consideration of cumulative impacts, these site-specific decisions are made without the full context of the condition and dynamics of the broader landscape.

In recent years, however, there has been significant activity towards improving shoreline management, including the development of new Shoreline Master Program Guidelines by the Washington State Department of Ecology and recent amendments to the Shoreline Management Act requiring Shoreline Master Program updates every seven years. The new draft guidelines, for example, will require local jurisdictions to recognize and protect ecological functions and processes as well as incorporate restoration, as appropriate, into their management programs. The new draft guidelines will also require local jurisdictions to use adaptive management, which requires ongoing environmental monitoring, assessment, and the incorporation of new science. Adaptive management also implies that day-to-day permitting and enforcement activities will be conducted based on up-to-date information and in context of the condition and dynamics of the broader landscape.

During the past two and one-half years, The city has been working on developing a shoreline management program that is both comprehensive and adaptive. As required by the Shoreline Management Act, the city conducted various inventory, data gathering, and literature review efforts. The city conducted on-the-ground inventories of shoreline modifications and selected natural shoreline features (Best in prep.). We also collected a broad-range of existing scientific information, including ShoreZone Inventory data from the Washington State Department of Natural Resources (2001) as well as data from the Washington state departments of Ecology, Fish and Wildlife, and Health. Data collected from on-the-ground efforts and other agencies were compiled into GIS databases. Under a grant from the Washington State Salmon Recovery Funding Board, the city has also been conducting a related project called the Bainbridge Island Nearshore Assessment, for which consultants have prepared a summary of the best available shoreline management science (Williams *et al.* 2002) and are now using the compiled GIS data to characterize and assess the current ecological condition of the Bainbridge Island shoreline (Williams *et al.* in prep.). Future products of the Nearshore Assessment project include the

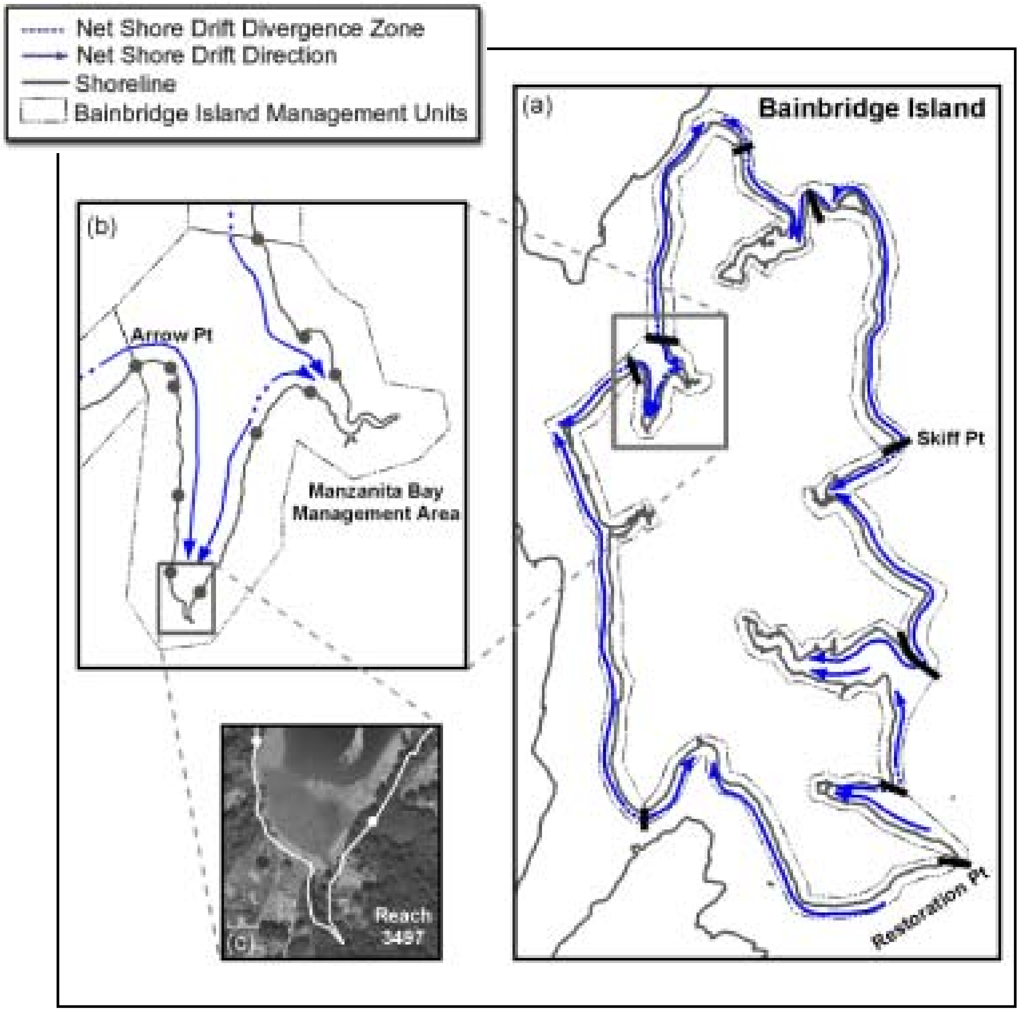


Figure 1. Bainbridge Island drift cells, Shoreline Management Areas, and Shoreline Reaches.

development of a framework for ranking nearshore restoration and preservation opportunities, designing a nearshore monitoring program, and evaluating the potential use of cumulative impact thresholds.

