Final

CITY OF BELLINGHAM

Marine Nearshore Habitat Connectivity Study

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1.0 INTRODUCTION

In 2013 the City of Bellingham (City) finalized a subarea plan for its Waterfront District, which extends along a portion of the Bellingham Bay shoreline in Puget Sound (Port of Bellingham and City of Bellingham, 2013). The Waterfront District includes lands of the former Georgia Pacific Corporation mill, Port of Bellingham, City and private properties, and the bluff along Boulevard and State Streets. The subarea plan provides a framework for future development of the Waterfront District that seeks to balance the environmental, economic, and community objectives for the site.

The subarea plan includes an element that specifically addresses potential restoration projects within the Waterfront District aimed at improving habitat conditions for Chinook salmon. After review of the subarea plan there was some concern by stakeholders that it did not consider ecological connectivity between and among habitat elements located within the Waterfront District. Based on this input, the City decided to fund a limited effort to assess marine nearshore habitat connectivity within the District and the shoreline that falls within the City's Urban Growth Area (UGA). Environmental Science Associates (ESA) was retained to assist with this effort. The connectivity study area is shown on Figure 1.1.
This study report is divided into the following sections:

Section 2.0 Background introduces the concept of connectivity and applicable literature and describes nearshore ecosystems and processes.

Section 3.0 Methods summarizes the sequence and methods that were used to evaluate connectivity.

Section 4.0 Results and Discussion describes the results of applying the analysis methods.

Section 5.0 Summary explains the results and implications regarding the Waterfront Subarea Plan.

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SOURCE: City of Bellingham, 2014; USDA NAIP, 2013

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Figure 1.1
Vicinity Map

2.0 BACKGROUND

A central issue in ecology is how drastic changes in landscapes by humans cause habitat fragmentation and loss of connectivity for species and large-scale, habitat-forming processes. Connectivity is often vaguely defined (Brotons et al. 2003; Thies et al. 2003) or described in a variety of ways. These definitions include "*the degree to which landscape facilitates or impedes movement of organisms among patches*" (Taylor et al. 1993; Schooley and Wiens 2003); "*the functional relationship among habitat patches due to their spatial distribution and the movement of organisms in response to landscape structure*" (Taylor et al. 1993; With et al. 1997); or "*the ease with which these individuals can move about within the landscape*" (Kindlmann and Burel 2007).

Two main definitions of connectivity can be distinguished from these studies: structural and functional connectivity. *Structural connectivity* is based entirely on landscape form; it has no direct link to organism behaviors. *Functional connectivity* considers an organism's behavioral response to landscape attributes, form, and spacing. Landscapes themselves are not associated with an intrinsic value for connectivity; rather connectivity is determined by the organism under consideration and the relative landscape (Kindlmann and Burel 2007). Only by considering both these dimensions can we arrive at a relative level of connectivity for a given landscape or evaluation unit. In sum, different landscapes can have a range of connectivity for the same species, or the same landscape can have different connectivity for different species.

Nearshore Ecosystems and Processes

The landscape assessed in this study is the nearshore ecosystem or ecotone of Bellingham Bay (Figure 1.1). As the interface between land and sea, the nearshore ecotone is a place where nutrients, detritus, and organisms from marine and terrestrial ecosystems converge, and some may cross the ecotone into the adjacent ecosystem. Along the barrier beaches (shoreform type – see Shipman 2008) of Puget Sound such as Bellingham Bay, this ecotone (in its undisturbed condition) is characterized by riparian vegetation and accumulation of logs and beach wrack along the upper shore, composed of a mix of debris from marine macrophytes, algae, and terrestrial plants. The seaward, lower tidal elevation ecosystem is an active beach face composed of relatively bare sediment (typically a mix of sand, pebbles, and cobbles), with algae and seagrass beds in the low intertidal to subtidal zones (Heerhartz 2013). Beach wrack in the intertidal zone, consisting of piles of seaweed, seagrass, and terrestrial plant debris suspended in water and deposited on shore as the tide ebbs, is important in supplying and exchanging organic materials between ecosystems (Heerhartz 2013).

Development along the Puget Sound shoreline has had detrimental effects to physiochemical processes such as movements of sediment, recruitment of large woody debris and beach wrack, tidal hydrodynamics, and freshwater inputs (Fresh et al. 2011). Shoreline armoring is one common type of change, referring to any kind of artificial hard structure constructed in the nearshore environment to prevent natural erosion of shoreline sediments. This armoring imposes a distinct barrier within the gradient of the intertidal zone and thus can significantly alter ecotone dynamics. Shoreline armoring disrupts the exchange of materials, nutrients, and prey resources between land and sea. Heerhartz (2013) highlighted multiple physical and biological impacts of armoring in intertidal mixed sand and gravel barrier beaches as illustrated in the conceptual model in Figure 2.1. Specifically, she found that in terms of both biomass and abundance, there was less beach wrack at armored beaches and a lower proportion of terrestrial plant material in the wrack. Logs were rare at armored beaches but present at all unarmored beaches. Armored beaches were narrower, had lower maximum elevations, and coarser upper beach sediments. Also, armored beaches had fewer invertebrates than unarmored beaches, and unarmored invertebrate assemblages were correlated with wrack biomass, the proportion of terrestrial material in the wrack, the maximum elevation of the beach, and the width of the log line (Heerhartz 2013).

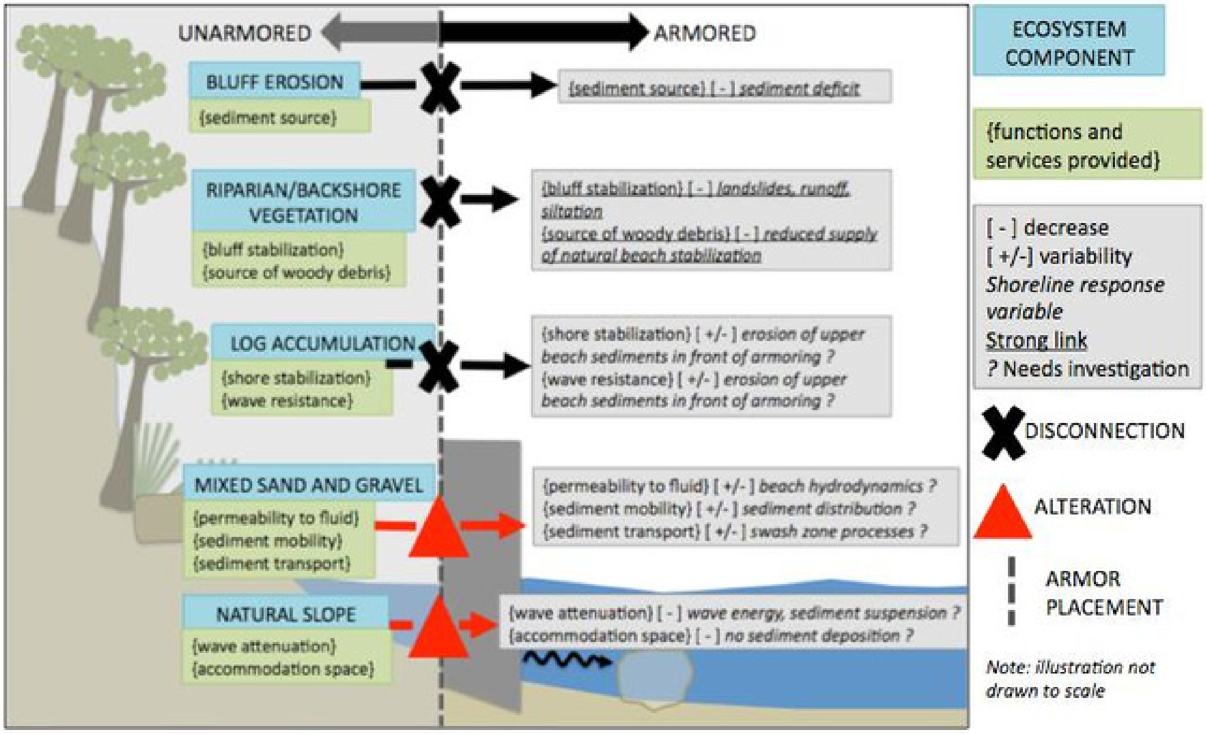


Figure 2-1. Conceptual model of the physical effects of shoreline armoring (Heerhartz 2013).

Study Area and Definition of Connectivity

For the purposes of this connectivity study, the nearshore includes intertidal estuarine and marine areas, shallow subtidal areas (<20 feet deep), supralittoral areas (above high tide mark), and the marine riparian zone (defined here as 200 feet inland of the ordinary high water mark (OHWM), which coincides with the Shoreline Master Program jurisdiction). For simplicity, we also used 200 feet waterward of the OHWM as the study area boundary that includes the intertidal and shallow subtidal zones. Marine nearshore connectivity in this study is defined as follows:

> *The ease with which organisms move about or processes can function unimpeded within the landscape of the nearshore environment.*

Connectivity was analyzed along two axes: (1) connectivity parallel to the shoreline or "Marine connectivity"; and (2) perpendicular to the shoreline or "Terrestrial – Marine connectivity", which analyzes the connections between the marine and marine riparian environment.

An example of a *marine connectivity* issue is the ability of juvenile salmon to access continual areas of shallow water habitat without the interference of intertidal fill, built structures, and overhead docks that force them into deeper water. The *terrestrial-marine connectivity* can be impeded by built structures (fill, armoring) along the shore that interfere with the transfer of wrack and wood from the marine to upper beach area, and the movement of leaves/wood from the marine riparian area to the upper beach and intertidal zones.

To facilitate a comprehensive analysis of connectivity we selected a set of shoreline physical processes, species, and species groups (Table 2.1). Evaluation elements were selected to cover a broad group of ecosystem components important within the Bellingham UGA that together represent the ecological connectivity of the study area.

Table 2-1 Evaluation Elements

Marine Connectivity Elements	
Element	**Description**
Sediment transport	Sediment transport along the shoreline is an important component of beach maintenance and forage fish habitat in Puget Sound.
Juvenile salmon|forage fish	Juvenile salmon and forage fish (herring, surf smelt, and sand lance) make extensive use of the shallow nearshore areas along the shoreline. Forage fish are an important food source for a variety of marine birds, fish, and mammals. Chinook salmon are federally listed as a threatened species in Puget Sound. Juvenile salmon generally avoid habitat beneath piers and docks.
Mobile invertebrates (crabs)	Crabs represent a mobile benthic species that is somewhat tolerant of nearshore infrastructure. While mobile they are tied to the benthic environment and are less mobile than fish.
Shorebirds	Puget Sound shorebirds are a diverse group but generally share the trait of foraging on the upper beach and intertidal zone. They have long legs and bills and make extensive use of shorelines particularly during migration. Shorebirds include but are not limited to dunlin, yellow legs, oystercatcher, black-bellied plover, killdeer, and western sandpiper. They forage extensively for invertebrates in the upper beach and intertidal zone.
River otter	River otters are a unique species because of their extensive use of both the freshwater and marine environment. They forage on fish and shellfish and often den beneath man-made structures. Because they also use the marine riparian zone they are evaluated under that heading as well.
Great blue heron	Herons are a versatile species that use the shallow intertidal, estuarine, and marine riparian habitat of the nearshore. They forage on a wide range of invertebrates, fish, small mammals, amphibians, and reptiles associated with both the marine, freshwater, and terrestrial environments.They can be sensitive to human disturbance but also forage around structures in the nearshore. Post Point lagoon is home to the City's only heron rookery. They also commonly occur in the mudflats and estuaries of the study area.
Marine birds	A diverse group of marine birds use Puget Sound seasonally and year-round. They have a variety of foraging strategies – some such as scoters rely heavily on shellfish, while others such as cormorants and grebes are piscivorous. They make extensive use of the intertidal and shallow subtidal zones. Typical species in this group include scoters, goldeneyes, cormorants, alcids, guillemots, and grebes. Scoters and goldeneyes in particular make use of piers and pilings for foraging.
Harbor seal	Harbor seals are the most common marine mammal in Puget Sound. They are an apex predator in Puget Sound nearshore areas, foraging on a variety of fish species. While sensitive to human disturbance they use structures as haul-outs if they are isolated from human activity, such as the docks at Squalicum Harbor
Terrestrial – Marine Connectivity Elements	
Element	**Description**
Organic material/invertebrate import/export	Organic material and invertebrates are transferred two ways across the beach/terrestrial interface. Leaves, woody material, and insects are transferred from the marine riparian area to the beach and intertidal zone by wind. Insects from the terrestrial habitat are a valuable food source for nearshore marine fish. Wood, wrack (non-woody vegetation), and marine invertebrates are transferred in the opposite direction across this ecotone from the marine zone to the beach from wave action. These elements provide foraging opportunities for shorebirds and the marine riparian birds that use the upper beach.
Sediment input	Landslide areas, eroding slopes, and bluffs are all sources of sediment along the shoreline. Nearshore currents move and deposit these sediments and contribute to the maintenance of beaches. Drift cells can become starved for sediment when shoreline development such as armoring blocks the delivery of sediment to the tidal zone.
River otter	As described above, otters use the marine environment and regularly cross the marine riparian/beach zone.
Riparian birds	Marine riparian birds such as crow, song sparrow, American robin, white-crowned sparrow, and others use the beach and upper intertidal zone for foraging. Beach wrack can be an

Marine Connectivity Elements	
Element	**Description**
	important component for invertebrate foraging. Human development along the shoreline can remove marine riparian habitat and ultimately reduce or eliminate the accumulation of wrack and marine derived woody material, thus reducing potential forage opportunities.
Great blue heron	This versatile species discussed above uses a wide range of habitats including intertidal, upper beach, and the marine and freshwater riparian zones.