Shoreline Management Areas

The fundamental objective for the city's new shoreline management program is to actively manage the shoreline in a manner that achieves a long-term self-sustaining condition. This objective implies that shoreline processes will continue to function appropriately across the landscape in order to sustain shoreline habitats and ecological functions. To accomplish this, the city has been exploring new management approaches and developing new management tools. The most important of these new management approaches is the designation of "shoreline management areas." Shoreline management areas are essentially mutually exclusive ecological units, which we believe to be the equivalent of upland watersheds. As shown in Figure 1a, nine shoreline management areas have been delineated around Bainbridge Island.

As with upland watersheds, shoreline management areas are based on the principle that physical factors and environmental conditions are the basis for establishing and maintaining habitat structure, ecological processes, and ecological functions. Drift cells provide a useful basis upon which to delineate shoreline management areas because they "act as closed or nearly closed systems with respect to transport of beach sediment" (Schwartz *et al.* 1991). As discussed below, shoreline areas where longshore drift is an insignificant process are also used in the delineation of shoreline management areas. The process of sediment recruitment, transport, and deposition that define drift cells are driven by the interplay of many of the controlling factors outlined by Williams and Thom (2001), including upland hydrology, upland geology, beach slope, water depth, and wave energy. The remaining controlling factors outlined by Williams and Thom (2001) include light, temperature, salinity, nutrients, and water quality. These remaining controlling factors are environmental conditions that greatly affect the distribution of living resources but may occur at larger or smaller geographic scales than shoreline management areas and, therefore, are best addressed within or across shoreline management areas.

Delineating Shoreline Management Areas

Determining the appropriate scale upon which to draw ecological management boundaries is a continual dilemma for natural resource managers because ecosystems are typically nested with various influences and interconnections at various scales. As described above, drift cells are considered to be closed or nearly closed systems, but drift cells either converge (e.g. forming points) or terminate into areas considered to lack longshore drift (e.g. back bays) and therefore aggregate to form larger interrelated systems. As shown in Figure 1a and 1b, shoreline management areas often include such aggregations of drift cells, just as upland watersheds may include aggregations of smaller watersheds or sub-basins. Ultimately, the boundaries between shoreline management areas typically fall where drift cells diverge. More specifically, these boundaries fall at the nearest boundary between shoreline reaches (discussed below) to the divergence area (see Arrow Point and Skiff Point in Figure 1a & 1b). There may be exceptions to this rule due to the lack of longshore drift or the need to break exceptionally large areas into more meaningful sub-areas. One example of this on Bainbridge Island was at Restoration Point (see Figure 1a) where the boundary was drawn at the tip of the point because longshore drift is not demonstrated along the rocky shoreline for quite some distance on either side of the point. Because of their nature, divergence areas, which are often feeder bluffs, must be considered in both of their bordering management areas. It should also be noted that shoreline management area boundaries do not neatly align with upland watershed boundaries, but interconnections between the two can be accounted for in management planning.

Drift cells in Puget Sound have been delineated through a series of masters theses produced at Western Washington University and later republished in a series of reports by the Washington State Department of Ecology. The 21 drift cells mapped around Bainbridge Island were first delineated by Taggart (1984) and later republished by Schwartz (1991). Ecology has also created a GIS database of drift cells, which the city acquired as draft data. The city independently reviewed the written reports and GIS data for internal consistency and consistency with local knowledge. We found the reports to be consistent with local knowledge, but the draft GIS data required corrections.

As shown in Figure 1b & 1c, shoreline management areas were also further divided into smaller definable landscapes using “ShoreZone Units,” which are areas of largely homogenous beach geomorphology that were delineated in the ShoreZone Inventory (WDNR 2001). These are called “reaches” in the city’s work because they are segments of longer linear features and are basically analogous to stream reaches in the context of upland watersheds. Therefore, the city has three significantly different, but “nestable,” landscape scales upon which shoreline management actions, research, and monitoring can occur: the shoreline reach (Figure 1c: ~100 feet to 1 mile long); the shoreline management area (Figure 1b: ~3.2 miles to 9 miles long); and the entire island (Figure 1a: ~ 53 miles long). Ultimately, this nestable landscape concept could be used at much larger scales. For example, Bainbridge Island could be nested within the East Kitsap Peninsula, which in turn could be nested within the Central Puget Sound, which could then be nested within the whole of the Puget Sound/Georgia Basin.