3.0 METHODS

The following methods were used to develop the analysis framework and to determine the relative nearshore connectivity within the study area.

Literature Review

The ESA team first assembled and reviewed local planning and science documents. Information from these documents provided context to our study and in some cases details (drift cell assessment) that were used as part of the evaluation process. The documents include the following:

- WRIA 1 Nearshore and Estuarine Assessment and Restoration Prioritization (MacLennan et al. 2013)
- Whatcom County Nearshore Habitat Restoration Prioritization (MacLennan et al. 2007)
- Bellingham Waterfront District Subarea Plan (Port of Bellingham and City of Bellingham 2013)
- Washington Department of Fish and Wildlife Watershed Characterization Study (WDFW 2013)
- City of Bellingham Shoreline Management Program Maps
- Limiting Factors Analysis, City of Bellingham Habitat Restoration Master Plan (Anchor 2012)
- City of Bellingham Wildlife Habitat Assessment and Wildlife Habitat Plan (Eissinger 1995)
- Marine Resources of Whatcom County (Anchor 2001)
- Management Recommendations for City of Bellingham Pocket Estuaries (NW Ecological Services 2006)

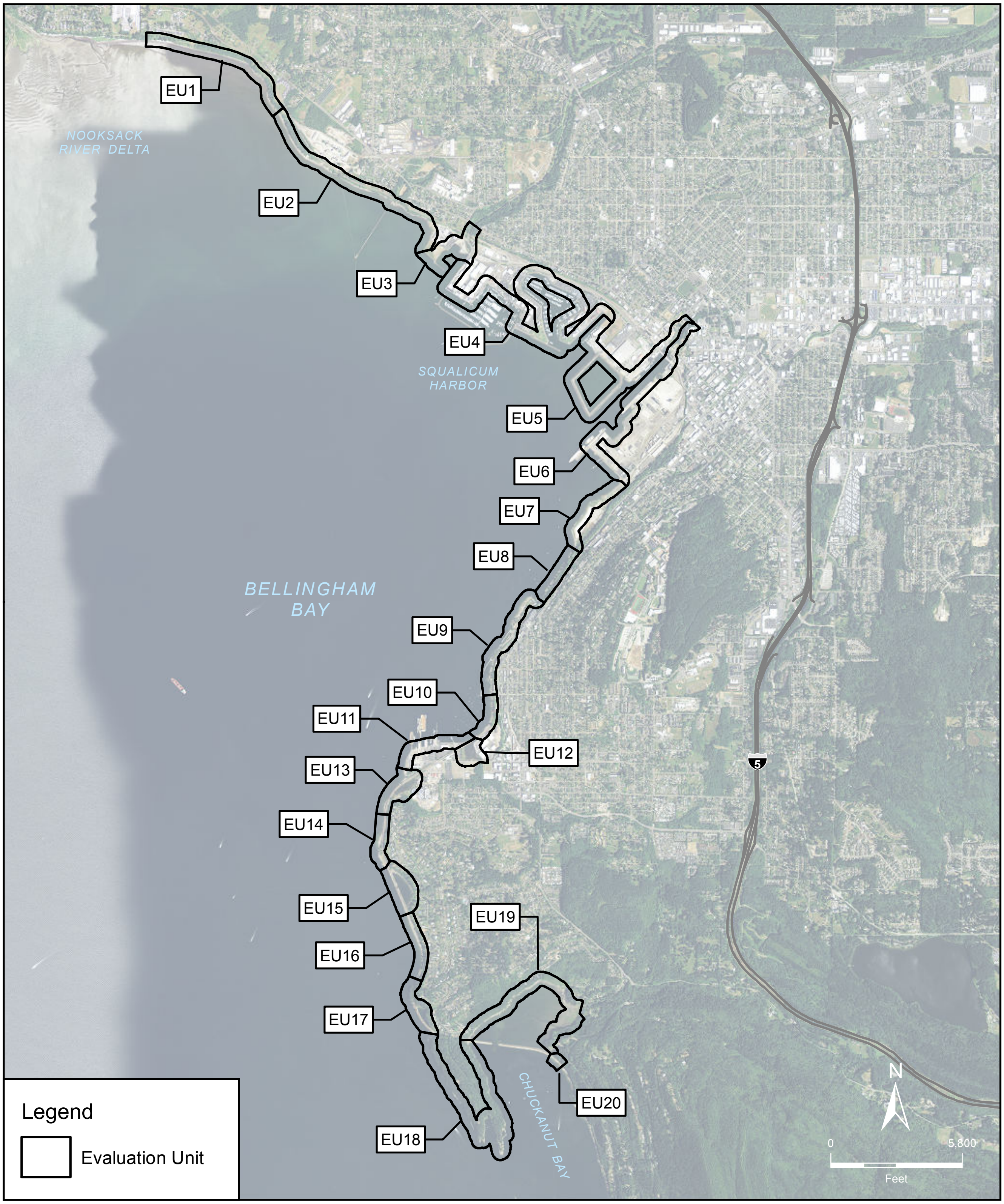
In addition, the ESA team reviewed scientific papers on species, species groups, or effects on physical processes resulting from development along the marine shoreline. Because built environment features can affect the evaluation elements differently, a wide range of literature was reviewed that pertained to specific elements of this study.

Information gained from this review was used to develop the criteria for each of the evaluation elements. The criteria are discussed in detail below, and a summary of the literature as it relates to the various criteria is presented as Appendix A.

Connectivity Evaluation Units

The assessment team divided the study area into 20 discrete Evaluation Units (EUs). Rather than develop a new set of landscape units for this study, we built on the foundation of the Shoreline Master Program (SMP) shoreline reach units previously developed during the City's SMP update. The ESA team reviewed and used the same boundaries in many of the units but subdivided some reaches to provide more precision to the analysis. Some of the SMP reaches extended over variable shoreline conditions, which could produce different connectivity scores in this study. These SMP units were divided into smaller EUs more appropriate for this study's analysis scale.

Evaluation units are sudivided into the marine zone (intertidal/shallow subtidal) to evaluate marine connectivity, and the marine riparian zone to evaluate terrestrial-marine connectivity. The 20 EUs used for this connectivity study are shown in Figure 3.1.



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SOURCE: City of Bellingham, 2014; USDA NAIP, 2013

Figure 3.1
Connectivity Evaluation Units

Connectivity Assessment Factors

Developing quantitative models to evaluate changes in ecological condition, function, or connectivity is extremely complex and labor-intensive. Most often literature on ecological effects provide insight on general trends – for example, shoreline armoring increases wave refraction– rather than a series of thresholds for the varying levels of effects. Thus, for this effort we developed a qualitative approach based on the cause-effect relationships researched in the literature and the cumulative knowledge, experience, and best professional judgment of the assessment team. The evaluation factors are discussed in detail below. Connectivity was rated on a scale relative to the range that occurs within the study area and not to some hypothetical "best" connectivity example that occurs elsewhere along Puget Sound. Thus, the areas that have the highest scores are the best within the study area, but connectivity is likely more functional in less altered areas around the Puget Sound shoreline.

Habitat Patch Size and Alteration

Two scales were used to measure the habitat patch size within an EU: the area of the EU (calculated using GIS) and the proportion of the EU that contains relatively unaltered habitat. Considering both of these scales reduces the bias inherent with large, less altered EUs outside of the developed downtown shoreline while acknowledging the relative importance of smaller habitats in the site-specific scale.

This factor also addresses habitat availability. For instance, if the marine riparian zone was intact in the adjoining units and permeability between the EU and adjoining units was functional, but the unit under consideration had little or no available marine riparian habitat it would score lower than a unit with available habitat and functional connectivity.

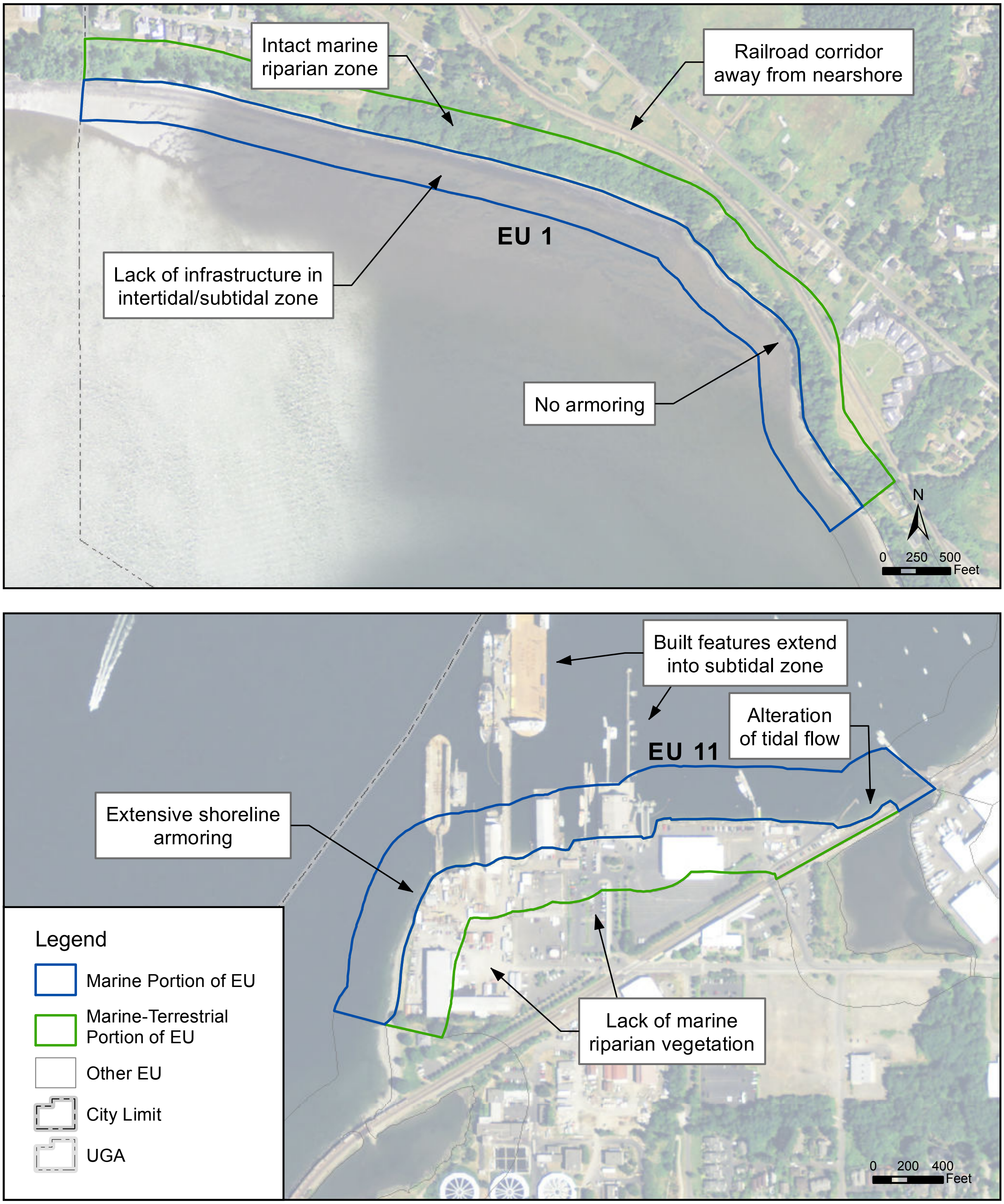
Permeability within the Evaluation Unit

This factor evaluates how freely an organism can move or a process function within the EU. For instance, an area of fill and infrastructure could occupy half of the shoreline of an EU extending into the shallow subtidal zone. This feature could prevent the movement of sediment through the EU to the next unit "downstream" within the drift cell. Because the fill occupies what was intertidal habitat, it is affecting the delivery of organic material (wrack and driftwood) to the beach, thus reducing the functional connectivity of this process.

The relative effect of such structures was considered by the assessment team and assigned the appropriate score. Depending on the specifics of a built feature and its position in the landscape, it could completely or partially block connectivity. Figure 3.2 illustrates some of the factors affecting connectivity within an EU.