Applying Shoreline Management Areas

The city is already using shoreline management areas and shoreline reaches as a framework for characterizing and assessing the ecological condition of our nearshore (Williams *et al.* in prep). This has proven to be very effective for giving geographic context to important ecological resoureces so that they can be protected by the shoreline management program. We will also be using shoreline management areas and shoreline reaches as a framework for our day-to-day shoreline management activities, including ongoing monitoring as well as permitting and enforcement. As currently envisioned, the city’s shoreline management activities will be conducted through three vehicles, the city’s Shoreline Master Program, a *Shoreline Management Work Plan,* and a *Shoreline Management Implementation Manual.* The master program will set out the legal structure consistent with the Shoreline Management Act, including policies and fundamental standards for shoreline management, and would require the development, use, and regular update of the work plan and implementation manual. The implementation manual is basically an administrator’s and applicant’s desk reference for administering the shoreline management program that will be updated on an ongoing basis.

The *Shoreline Management Work Plan* will be the vehicle for addressing ecosystem management through the use of shoreline management areas and shoreline reaches. The work plan will also embody adaptive management by establishing management priorities, objectives, and standards; incorporating new scientific information from literature as well as local research and monitoring; and by regularly reviewing and updating the work plan at least every seven years. Most importantly, the work plan will provide the up-to-date information and landscape context upon which an applicant can design a proposed project and upon which the city can review and then approve or deny a proposed project. The work plan will be organized based on shoreline management areas and shoreline reaches and will include the following:

- Characterization and assessment of land uses, shoreline modifications, controlling factors, habitat structure, ecological processes, and ecological functions, including any distinctions or trends that have been observed based on historic analysis and ongoing monitoring.
- Identification of factors limiting the formation and maintenance of habitats, ecosystem processes, and ecosystem functions.
- Identification of opportunities for restoration and preservation of habitats, ecosystem processes, and ecosystem functions.
- Recommended standards and/or actions necessary to correct limiting factors and achieve restoration and preservation goals.
- Identification of preferred land uses and appropriate locations for development.
- Recommended changes in monitoring programs and the identification of new research needs.
- Identification of the resources, partnerships, and timelines necessary to implement the work plan.

Conclusions

The management of shoreline ecosystems needs to be conducted through a comprehensive and adaptive process with the goal of maintaining a self-sustaining shoreline ecosystem. To achieve this, jurisdictions need to conduct their management activities based on landscapes and up-to-date information. Shoreline management areas are easily defined and useful for shoreline ecosystem management because they represent mutually exclusive ecosystem units. Shoreline management areas can be further divided into smaller shoreline reaches or combined into larger regions. These nestable landscape scales provide a consistent and effective basis upon which to assess the shoreline ecosystem, conduct research and monitoring, define management objectives, and implement permitting and enforcement programs.

Notes

[1] The original master programs applicable to Bainbridge Island, for example, were adopted in 1977 and were not updated until 1996. The 1996 master program was very controversial and took five years to complete followed by a lengthy appeal.

[2] On Bainbridge Island, these areas principally included back bay or estuarine areas. Elsewhere, these areas would likely include river deltas.

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Marine Ecosystem Health Program
Call for Proposals

The Marine Ecosystem Health Program (MEHP) is requesting research proposals scientifically investigating the efficacy and design of **marine protected areas** as tools for the conservation and enhancement of marine wildlife and ecosystem health. For more information, please see the MEHP website at www.mehp.org

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2003 Georgia Basin / Puget Sound Research Conference

PROCEEDINGS

The proceedings of the **2003 Georgia Basin-Puget Sound Research Conference** will be available in late fall on the Puget Sound Action Team's Web site. (Go to **www.psat.wa.gov** and select the link to the 2003 Proceedings.)

Conference registrants will receive a CD-ROM containing the proceedings. If you did not attend the conference and would like a CD-ROM, you may order a copy for $15.
Call **(360) 407-7311** or e-mail: **gwilliams@psat.wa.gov.**

Proceedings of the climate change sessions from the conference will be published in a separate journal this fall. For information on how to get a copy, check the Action Team's Web site at **www.pugetsound.wa.gov** for updated information.

Puget Sound *NOTES*

Published by the Puget Sound Action Team

Staff editor................**Doug Myers,** wetlands and habitat specialist. (360) 407-7322 or dmyers@psat.wa.gov

Design/layout...........**Toni Droscher,** publications coordinator/ graphic designer. (360) 407-7328 or tdroscher@psat.wa.gov

Puget Sound *NOTES* is intended to inform the interested public about scientific advances that affect Puget Sound. Publication of this newsletter has been funded wholly or in part by the U.S. Environmental Protection Agency to the Puget Sound Action Team. It is distributed free of charge as a public service.

Address corrections or mailing list additions should be mailed to:
Puget Sound Notes, Puget Sound Action Team, P.O. Box 40900, Olympia, WA 98504-0900 or gwilliams@psat.wa.gov.

For more information about the Action Team, visit **www.psat.wa.gov**.

Puget Sound Action Team
P.O. Box 40900
Olympia, WA 98504-0900