Permeability to Adjacent Evaluation Unit

This factor evaluates how easily an evaluation element can pass from the EU to an adjoining unit. In this case, connectivity for a species, species group, or nearshore process may be partially or wholly blocked on one side of the EU but not the other, or could be affected on both sides of the EU by features in adjoining units.



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SOURCE: City of Bellingham, 2014; USDA NAIP, 2013

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Figure 3.2
Example Connectivity Barriers

Rating System Matrix

The assessment team developed a rating system matrix for evaluating marine nearshore habitat connectivity (Appendix B). The matrix is divided into two main headings for the two connectivity axes evaluated: Marine and Terrestrial-Marine. Rows contain the evaluation element (sediment transport, juvenile salmon, etc.) and the column headings are the habitat/connectivity element questions. Within each cell at a row/column intersection the assessment team is prompted to answer a question that rates the subject EU on a scale of 1 to 4, with 1 as the lowest score and 4 as the highest. A Microsoft Excel spreadsheet was set up according to the rating system matrix to calculate individual EU scores and overall results.

Evaluation unit area or patch size is the only quantitative set of answers required – all other answers are qualitatively rated on a relative scale (significant, moderate, minor, none). All questions are scored on a 1 to 4 scale and then totaled by row (evaluation element). Because each evaluation element does not contain the same number of questions (some apply, others do not to a specific element) the final score must be normalized against the highest possible score for that row to provide a comparable score among evaluation elements. As an example, the highest score for the juvenile salmon/forage fish element is 20 (score of 4 in all five questions). An EU that had a score of 16 would be normalized (16/20) for a final score of 0.8. All scores are between 0 and 1 and allow for the relative comparison of connectivity within and between EUs for the evaluation elements.

A total score for each EU is provided by adding up each element score within a unit for the Marine and Terrestrial-Marine axis Connectivity depends on the interaction of the landscape features and the species/species group or process being evaluated. The total connectivity score for that EU provides a relative cumulative index for comparison among units, but should be done with the understanding of the underlying variation and complex interactions within each EU. For a full understanding of the rating process the scores for each individual element within an EU should be reviewed.

How the Evaluation Units were Scored

As is typical for ecological modeling efforts, the literature often provides general parameters and trends – for example, armoring modifies wave action and the contribution of wood and wrack to the upper beach, or juvenile salmon avoid shadows caused by overhead structures and swim into deeper water and around such features rather than under them. Rarely does the literature provide thresholds of effects or levels of effects for such features, such as when does the length of shoreline armoring become a significant factor, or what is the incremental effect of wider piers on juvenile salmon viability? Because natural systems are complex, dynamic, and interactive, attempting to quantify the effects of a range of conditions is difficult if not impossible.

Thus, the assessment team evaluated connectivity guided by the general principles and trends presented in the scientific literature and through a team discussion during the evaluation process. Three initial EUs representing the range of conditions in the study area were selected for testing the evaluation model: one relatively undeveloped unit (EU1), one with moderate shoreline development (EU15), and a third with dense shoreline development (EU4). The evaluation model was applied to these units and the scores were reviewed. During this process some questions in the rating system matrix were modified for clarity. The results correlated well with the team's overall impression and best professional judgment of the relative connectivity of each EU. The evaluation model was then applied to each of the units using aerial photographs and the previously listed reference information.

The most common barriers and disruption to connection within the EUs included piers and docks, breakwaters, fill from previous mill operations, and the Burlington Northern Santa Fe (BNSF) Railway

Line. The assessment team focused on the static structural attributes of these barriers and to a lesser extent, their utilization. For example, the width, height, length, and frequency of docks were included in the assessment, and given more consideration than pedestrian use or noise and light generation as the latter factors were more difficult to assess. The assessment team also considered if the structure was a total barrier (a jetty or a breakwater) or a partial barrier (a wooden dock) that could still be navigated by some organisms.

It is also important to note that EUs were evaluated relative to each other and the level of shoreline development and available habitat in its current state. EUs were not evaluated based on the quality of various habitats but instead, were evaluated based on the relative connectivity within the study area. As mentioned above, due to the dynamic and ranging conditions of natural systems, thresholds of effects are extremely difficult to quantify, and best professional judgment of the assessment team, based on the scientific literature, was used to quantify the effects of existing connectivity and barriers in each EU. Evaluating the EUs relative to each other, in addition to their physical characteristics, allowed the assessment team to decipher if a barrier would be considered a moderate or minor interference, in instances when the more obvious case of “significant” or “no interference” was not present. For example, a dock in the intertidal portion of an EU will always be an interference for juvenile salmon as they are known to move into deeper water to avoid solid structures. This EU would never receive a score of 4 points for “no interference.” However, a 100-foot dock would be less of an interference than a 200-foot dock, but more of an interference than a 50-foot dock, and therefore, receive a “moderate” rating, with a score of 2 for juvenile salmon permeability. Similarly, the cumulative effect of more than one structure, the length of shoreline armoring, and the relative occurrence of marine riparian vegetation all contributed to the connectivity rating.

4.0 RESULTS AND DISCUSSION

The results of the connectivity evaluation are summarized in Table 4.1 and shown on Figures 4.1-4.4. For the Marine connectivity axis, the scores ranged between 2.2 and 8.0 with a median score of 5.8. For the Terrestrial-Marine connectivity axis, the scores ranged between 0.8 and 5.0 with a median score of 2.8. The combined connectivity ratings are also shown in Table 4.1; however as described previously, these combined scores have limited usefulness in prioritization of restoration opportunities because the total score combines all of the evaluation elements. Details of each EU score are shown in Appendix C.

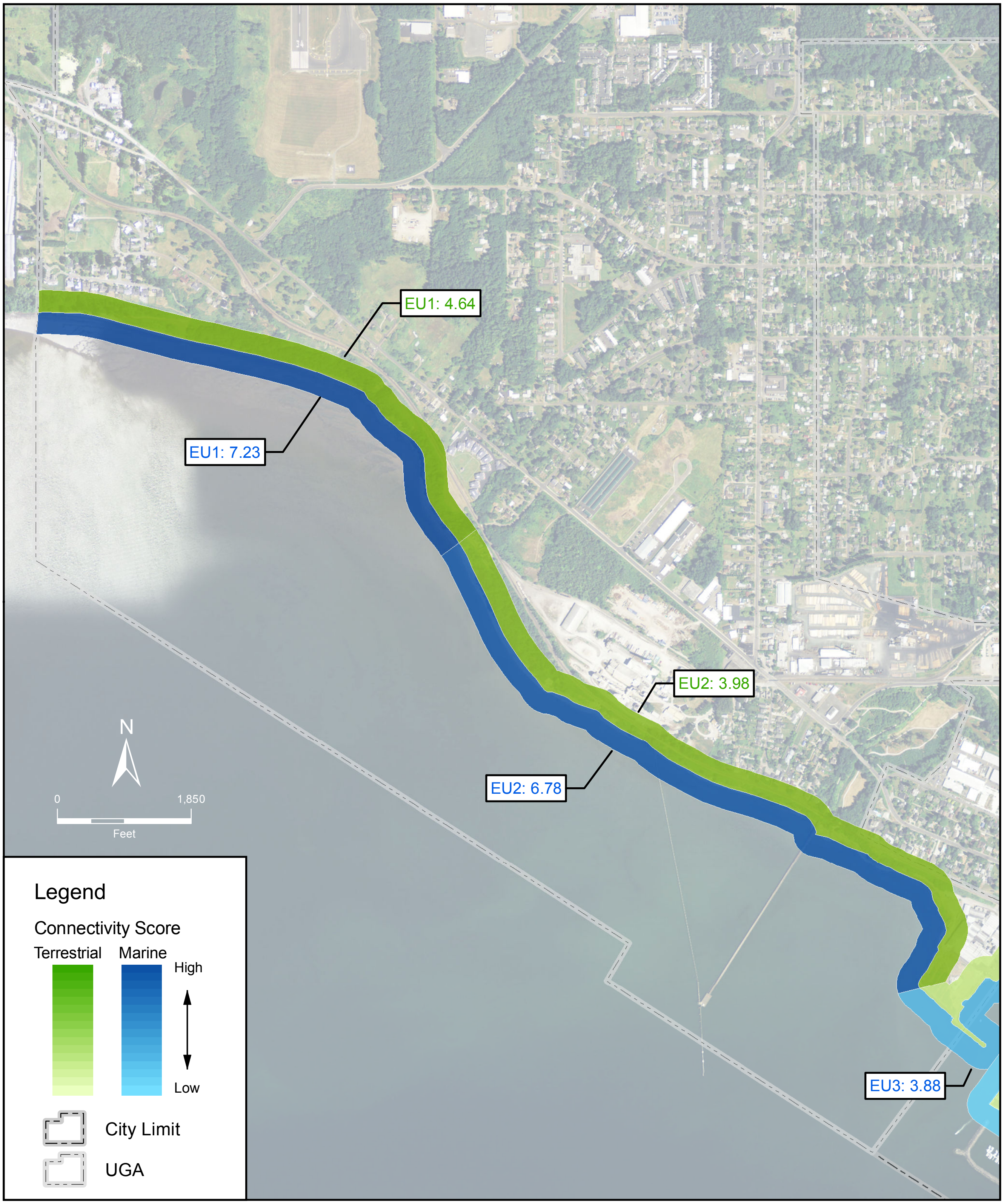
The dominant feature impacting connectivity along both axes is the BNSF railway line, which follows the high tide line along nearly the entire length of the study area. The connectivity ratings for the majority of the EUs in the study area are affected by this feature. Overall, marine connectivity in EUs containing industrial ports, marinas, docks, or piers received the lowest scores and the less developed EUs received higher scores. As expected, these structures inhibit or limit the alongshore transport of sediment and organisms resulting in lower scores. Terrestrial-Marine connectivity was highest in EUs with freshwater inputs and no tidal restrictions, a natural beach, or a pocket estuary. For total scores, the EUs that included the BNSF railroad corridor tended to be closer to the median score, but tended to score higher if the unit contained green space or a freshwater stream.

Table 4-1. Summary of Connectivity Ratings

Evaluation Unit	Marine Axis Score	Terrestrial-Marine Axis Score	Overall Score*	EU Rank
1	7.23	4.64	11.86	2
2	6.78	3.98	10.76	4
3	3.88	2.14	6.01	16
4	2.88	1.82	4.69	18
5	2.23	1.81	4.03	19
6	3.65	2.10	5.75	17
7	5.15	2.44	7.59	12
8	5.78	2.15	7.93	11
9	6.63	3.05	9.68	5
10	4.93	2.42	7.35	14
11	3.23	0.76	3.99	20
12	4.78	2.79	7.57	13
13	4.43	2.74	7.16	15
14	5.80	2.42	8.22	10
15	5.80	3.70	9.50	6
16	6.18	2.95	9.13	7
17	5.98	2.77	8.75	9
18	8.00	5.00	13.00	1
19	6.88	4.61	11.48	3
20	6.05	2.95	9.00	8

*For some EUs, overall score listed in table does not equal sum of two axes due to rounding.

The following narrative summarizes important characteristics of each EU. The discussion is grouped into three parts based on the combined connectivity rating of low, moderate, or high score. Connectivity scores in the two axes (Marine and Terrestrial-Marine) generally followed the same trends. Highly developed nearshore sites scored low, while areas with less shoreline development and more marine riparian vegetation scored higher. Details are provided on the conditions of the EUs that are driving the scores, differences among and between these EU groups, and the relationship to potential restoration actions described in the Waterfront District Subarea Plan. The range of scores are summarized in Table 4-2.



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SOURCE: City of Bellingham, 2014; USDA NAIP, 2013

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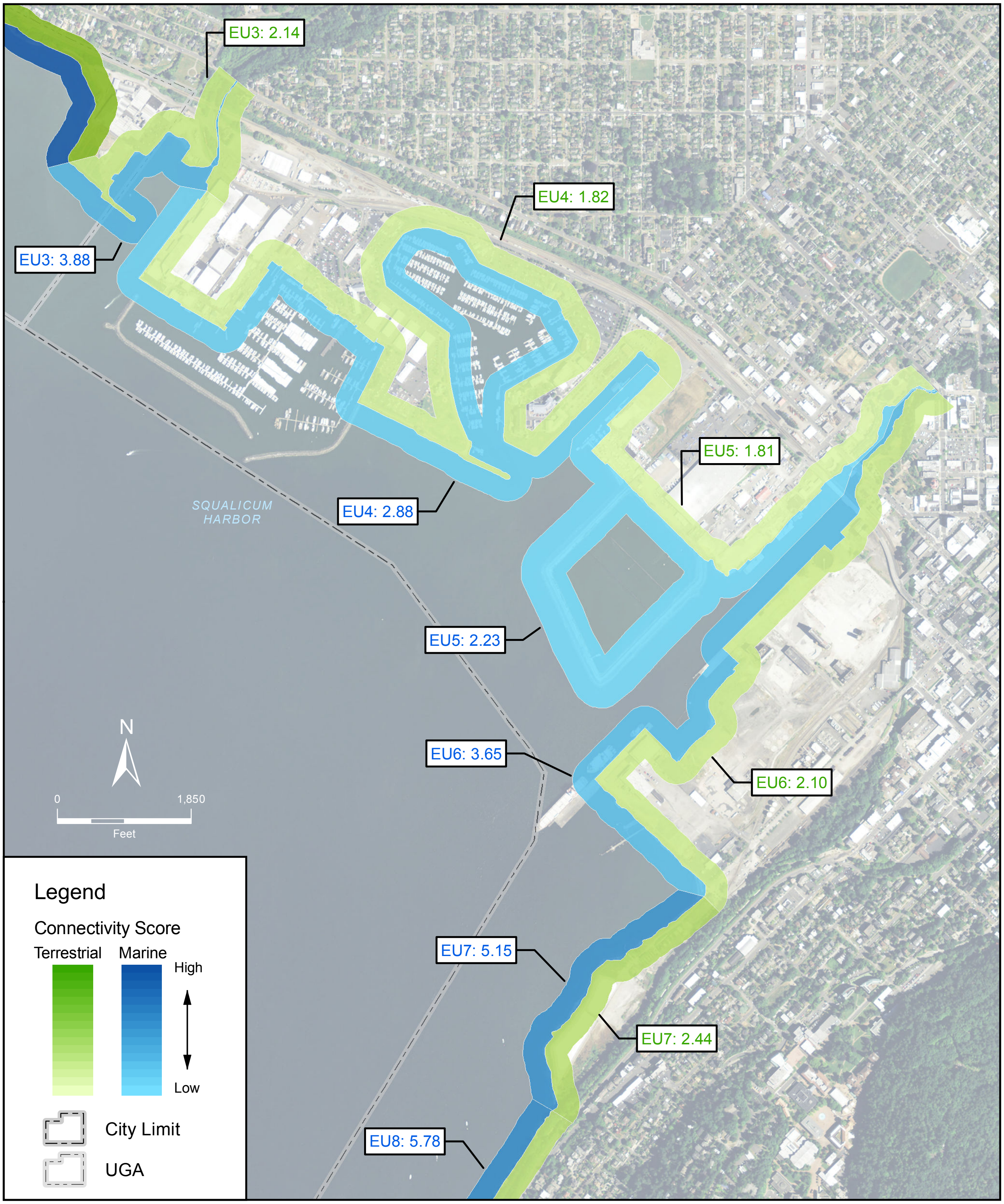
Figure 4.1
Connectivity Evaluation Score



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SOURCE: City of Bellingham, 2014; USDA NAIP, 2013

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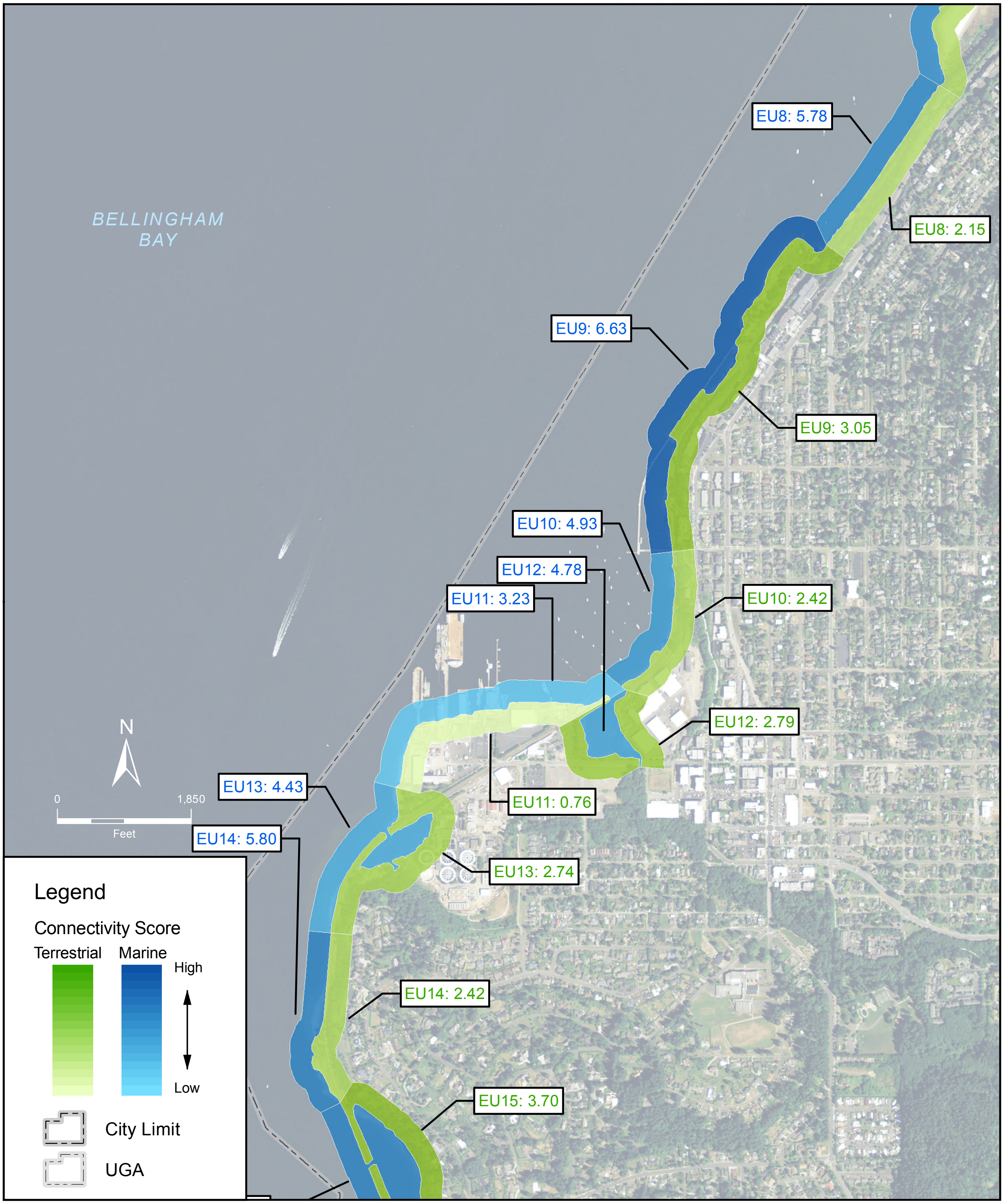
Figure 4.2

Connectivity Evaluation Score



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SOURCE: City of Bellingham, 2014; USDA NAIP, 2013

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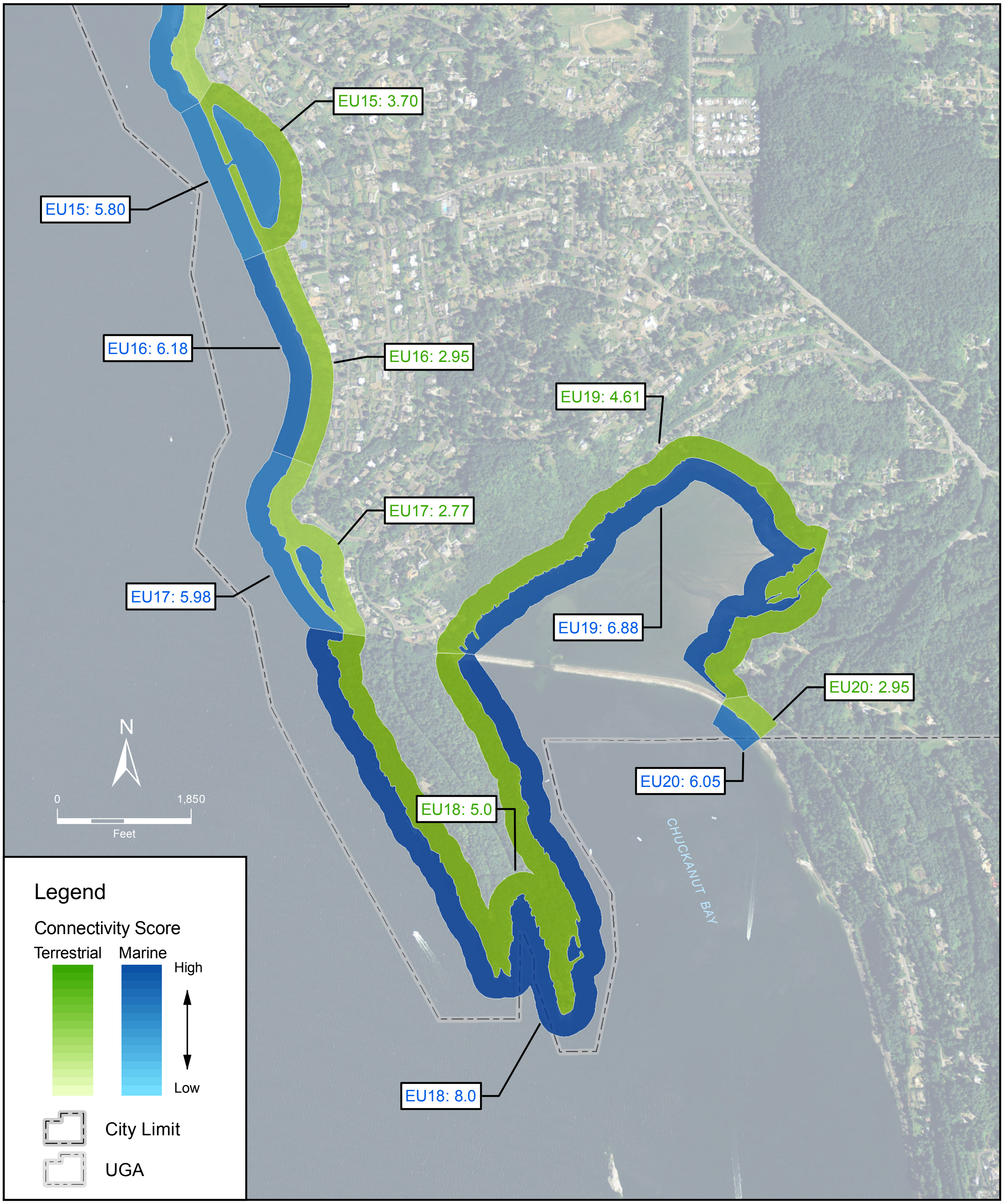
Figure 4.3
Connectivity Evaluation Score



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SOURCE: City of Bellingham, 2014; USDA NAIP, 2013

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Figure 4.4

Connectivity Evaluation Score

Table 4-2. Range of Combined EU Scores by Category

Low Scoring EUs	Moderate Scoring EUs	High Scoring EUs
Combined Score of 3.99-6.01	Combined Score of 7.16-9.68	Combined Score of 10.76-13.00

Low Score EUs

These include EUs 3 through 6 and 11 and the overall scores ranged from 3.99 to 6.01. EUs 3 through 6 are clustered around the central Waterfront District, while EU 11 includes the Alaska ferry dock in the Fairhaven District. These EUs are highly developed with fill, docks, jetties, and other built features projecting into the intertidal/subtidal zone. Little or no marine vegetation is present directly adjacent to the developed shoreline or within the 200-foot-wide study area. The only connections between the marine riparian zone and the intertidal zone are the narrow stream corridors of Squalicum Creek and Whatcom Creek that flow through an otherwise developed landscape. EUs 3 and 6 have slightly higher, but still low, scores because the EUs adjacent to them on the north and south, respectively, are less developed and provide some connectivity between the adjacent marine sections. This is similarly reflected in the Terrestrial-Marine axis score but this difference is minimal (0.3 points) for EUs 3 and 6 compared to EUs 4 and 5, which are in the center of the Waterfront District. The presence of the streams in the units provided the basis for a minor increase in the Within Unit Permeability score. For instance, juvenile salmon can make use of the stream mouth for resting/foraging, while otters can travel between the tidal and freshwater segments of the stream.

EU 11 scored low because several combined factors are limiting connectivity in both axes. These include a highly developed waterfront with several docks, shoreline armoring, a lack of marine riparian vegetation, and the presence of the railroad corridor. Organism movement in the intertidal/subtidal zone is severely affected by the presence of built features and level of human activity. Juvenile salmon, for instance, would have to detour into deep water around seven different docks in an attempt to stay close to the shoreline and in shallow water to traverse EU 11. Other more mobile species, such as shorebirds, would expend additional energy flying from one isolated habitat patch. The lack of large habitat parcels in the center of the study area affects the use patterns of these mobile species and can affect the ability of the area to support these species or species groups.

Several site-specific restoration opportunities have been identified in the central Waterfront District (Port of Bellingham and City of Bellingham 2013). These are briefly discussed here in the context of connectivity.

A small beach at the I & J Waterway extends across EUs 4 and 5. This small, isolated patch provides potential habitat for a number of nearshore species, but because of the lack of habitat connections in the Marine axis and the level of development landward and on both sides of the Whatcom Waterway, restoration of this beach would provide limited habitat connectivity.

Several restoration concepts have been developed for the ASB lagoon in EU5 including opening it up to the Whatcom Waterway as a fish passage corridor and protecting or enhancing the eelgrass bed and beach on the north side. The “fish passage corridors” are not detailed in the plan, but if some element of fish passage could be developed it would provide a minor benefit for fish and potentially other species groups such as sea birds. The large scale of development here eliminates any benefit to sediment transport processes.

Undefined enhancement of the Whatcom Creek estuary adjacent to the Roeder Street Bridge could benefit forage fish/salmon, otters, and heron/shorebirds by improving the connection to upstream available habitat.

Similarly in EU6 the restoration concepts call for restoration and enhancement of hardened portions of the shoreline on the south side of the Whatcom Waterway and protection/enhancement of the Log Pond eelgrass bed and beach. Together these elements provide a narrow but connected habitat element in an otherwise significantly developed landscape. From a larger perspective, nearby elements such as the Roeder Street Bridge estuary and the ASB lagoon begin to form a "stepping stone" approach to providing habitat connectivity within a matrix of nearshore development.

Moderate Score EUs

These include EUs 7 through 10, EUs 12 through 17, and EU 20. Combined scores for this group ranged from 7.16 to 9.68. Higher scoring EUs within this group (EUs 9, 15, 16, 20) had less shoreline development, some marine riparian habitat adjacent to the shoreline, less armoring and some natural shoreline, a lack of piers or docks, and less human disturbance. Sediment transport and sediment input process are somewhat functional, and there are areas where the transfer of organic material and invertebrates is relatively unimpeded. Though EU 9 has a long pedestrian pathway within its marine unit, it also contains a relatively undeveloped shoreline with several areas of beaches and native vegetation. In addition, the dock is relatively narrow, compared to others in the study area, and is considered to be navigable by several of the assessed connectivity elements, based on its physical structure.

In contrast, lower scoring EUs (7, 10, 13) within the moderate group exhibited higher levels of shoreline development and fractured connections between the marine and terrestrial environment. As an example, EU 13 is dominated by the railroad fill that bisects the connection to an intertidal lagoon, with a small bridge as the only tidal connection. This tidal lagoon could offer a prime resting area for juvenile salmon, but accessibility is severely constrained by the railroad fill and narrow tidal opening. The railroad corridor also disrupts the connection between the marine riparian zone and the upper beach, has corresponding effects to organic material transfer, and reduces the connectivity between the land and marine water for evaluation species such as otter.

Within EU7 the Waterfront District Subarea Plan calls for enhancing the beach, improving habitat, and protecting eelgrass beds at Boulevard Park. This approximately 16-acre parcel is one of the largest areas for potential restoration within the Waterfront District. In contrast to the extremely developed nearshore adjacent on the north side of Boulevard Park, the south side has more functional connectivity. Habitat enhancement here would improve the marine connectivity, and the addition of native woody vegetation along the shoreline could improve the transfer of organic material to the beach. From the landscape perspective, this larger parcel of land provides another link in the "stepping stone" approach to connectivity in providing some linkage through the developed central waterfront nearshore.

EU 12 is an interesting example of an isolated habitat parcel that is connected to Padden Creek but adjacent to developed EUs on both sides. There is some connectivity to the freshwater riparian corridor through a narrow, remnant vegetated zone at the stream mouth, but the connection between the delta and the open marine environment is restricted by the railroad corridor fill. Thus, while this small patch could provide limited habitat for fish, shorebirds, and herons, its connectivity is restricted by adjacent parcels.

EU 20 at the south end of the study area scored at the higher end of this moderate grouping. Its score would have been higher, but compared to other parcels in the study area it is relatively small. It has some restriction in the Terrestrial-marine axis due to the railroad corridor, but otherwise has relatively high functions.

High Score EUs

These include EUs 1, 2, 18, and 19 with combined scores that ranged from 10.76 to 13.00. These EUs are located on the extreme north and south ends of the study area, and a review of aerial photography makes it obvious why these units scored relatively high. In general, this group of EUs exhibits minimal development, an intact marine riparian zone with strong connections to the upper beach, and a lack of docks or other protrusions into the marine zone.

In EUs 1 and 2 the railroad corridor is atop high bluffs and away from the shoreline; sediment input and organic material exchange are relatively unimpeded compared to most of the study area. The movement of sediment, juvenile fish, marine birds, shorebirds and other marine evaluation elements is not impeded along the shoreline and ecological functions are generally intact.

At the south end of the study area EU 18 contains the Clark's Point peninsula, a large and intact forest, and no shoreline development. This was the highest rated unit in the study area and received the highest points available for all connectivity categories. Similarly the adjacent EU 19 was highly rated. This unit includes a relatively undeveloped shoreline and marine riparian zone with a functional connection to the beach, an unimpeded connection to Chuckanut Creek, and a stream delta. The one factor affecting connectivity here is the presence of the railroad corridor fill and narrow bridge opening between the delta and the marine zone. Thus EU 19 had lower scores compared to EU 18 for Within Unit Permeability for juvenile fish and for Barriers to Surface Water or Tidal Flow. Otherwise, this EU exhibits a high level of connectivity and intact habitat.

5.0 SUMMARY

The Bellingham nearshore connectivity analysis indicates a strong relationship between shoreline development and relative connectivity for the movement of organisms and processes along the shoreline and between the shoreline and the marine riparian zone. General conclusions include the following:

- The highly developed areas of the downtown waterfront and the Fairhaven Alaska ferry dock impose severe obstacles to the movement of organisms and block shoreline processes critical to the development of nearshore habitats.
- Much of the study area has a relatively "moderate" level of connectivity that varies with level of development, presence of shoreline armoring, and the presence of patches of intact forest in the marine riparian zone.
- Built factors most affecting the connectivity scores include fill, docks and jetties, habitat fragmentation from the railroad corridor, industrial development, and lack of marine riparian vegetation along the shoreline.
- There are limited opportunities for improving connectivity within the downtown Waterfront District Subarea because of the dominance of fill, marinas, docks, and other developed features.
- Proposed restoration activity within the downtown Waterfront District Subarea may improve connections to habitat within a specific EU but will be unable to provide improved connectivity between EUs.
- Restoration within the Waterfront District Subarea can provide a crucial function to nearshore organisms by increasing the habitat availability in a highly-developed landscape.

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Appendix A –Rating System Background and References

Table A-1. Bellingham Marine Nearshore Habitat Connectivity Study Rating System Background and References

	Unit Unaltered Marine Relative Size	Unit Marine Patch Area	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Patch Size	Unit Marine Riparian Patch Area	Permeability of Beach-Marine/Riparian Zone	Barriers to surface water flow or tidal input
Marine axis								
Sediment Transport	NA	NA	Interference with sediment transport parallel to the shoreline can occur when armoring, fill, solid structures, or docks with dense piling are present (Shipman et al. 2014). While it is well documented that solid structures, such as groins, disrupt sediment transport, the level of interference by open-spaced piers is not clear and no specific threshold for pier density is identified in the literature. Generally, the evaluation team considered pier density above 20% occlusion of the space below a dock as a significant barrier to sediment transport.	This question is similar to the one in the adjacent left column, but refers to the permeability of the two adjacent evaluation units.	NA	NA	NA	NA
Juvenile salmon/forage fish	The level of alteration of intertidal habitats in the unit dictates if the unit will be used by a species or species group. A unit with significant alteration will score lower and a unit will minor to no alteration will score higher.	The general size of the intertidal zone in a particular evaluation unit is a factor in how or if it will be used by a species or species group. A unit will score higher if habitat is present AND there is good connectivity to adjacent units. Conversely – if little habitat is present it receives a lower score.	Solid structures such as groins will force juvenile into deeper water while traveling along the shoreline. In addition, overhead structures that cast wide shadows are avoided by juvenile salmon and act as barriers. It is thought that juvenile fish are more susceptible to predation as the move into these less protected waters. Structures extending into deeper subtidal areas create barriers to movement and can delay migration of juvenile salmon (Ono et al. 2010, Toft et al 2007). Bulkheading of upper intertidal shorelines can directly remove forage fish habitat, impact lower forage fish spawning habitat (through wave refraction), and eliminate sources of sediment vital to maintenance of forage fish (Rice 2006; Pentilla 2007).		NA	NA	NA	Juvenile salmon will make use of the mouths and lower reaches of small streams for foraging, avoiding predators, and general maturation (Levings, Boyle et al. 1995; Hirschi, Doty et al. 2003; Redman, Myers et al. 2005; Beamer, McBride et al. 2006; Marin Jarrin, Shanks et al. 2009; Trotter 1989). Dikes, weirs, breakwaters, and other physical structures can prevent juvenile fish access to these habitats.
Mobile invertebrates (crabs)			Dungeness and red rock crab forage in the intertidal and subtidal zones of the shoreline and substrates of gravel-sand, bivalve shells, eelgrass, and macroalgae (Kozloff 1993; Buchanan 2006). Fill and solid wall developments in the intertidal zone will displace usable habitat and affect the		NA	NA	NA	NA

	Unit Unaltered Marine Relative Size	Unit Marine Patch Area	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Patch Size	Unit Marine Riparian Patch Area	Permeability of Beach-Marine/Riparian Zone	Barriers to surface water flow or tidal input
			availability of food sources such as barnacles, bivalves, and smaller living crabs. Crabs will use habitat beneath overhead structures but it is not preferable habitat (Toft et al. 2007). Overhead structures do not necessarily block movement crabs but habitat under piers is likely more modified and less attractive for foraging and hiding.					
Shorebirds			Dunlin, sandpiper, sanderling, and other shorebirds forage along the intertidal zone and upper beach, particularly during the winter and migration times in Puget Sound (Goss-Custard et al. 1991; Colwell and Landrum 1993; Burger et al. 1997; Butler et al. 2002). Overhead structures fill, and shoreline development can interfere with their use of these zones by posing physical barriers, replacing natural habitat, and increasing human disturbance (Burton et al. 1996; Ainley and Lewis 1974; Ronconi and St. Clair 2002, Bellefleur et al. 2009).		NA	NA	NA	NA
River otter			River otters will make regular use of adjacent nearshore areas for foraging. While they appear to not be affected by overhead docks and piers (WDFW 2005). Solid structures, groins, and other developed features can block access to continuous areas of shoreline and displace habitat.		NA	NA	NA	NA
Great blue heron			Great blue herons rely on intertidal and mudflats to forage for marine prey such as fish and crustaceans (Eissinger 2007). Herons are versatile and will forage among piers, docks, and jetties if there is sufficient foraging opportunities and where human disturbance is low, but they prefer eelgrass shallows in the intertidal zone (Eissinger 2007).		NA	NA	NA	NA

	Unit Unaltered Marine Relative Size	Unit Marine Patch Area	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Patch Size	Unit Marine Riparian Patch Area	Permeability of Beach-Marine/Riparian Zone	Barriers to surface water flow or tidal input
Marine birds			Surf scoters, goldeneyes, grebes and other marine birds use the nearshore areas of Puget Sound for foraging and resting (Baldwin & Lovvorn 1994; Moore et al. 2006; Badzinski et al. 2008). Some marine birds such as scoter are adaptable and will forage on mussels attached to pilings or other artificial structures and will travel beneath piers and docks. Fill and solid wall developments in the intertidal zone will displace usable habitat. Similarly cormorants readily use docks and pilings for perching and will forage around these features. Grebes and alcids generally are found further off-shore and away from built features. While docks on pilings can be somewhat porous features for seabirds, solid structures or fill act as barriers and require birds to expend additional energy moving around these obstacles.		NA	NA	NA	NA
Harbor seals			Harbor seals use beaches or rock outcroppings as haul-out areas during low tide to rest, digest food, molt, or to nurse young. The availability of protected beaches is directly correlated to the amount of potential haul-out areas although the presence of human activities is major consideration for seals (they typically select unpopulated areas) (Reijnders 1980; Scheffer and Slipp 1944; Calambokidis et al. 1990, London et al. 2002). Seals typically forage within 4km of their primary haul-out site but can also travel longer distances for seasonally abundant prey (Zier and Gaydos 2014). Seals will use areas beneath docks and piers and do not particularly avoid these features. Fill and solid features in the intertidal/subtidal zone require seals to swim		NA	NA	NA	NA

	Unit Unaltered Marine Relative Size	Unit Marine Patch Area	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Patch Size	Unit Marine Riparian Patch Area	Permeability of Beach-Marine/Riparian Zone	Barriers to surface water flow or tidal input
			around these features to access nearby habitat.					
Terrestrial-Marine axis								
Organic material / invertebrate import/export	The level of alteration of intertidal habitats in the unit dictates if the unit will be used by a species or species group. A unit with significant alteration will score lower and a unit will minor to no alteration will score higher.	Organic material can be transferred from the marine riparian zone to the intertidal zone or from the intertidal zone to the upper beach (upper intertidal and supralittoral zones) (Simenstad and Wissmar 1985; Brennan 2007; Johannessen and MacLennan 2007). The relative extent of the intertidal zone in an evaluation unit will affect how transferred organic material from the marine riparian zone can be used and affect the contribution of wrack and driftwood to the upper intertidal and supralittoral zones.	Tidal action carries wrack (non-woody vegetation) and driftwood to the beach and provides important food and structural elements for a variety of invertebrates that are fed upon by fish and birds (Bradley and Bradley 1993; Heerhartz 2013). Armoring and shoreline development can significantly alter the input of organic material to the beach from the riparian zone. In addition, armoring can significantly alter the wave action and contribution of wrack to the upper beach (Heerhartz 2013).	NA	The level of alteration of marine riparian habitats in the unit dictates the potential for organic material to be contributed to the unit and adjacent units.	The export of organic material to the beach is an import process contributing to invertebrate, bird, and nearshore fish use of the upper beach and intertidal zone (Romanuk and Levings 2003; Sibert, Brown et al. 1977; Levings, Boyle et al. 1995; Miller and Simenstad 1997; Cordell, Higgins et al. 1998; Brennan, Higgins et al. 2004; Quinn 2005; Northcote, Gregory et al. 2007; Duffy, Beauchamp et al. 2010; Brennan 2007). The relative size of the unaltered marine riparian zone corresponds to the relative amount of organic material exported. Invertebrate production in the terrestrial environment and transfer to the adjacent beach provides forge opportunities for both riparian birds and for shorebirds.	Shoreline development, extensive armoring, sheet piles, roads, railroads, and other structures can interfere with the transfer of organic material from the marine riparian zone to the beach (Heerhartz 2013). Similar to the transfer of organic matter, the transfer of invertebrates to the beach from the terrestrial environment can be severely altered or blocked by development and land clearing (Sobocinski et al. 2010). Wrack provides cover and a food source for many intertidal invertebrates, and tends to be more prevalent along unaltered shorelines (Dugan et al. 2003, Sobocinski 2003). Shoreline anchoring structures do provide vertical habitat space for particular groups of marine invertebrates such as barnacles and mussels (Kozloff 1993).	Barriers to freshwater or tidal flow can impede the transfer of organic materials in flowing water to the nearshore or from tidal input to the upper intertidal zone.

	Unit Unaltered Marine Relative Size	Unit Marine Patch Area	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Patch Size	Unit Marine Riparian Patch Area	Permeability of Beach-Marine/Riparian Zone	Barriers to surface water flow or tidal input
Sediment Input	NA	NA	NA	NA	The level of alteration of marine riparian habitats in the unit dictates the potential for sediment input in unit and adjacent units.	The relative size of the unaltered marine riparian zone of the evaluation influences the extent of sediment processes interaction with the adjacent beach.	The marine riparian zone, particularly where there are steep slopes and bluffs, can provide important sediment sources for nearshore process and maintenance of habitats (Shipman 2008, Pentilla 2007, Finlayson 2006). This transfer of sediment can be altered or blocked by hardening of the shoreline (Shipman et al. 2014).	
River otter	NA	NA	NA	NA	The level of alteration of marine riparian habitats in the unit dictates if the unit will be used by a species or species group. A unit with significant alteration will score lower and a unit will minor to no alteration will score higher.	The general availability of an unaltered marine riparian zone can facilitate the movement of otters along the shoreline and provide potential denning and resting areas.	River otters will make use of the nearshore at different tide stages foraging for invertebrates and fish. The beach also serves as a travel corridor to the open water.	
Riparian birds	NA	NA	NA	NA		Size of a habitat patch has a direct correlation to riparian bird species richness and the interaction of these birds with the adjacent beach (Donnelly and Marzluff 2006).	Riparian birds will forage in the intertidal and back shore zones and nest in adjacent riparian areas. Shoreline development, extensive armoring, sheet piles, roads, railroads, and other structures displace habitat such as riparian vegetation, wrack, and logs and interrupt the movement of birds between the riparian areas and the beach zones (Heerhartz 2013; Keany 2011).	NA
Great blue heron	NA	NA	NA	NA		Size of a habitat patch dictates foraging area for terrestrial prey such as amphibians and reptiles and the interaction of great	Great blue herons will forage in the intertidal and back shore zones and nest in adjacent riparian areas (Eissinger 2007). Shoreline development, extensive	NA

	Unit Unaltered Marine Relative Size	Unit Marine Patch Area	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Patch Size	Unit Marine Riparian Patch Area	Permeability of Beach-Marine/Riparian Zone	Barriers to surface water flow or tidal input
						blue herons with the adjacent beach. Size also dictates potential suitability for breeding, perching/resting, or rookery site.	armoring, sheet piles, roads, railroads, and other structures displace habitat and interrupt the movement of birds between the riparian areas and the beach zones.	

Appendix B – Rating System Matrix

Table B-1. Bellingham Marine Nearshore Habitat Connectivity Rating System Matrix

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/Riparian Zone	Barriers to surface water flow or tidal input
Marine								
Sediment Transport	NA	NA	Does the unit include a built feature that significantly interferes with drift cell sediment transport? • Yes, significant=0 • Yes, moderate=2 • Yes, minor=3 • No=4	Does the adjacent unit include a built feature that significantly interferes with drift cell sediment transport? • Yes, on both adjacent units=0 • Yes, on one adjacent unit=2 • No=4	NA	NA	NA	NA
Juvenile salmon/forage fish	What is the relative size of the unaltered marine zone in relation to the unit size? • Negligible=1 • Small=2 • Medium=3 • Large=4	What is the area of the unaltered marine zone in this unit? • ≤10 acre =1 • >10 but ≤20 ac=2 • >20 but ≤30 ac=3 • >30 ac=4	Does this unit include a built feature that significantly interferes with the lateral movement of juvenile fish along the shoreline? • Yes, significant=0 • Yes, moderate=2 • Yes, minor=3 • No=4	Does the adjacent unit include a built feature that significantly interferes with the lateral movement of juvenile fish along the shoreline? • Yes, on both adjacent units=0 • Yes, on one adjacent unit=2 • No=4	NA	NA	NA	Is there a barrier that interferes with either the downstream flow of freshwater or tidal flow? • All tidal and freshwater (if present) flows have interference=0 • Either tidal or freshwater (if both present) flows have interference=2 • No tidal interference and if freshwater input present with no interference=4
Mobile invertebrates (crabs)			Does this unit include a built feature that significantly interferes with the lateral movement of crab species along the shoreline? • Yes, significant=0 • Yes, moderate=2 • Yes, minor=3 • No=4	Does the adjacent unit include a built feature that significantly interferes with the lateral movement of crab species along the shoreline? • Yes, on both adjacent units=0 • Yes, on one adjacent unit=2 • No=4	NA	NA	NA	NA

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/Riparian Zone	Barriers to surface water flow or tidal input
Shorebirds			Does this unit include a built feature that significantly interferes with the lateral movement of shorebirds along the shoreline? • Yes, significant=0 • Yes, moderate=2 • Yes, minor=3 • No=4	Does the adjacent unit include a built feature that significantly interferes with the lateral movement of shorebirds along the shoreline? • Yes, on both adjacent units=0 • Yes, on one adjacent unit=2 • No=4	NA	NA	NA	NA
River otter			Does this unit include a built feature that significantly interferes with the lateral movement of otters along the shoreline? • Yes, significant=0 • Yes, moderate=2 • Yes, minor=3 • No=4	Does the adjacent unit include a built feature that significantly interferes with the lateral movement of otters along the shoreline? • Yes, on both adjacent units=0 • Yes, on one adjacent unit=2 • No=4	NA	NA	NA	NA
Great blue heron			Does this unit include a built feature that significantly interferes with the lateral movement of herons along the shoreline? • Yes, significant=0 • Yes, moderate=2 • Yes, minor=3 • No=4	Does the adjacent unit include a built feature that significantly interferes with the lateral movement of herons along the shoreline? • Yes, on both adjacent units=0 • Yes, on one adjacent unit=2 • No=4	NA	NA	NA	NA
Marine birds			Does this unit include a built feature that significantly interferes with the lateral movement of marine birds along the shoreline? • Yes, significant=0 • Yes, moderate=2 • Yes, minor=3 • No=4	Does the adjacent unit include a built feature that significantly interferes with the lateral movement of marine birds along the shoreline? • Yes, on both adjacent units=0 • Yes, on one adjacent unit=2 • No=4	NA	NA	NA	NA

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/Riparian Zone	Barriers to surface water flow or tidal input
Harbor seals			Does this unit include a built feature that significantly interferes with the lateral movement of harbor seals along the shoreline? • Yes, significant=0 • Yes, moderate=2 • Yes, minor=3 • No=4	Does the adjacent unit include a built feature that significantly interferes with the lateral movement of harbor seals along the shoreline? • Yes, on both adjacent units=0 • Yes, on one adjacent unit=2 • No=4	NA	NA	NA	NA
Terrestrial-Marine								
Organic material/invertebrate import/export	What is the relative size of the unaltered marine zone in relation to the unit size? • Negligible=1 • Small=2 • Medium=3 • Large=4	What is the area of the unaltered marine zone in this unit? • <u><</u>10 acre =1 • >10 but <u><</u>20 ac=2 • >20 but <u><</u>30 ac=3 • >30 ac=4	Does the unit include a built feature that significantly interferes with tidal input of wrack and driftwood? Yes, significant-0 Yes, moderate=2 Yes, minor=3 No=4	NA	What is the relative size of the unaltered marine riparian zone relative to the unit size? • Negligible=1 • Small=2 • Medium=3 • Large=4	What is the area of the unaltered marine riparian zone in this unit? • <u><</u>10 acre =1 • >10 but <u><</u>20 ac=2 • >20 but <u><</u>30 ac=3 • >30 ac=4	Do shoreline built features significantly interfere with the exchange of organic material from the marine riparian zone to the upper beach? Yes, significant-0 Yes, moderate=2 Yes, minor=3 No=4	Is there a barrier that interferes with either the downstream flow of freshwater or tidal flow? • All tidal and freshwater (if present) flows have interference=0 • Either tidal or freshwater (if both present) flows have interference=2 • No tidal interference and freshwater input present with no interference=4
Sediment Input	NA	NA	NA	NA			Do shoreline built features significantly interfere with the exchange of sediment from the marine riparian zone to the upper beach? Yes, significant=0 Yes, moderate=2 Yes, minor=3 No=4	
River otter	NA	NA	NA	NA			Do shoreline built features significantly interfere with movement of otters between the beach and the marine riparian zone? Yes, significant=0 Yes, moderate=2 Yes, minor=3 No=4	

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/Riparian Zone	Barriers to surface water flow or tidal input
Riparian birds	NA	NA	NA	NA			Do shoreline built features significantly interfere with use of the beach by riparian birds? Yes, significant-0 Yes, moderate=2 Yes, minor=3 No=4	NA
Great blue heron	NA	NA	NA	NA			Do shoreline built features significantly interfere with use of the beach by great blue herons? Yes, significant-0 Yes, moderate=2 Yes, minor=3 No=4	NA

Appendix C – Rating and Summary Results

City of Bellingham Marine Nearshore Habitat Connectivity Study

Summary of Connectivity Assessment Results

Evaluation Unit	SMP Designation	Railroad Corridor	Docks/Piers	Industrial Port or Marina	Natural Beach	Tidal Restriction	Pocket Beach	Level of EU Development	Marine Axis Score	Marine-Terrestrial Axis Score	Overall Score	EU Rank
1	Natural	Yes	No	No	Yes	No	No	Low	**7.23**	**4.64**	11.86	2
2	Urban Conservancy	Yes	No	No	Yes	No	No	Low	**6.78**	**3.98**	10.76	4
3	Urban Conservancy	Yes	Yes	Yes	No	Yes	No	High	**3.88**	**2.14**	6.01	16
4	Urban Maritime	Yes	Yes	Yes	No	Yes	No	High	**2.88**	**1.82**	4.69	18
5	Mixed & Recreational Use	Yes	Yes	Yes	No	Yes	No	High	**2.23**	**1.81**	4.03	19
6	Mixed Use	Yes	Yes	Yes	No	Yes	No	High	**3.65**	**2.10**	5.75	17
7	Recreational Use	Yes	No	No	Yes (minor)	Yes	No	Med	**5.15**	**2.44**	7.59	12
8	Urban Conservancy	Yes	No	No	No	No	No	Med	**5.78**	**2.15**	7.93	11
9	Urban Conservancy	Yes	Yes	No	Yes	No	No	Med	**6.63**	**3.05**	9.68	5
10	Urban Conservancy	Yes	Yes	No	Yes (minor)	No	No	Med	**4.93**	**2.42**	7.35	14
11	Urban Maritime	Yes	Yes	Yes	No	Yes	No	High	**3.23**	**0.76**	3.99	20
12	Urban Conservancy	Yes	No	No	Yes	Yes	Yes	Med	**4.78**	**2.79**	7.57	13
13	Urban Conservancy	Yes	No	No	Yes	Yes	Yes	Med	**4.43**	**2.74**	7.16	15
14	Urban Conservancy	Yes	No	No	Yes	No	No	Med	**5.80**	**2.42**	8.22	10
15	Urban Conservancy	Yes	No	No	Yes	Yes	Yes	Med	**5.80**	**3.70**	9.50	6
16	Urban Conservancy	Yes	No	No	Yes (historic)	No	No	Med	**6.18**	**2.95**	9.13	7
17	Urban Conservancy	Yes	No	No	Yes	Yes	Yes	Med	**5.98**	**2.77**	8.75	9
18	Natural	No	No	No	Yes	No	No	Low	**8.00**	**5.00**	13.00	1
19	Natural	Yes	No	No	Yes	Yes	Yes	Low	**6.88**	**4.61**	11.48	3
20	Natural	Yes	No	No	Yes	No	No	Low	**6.05**	**2.95**	9.00	8

City of Bellingham Marine Nearshore Habitat Connectivity Study

Evaluation Unit Areas (calculated from GIS) and Scores

Evaluation Unit	Marine	ACRES	Score	Terrestrial	ACRES	Score
MARINE 1	Marine	21.48	3	Terrestrial	22.27	3
MARINE 2	Marine	30.10	3	Terrestrial	30.38	3
MARINE 3	Marine	12.63	2	Terrestrial	16.09	2
MARINE 4	Marine	61.27	4	Terrestrial	61.12	4
MARINE 5	Marine	50.50	4	Terrestrial	22.84	3
MARINE 6	Marine	28.16	3	Terrestrial	33.11	4
MARINE 7	Marine	12.34	2	Terrestrial	12.35	2
MARINE 8	Marine	7.94	1	Terrestrial	8.27	1
MARINE 9	Marine	17.64	2	Terrestrial	16.69	2
MARINE 10	Marine	6.32	1	Terrestrial	6.85	1
MARINE 11	Marine	12.23	2	Terrestrial	9.48	1
MARINE 12	Marine	3.99	1	Terrestrial	8.07	1
MARINE 13	Marine	10.41	2	Terrestrial	11.68	2
MARINE 14	Marine	7.98	1	Terrestrial	7.13	1
MARINE 15	Marine	13.88	2	Terrestrial	10.92	2
MARINE 16	Marine	8.85	1	Terrestrial	9.49	1
MARINE 17	Marine	10.51	2	Terrestrial	10.11	1
MARINE 18	Marine	44.43	4	Terrestrial	37.92	4
MARINE 19	Marine	26.63	3	Terrestrial	32.39	4
MARINE 20	Marine	2.00	1	Terrestrial	2.06	1

SCORING SYSTEM	Area	Score
	≥ 10 acres	1
	>10 but ≤20 acres	2
	>20 but ≤30 acres	3
	>30 acres	4

City of Bellingham Marine Nearshore Habitat Connectivity Study

Evaulation Calculator

Evaluation Unit 1

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/ Riparian Zone	Barriers to surface water flow or tidal input	Raw Score	# of Questions	Normalized Score	
Marine												
Sediment Transport			4	2					6	2	0.75	
Juvenile salmon/forage fish	4	3	4	2				4	17	5	0.85	
Mobile invertebrates (crabs)	4	3	4	4					15	4	0.9375	
Shorebirds	4	3	4	4					15	4	0.9375	
River otter	4	3	4	4					15	4	0.9375	
Great blue heron	4	3	4	4					15	4	0.9375	
Marine birds	4	3	4	4					15	4	0.9375	
Harbor seals	4	3	4	4					15	4	0.9375	7.2
Terrestrial-Marine												
Organic material / invertebrate import / export	4	3	4		4	3	4	4	26	7	0.928571429	
Sediment Input					4	3	4	4	15	4	0.9375	
River otter					4	3	4	4	15	4	0.9375	
Riparian birds					4	3	4		11	3	0.916666667	
Great blue heron					4	3	4		11	3	0.916666667	4.6

Total Unit Score 11.86

City of Bellingham Marine Nearshore Habitat Connectivity Study

Evaulation Calculator

Evaluation Unit **2**

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/ Riparian Zone	Barriers to surface water flow or tidal input	Raw Score	# of Questions	Normalized Score	
Marine												
Sediment Transport			2	2					4	2	0.5	
Juvenile salmon/forage fish	4	3	0	2				4	13	5	0.65	
Mobile invertebrates (crabs)	4	3	4	4					15	4	0.9375	
Shorebirds	4	3	4	4					15	4	0.9375	
River otter	4	3	4	4					15	4	0.9375	
Great blue heron	4	3	4	4					15	4	0.9375	
Marine birds	4	3	4	4					15	4	0.9375	
Harbor seals	4	3	4	4					15	4	0.9375	6.8
Terrestrial-Marine												
Organic material / invertebrate import / export	4	3	4		2	3	4	4	24	7	0.857142857	
Sediment Input					2	3	4	4	13	4	0.8125	
River otter					2	3	4	4	13	4	0.8125	
Riparian birds					2	3	4		9	3	0.75	
Great blue heron					2	3	4		9	3	0.75	4.0

Total Unit Score 10.76

City of Bellingham Marine Nearshore Habitat Connectivity Study

Evaulation Calculator

Evaluation Unit 3

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/ Riparian Zone	Barriers to surface water flow or tidal input	Raw Score	# of Questions	Normalized Score	
Marine												
Sediment Transport			0	2					2	2	0.25	
Juvenile salmon/forage fish	1	2	0	0				2	5	5	0.25	
Mobile invertebrates (crabs)	1	2	4	2					9	4	0.5625	
Shorebirds	1	2	4	2					9	4	0.5625	
River otter	1	2	4	2					9	4	0.5625	
Great blue heron	1	2	4	2					9	4	0.5625	
Marine birds	1	2	4	2					9	4	0.5625	
Harbor seals	1	2	4	2					9	4	0.5625	3.9
Terrestrial-Marine												
Organic material / invertebrate import / export	1	2	2		1	2	2	2	12	7	0.428571429	
Sediment Input					1	2	2	2	7	4	0.4375	
River otter					1	2	2	2	7	4	0.4375	
Riparian birds					1	2	2		5	3	0.416666667	
Great blue heron					1	2	2		5	3	0.416666667	2.1

Total Unit Score 6.01

City of Bellingham Marine Nearshore Habitat Connectivity Study

Evaulation Calculator

Evaluation Unit 4

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/ Riparian Zone	Barriers to surface water flow or tidal input	Raw Score	# of Questions	Normalized Score	
Marine												
Sediment Transport			0	0					0	2	0	
Juvenile salmon/forage fish	1	4	0	0				0	5	5	0.25	
Mobile invertebrates (crabs)	1	4	0	2					7	4	0.4375	
Shorebirds	1	4	0	2					7	4	0.4375	
River otter	1	4	0	2					7	4	0.4375	
Great blue heron	1	4	0	2					7	4	0.4375	
Marine birds	1	4	0	2					7	4	0.4375	
Harbor seals	1	4	0	2					7	4	0.4375	2.9
Terrestrial-Marine												
Organic material / invertebrate import / export	1	4	0		1	4	0	0	10	7	0.357142857	
Sediment Input					1	4	0	0	5	4	0.3125	
River otter					1	4	0	0	5	4	0.3125	
Riparian birds					1	4	0		5	3	0.416666667	
Great blue heron					1	4	0		5	3	0.416666667	1.8

Total Unit Score 4.69

City of Bellingham Marine Nearshore Habitat Connectivity Study

Evaulation Calculator

Evaluation Unit 5

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/ Riparian Zone	Barriers to surface water flow or tidal input	Raw Score	# of Questions	Normalized Score	
Marine												
Sediment Transport			0	0					0	2	0	
Juvenile salmon/forage fish	1	4	0	0				2	7	5	0.35	
Mobile invertebrates (crabs)	1	4	0	0					5	4	0.3125	
Shorebirds	1	4	0	0					5	4	0.3125	
River otter	1	4	0	0					5	4	0.3125	
Great blue heron	1	4	0	0					5	4	0.3125	
Marine birds	1	4	0	0					5	4	0.3125	
Harbor seals	1	4	0	0					5	4	0.3125	2.2
Terrestrial-Marine												
Organic material / invertebrate import / export	1	4	0		1	3	0	2	11	7	0.392857143	
Sediment Input					1	3	0	2	6	4	0.375	
River otter					1	3	0	2	6	4	0.375	
Riparian birds					1	3	0		4	3	0.333333333	
Great blue heron					1	3	0		4	3	0.333333333	1.8

Total Unit Score 4.03

City of Bellingham Marine Nearshore Habitat Connectivity Study

Evaulation Calculator

Evaluation Unit 6

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/ Riparian Zone	Barriers to surface water flow or tidal input	Raw Score	# of Questions	Normalized Score	
Marine												
Sediment Transport			0	2					2	2	0.25	
Juvenile salmon/forage fish	1	3	0	2				2	8	5	0.4	
Mobile invertebrates (crabs)	1	3	2	2					8	4	0.5	
Shorebirds	1	3	2	2					8	4	0.5	
River otter	1	3	2	2					8	4	0.5	
Great blue heron	1	3	2	2					8	4	0.5	
Marine birds	1	3	2	2					8	4	0.5	
Harbor seals	1	3	2	2					8	4	0.5	3.7
Terrestrial-Marine												
Organic material / invertebrate import / export	1	3			1	4	0	2	11	7	0.392857143	
Sediment Input					1	4	0	2	7	4	0.4375	
River otter					1	4	0	2	7	4	0.4375	
Riparian birds					1	4	0		5	3	0.416666667	
Great blue heron					1	4	0		5	3	0.416666667	2.1

Total Unit Score 5.75

City of Bellingham Marine Nearshore Habitat Connectivity Study

Evaulation Calculator

Evaluation Unit 7

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/ Riparian Zone	Barriers to surface water flow or tidal input	Raw Score	# of Questions	Normalized Score	
Marine												
Sediment Transport			4	2					6	2	0.75	
Juvenile salmon/forage fish	2	2	3	2				4	13	5	0.65	
Mobile invertebrates (crabs)	2	2	4	2					10	4	0.625	
Shorebirds	2	2	4	2					10	4	0.625	
River otter	2	2	4	2					10	4	0.625	
Great blue heron	2	2	4	2					10	4	0.625	
Marine birds	2	2	4	2					10	4	0.625	
Harbor seals	2	2	4	2					10	4	0.625	5.2
Terrestrial-Marine												
Organic material / invertebrate import / export	1	2	4		2	2	2	0	13	7	0.464285714	
Sediment Input					2	2	2	0	6	4	0.375	
River otter					2	2	3	0	7	4	0.4375	
Riparian birds					2	2	3		7	3	0.583333333	
Great blue heron					2	2	3		7	3	0.583333333	2.4

Total Unit Score 7.59

City of Bellingham Marine Nearshore Habitat Connectivity Study

Evaulation Calculator

Evaluation Unit **8**

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/ Riparian Zone	Barriers to surface water flow or tidal input	Raw Score	# of Questions	Normalized Score	
Marine												
Sediment Transport			4	4					8	2	1	
Juvenile salmon/forage fish	2	1	4	2				4	13	5	0.65	
Mobile invertebrates (crabs)	2	1	4	4					11	4	0.6875	
Shorebirds	2	1	4	4					11	4	0.6875	
River otter	2	1	4	4					11	4	0.6875	
Great blue heron	2	1	4	4					11	4	0.6875	
Marine birds	2	1	4	4					11	4	0.6875	
Harbor seals	2	1	4	4					11	4	0.6875	5.8
Terrestrial-Marine												
Organic material / invertebrate import / export	1	1	0		2	1	0	4	9	7	0.321428571	
Sediment Input					2	1	0	4	7	4	0.4375	
River otter					2	1	2	4	9	4	0.5625	
Riparian birds					2	1	2		5	3	0.416666667	
Great blue heron					2	1	2		5	3	0.416666667	2.2

Total Unit Score 7.93

City of Bellingham Marine Nearshore Habitat Connectivity Study

Evaulation Calculator

Evaluation Unit 9

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/ Riparian Zone	Barriers to surface water flow or tidal input	Raw Score	# of Questions	Normalized Score	
Marine												
Sediment Transport			4	4					8	2	1	
Juvenile salmon/forage fish	3	2	2	4				4	15	5	0.75	
Mobile invertebrates (crabs)	3	2	4	4					13	4	0.8125	
Shorebirds	3	2	4	4					13	4	0.8125	
River otter	3	2	4	4					13	4	0.8125	
Great blue heron	3	2	4	4					13	4	0.8125	
Marine birds	3	2	4	4					13	4	0.8125	
Harbor seals	3	2	4	4					13	4	0.8125	6.6
Terrestrial-Marine												
Organic material / invertebrate import / export	2	2	2		2	2	2	4	16	7	0.571428571	
Sediment Input					2	2	2	4	10	4	0.625	
River otter					2	2	3	4	11	4	0.6875	
Riparian birds					2	2	3		7	3	0.583333333	
Great blue heron					2	2	3		7	3	0.583333333	3.1

Total Unit Score 9.68

City of Bellingham Marine Nearshore Habitat Connectivity Study

Evaulation Calculator

Evaluation Unit **10**

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/ Riparian Zone	Barriers to surface water flow or tidal input	Raw Score	# of Questions	Normalized Score	
Marine												
Sediment Transport			3	2					5	2	0.625	
Juvenile salmon/forage fish	3	1	3	0				4	11	5	0.55	
Mobile invertebrates (crabs)	3	1	4	2					10	4	0.625	
Shorebirds	3	1	4	2					10	4	0.625	
River otter	3	1	4	2					10	4	0.625	
Great blue heron	3	1	4	2					10	4	0.625	
Marine birds	3	1	4	2					10	4	0.625	
Harbor seals	3	1	4	2					10	4	0.625	4.9
Terrestrial-Marine												
Organic material / invertebrate import / export	3	1	0		2	1	2	4	13	7	0.464285714	
Sediment Input					2	1	2	4	9	4	0.5625	
River otter					2	1	2	4	9	4	0.5625	
Riparian birds					2	1	2		5	3	0.416666667	
Great blue heron					2	1	2		5	3	0.416666667	2.4

Total Unit Score 7.35

City of Bellingham Marine Nearshore Habitat Connectivity Study

Evaulation Calculator

Evaluation Unit 11

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/ Riparian Zone	Barriers to surface water flow or tidal input	Raw Score	# of Questions	Normalized Score	
Marine												
Sediment Transport			0	2					2	2	0.25	
Juvenile salmon/forage fish	1	2	0	4				0	7	5	0.35	
Mobile invertebrates (crabs)	1	2	0	4					7	4	0.4375	
Shorebirds	1	2	0	4					7	4	0.4375	
River otter	1	2	0	4					7	4	0.4375	
Great blue heron	1	2	0	4					7	4	0.4375	
Marine birds	1	2	0	4					7	4	0.4375	
Harbor seals	1	2	0	4					7	4	0.4375	3.2
Terrestrial-Marine												
Organic material / invertebrate import / export	1	2	0		1	1	0	0	5	7	0.178571429	
Sediment Input					1	1	0	0	2	4	0.125	
River otter					1	1	0	0	2	4	0.125	
Riparian birds					1	1	0		2	3	0.166666667	
Great blue heron					1	1	0		2	3	0.166666667	0.8

Total Unit Score 3.99

City of Bellingham Marine Nearshore Habitat Connectivity Study

Evaulation Calculator

Evaluation Unit **12**

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/ Riparian Zone	Barriers to surface water flow or tidal input	Raw Score	# of Questions	Normalized Score	
Marine												
Sediment Transport			0	0					0	2	0	
Juvenile salmon/forage fish	4	1	4	2				2	13	5	0.65	
Mobile invertebrates (crabs)	4	1	4	2					11	4	0.6875	
Shorebirds	4	1	4	2					11	4	0.6875	
River otter	4	1	4	2					11	4	0.6875	
Great blue heron	4	1	4	2					11	4	0.6875	
Marine birds	4	1	4	2					11	4	0.6875	
Harbor seals	4	1	4	2					11	4	0.6875	4.8
Terrestrial-Marine												
Organic material / invertebrate import / export	4	1	0		2	1	4	2	14	7	0.5	
Sediment Input					2	1	4	2	9	4	0.5625	
River otter					2	1	4	2	9	4	0.5625	
Riparian birds					2	1	4		7	3	0.583333333	
Great blue heron					2	1	4		7	3	0.583333333	2.8

Total Unit Score 7.57

City of Bellingham Marine Nearshore Habitat Connectivity Study

Evaulation Calculator

Evaluation Unit **13**

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/ Riparian Zone	Barriers to surface water flow or tidal input	Raw Score	# of Questions	Normalized Score	
Marine												
Sediment Transport			0	2					2	2	0.25	
Juvenile salmon/forage fish	3	1	3	2				2	11	5	0.55	
Mobile invertebrates (crabs)	3	1	3	2					9	4	0.5625	
Shorebirds	3	1	4	2					10	4	0.625	
River otter	3	1	4	2					10	4	0.625	
Great blue heron	3	1	4	2					10	4	0.625	
Marine birds	3	1	4	2					10	4	0.625	
Harbor seals	3	1	3	2					9	4	0.5625	4.4
Terrestrial-Marine												
Organic material / invertebrate import / export	3	2	0		3	2	3	0	13	7	0.464285714	
Sediment Input					3	2	2	0	7	4	0.4375	
River otter					3	2	3	0	8	4	0.5	
Riparian birds					3	2	3		8	3	0.666666667	
Great blue heron					3	2	3		8	3	0.666666667	2.7

Total Unit Score 7.16

City of Bellingham Marine Nearshore Habitat Connectivity Study

Evaulation Calculator

Evaluation Unit 14

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/ Riparian Zone	Barriers to surface water flow or tidal input	Raw Score	# of Questions	Normalized Score	
Marine												
Sediment Transport			0	4					4	2	0.5	
Juvenile salmon/forage fish	3	1	4	4				4	16	5	0.8	
Mobile invertebrates (crabs)	3	1	4	4					12	4	0.75	
Shorebirds	3	1	4	4					12	4	0.75	
River otter	3	1	4	4					12	4	0.75	
Great blue heron	3	1	4	4					12	4	0.75	
Marine birds	3	1	4	4					12	4	0.75	
Harbor seals	3	1	4	4					12	4	0.75	5.8
Terrestrial-Marine												
Organic material / invertebrate import / export	2	2	0		2	1	2	4	13	7	0.464285714	
Sediment Input					2	1	2	4	9	4	0.5625	
River otter					2	1	2	4	9	4	0.5625	
Riparian birds					2	1	2		5	3	0.416666667	
Great blue heron					2	1	2		5	3	0.416666667	2.4

Total Unit Score 8.22

City of Bellingham Marine Nearshore Habitat Connectivity Study

Evaulation Calculator

Evaluation Unit 15

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/ Riparian Zone	Barriers to surface water flow or tidal input	Raw Score	# of Questions	Normalized Score	
Marine												
Sediment Transport			0	4					4	2	0.5	
Juvenile salmon/forage fish	3	2	2	4				0	11	5	0.55	
Mobile invertebrates (crabs)	3	2	3	4					12	4	0.75	
Shorebirds	3	2	4	4					13	4	0.8125	
River otter	3	2	4	4					13	4	0.8125	
Great blue heron	3	2	4	4					13	4	0.8125	
Marine birds	3	2	4	4					13	4	0.8125	
Harbor seals	3	2	3	4					12	4	0.75	5.8
Terrestrial-Marine												
Organic material / invertebrate import / export	3	2	2		3	2	4	0	16	7	0.571428571	
Sediment Input					3	2	4	4	13	4	0.8125	
River otter					3	2	4	4	13	4	0.8125	
Riparian birds					3	2	4		9	3	0.75	
Great blue heron					3	2	4		9	3	0.75	3.7

Total Unit Score 9.50

City of Bellingham Marine Nearshore Habitat Connectivity Study

Evaulation Calculator

Evaluation Unit **16**

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/ Riparian Zone	Barriers to surface water flow or tidal input	Raw Score	# of Questions	Normalized Score	
Marine												
Sediment Transport			4	3					7	2	0.875	
Juvenile salmon/forage fish	3	1	4	4				4	16	5	0.8	
Mobile invertebrates (crabs)	3	1	4	4					12	4	0.75	
Shorebirds	3	1	4	4					12	4	0.75	
River otter	3	1	4	4					12	4	0.75	
Great blue heron	3	1	4	4					12	4	0.75	
Marine birds	3	1	4	4					12	4	0.75	
Harbor seals	3	1	4	4					12	4	0.75	6.2
Terrestrial-Marine												
Organic material / invertebrate import / export	1	1	2		4	1	2	4	15	7	0.535714286	
Sediment Input					4	1	0	4	9	4	0.5625	
River otter					4	1	2	4	11	4	0.6875	
Riparian birds					4	1	2		7	3	0.583333333	
Great blue heron					4	1	2		7	3	0.583333333	3.0

Total Unit Score 9.13

City of Bellingham Marine Nearshore Habitat Connectivity Study

Evaulation Calculator

Evaluation Unit 17

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/ Riparian Zone	Barriers to surface water flow or tidal input	Raw Score	# of Questions	Normalized Score	
Marine												
Sediment Transport			0	4					4	2	0.5	
Juvenile salmon/forage fish	2	2	4	4				0	12	5	0.6	
Mobile invertebrates (crabs)	3	2	4	4					13	4	0.8125	
Shorebirds	3	2	4	4					13	4	0.8125	
River otter	3	2	4	4					13	4	0.8125	
Great blue heron	3	2	4	4					13	4	0.8125	
Marine birds	3	2	4	4					13	4	0.8125	
Harbor seals	3	2	4	4					13	4	0.8125	6.0
Terrestrial-Marine												
Organic material / invertebrate import / export	3	2	2		4	1	2	0	14	7	0.5	
Sediment Input					4	1	2	0	7	4	0.4375	
River otter					4	1	3	0	8	4	0.5	
Riparian birds					4	1	3		8	3	0.666666667	
Great blue heron					4	1	3		8	3	0.666666667	2.8

Total Unit Score 8.75

City of Bellingham Marine Nearshore Habitat Connectivity Study

Evaulation Calculator

Evaluation Unit **18**

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/ Riparian Zone	Barriers to surface water flow or tidal input	Raw Score	# of Questions	Normalized Score	
Marine												
Sediment Transport			4	4					8	2	1	
Juvenile salmon/forage fish	4	4	4	4				4	20	5	1	
Mobile invertebrates (crabs)	4	4	4	4					16	4	1	
Shorebirds	4	4	4	4					16	4	1	
River otter	4	4	4	4					16	4	1	
Great blue heron	4	4	4	4					16	4	1	
Marine birds	4	4	4	4					16	4	1	
Harbor seals	4	4	4	4					16	4	1	8
Terrestrial-Marine												
Organic material / invertebrate import / export	4	4	4		4	4	4	4	28	7	1	
Sediment Input					4	4	4	4	16	4	1	
River otter					4	4	4	4	16	4	1	
Riparian birds					4	4	4		12	3	1	
Great blue heron					4	4	4		12	3	1	5

Total Unit Score 13.00

City of Bellingham Marine Nearshore Habitat Connectivity Study

Evaulation Calculator

Evaluation Unit 19

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/ Riparian Zone	Barriers to surface water flow or tidal input	Raw Score	# of Questions	Normalized Score	
Marine												
Sediment Transport			0	4					4	2	0.5	
Juvenile salmon/forage fish	4	3	2	4				2	15	5	0.75	
Mobile invertebrates (crabs)	4	3	4	4					15	4	0.9375	
Shorebirds	4	3	4	4					15	4	0.9375	
River otter	4	3	4	4					15	4	0.9375	
Great blue heron	4	3	4	4					15	4	0.9375	
Marine birds	4	3	4	4					15	4	0.9375	
Harbor seals	4	3	4	4					15	4	0.9375	6.9
Terrestrial-Marine												
Organic material / invertebrate import / export	4	3	3		4	4	4	2	24	7	0.857142857	
Sediment Input					4	4	4	2	14	4	0.875	
River otter					4	4	4	2	14	4	0.875	
Riparian birds					4	4	4		12	3	1	
Great blue heron					4	4	4		12	3	1	4.6

Total Unit Score 11.48

City of Bellingham Marine Nearshore Habitat Connectivity Study

Evaulation Calculator

Evaluation Unit 20

	Unit Unaltered Marine Relative Size	Unit Marine Patch Size	Within Unit Permeability	Adjacent Unit Permeability	Unit Unaltered Marine Riparian Relative Size	Unit Marine Riparian Patch Size	Permeability of Beach-Marine/ Riparian Zone	Barriers to surface water flow or tidal input	Raw Score	# of Questions	Normalized Score	
Marine												
Sediment Transport			4	2					6	2	0.75	
Juvenile salmon/forage fish	3	1	4	4				4	16	5	0.8	
Mobile invertebrates (crabs)	3	1	4	4					12	4	0.75	
Shorebirds	3	1	4	4					12	4	0.75	
River otter	3	1	4	4					12	4	0.75	
Great blue heron	3	1	4	4					12	4	0.75	
Marine birds	3	1	4	4					12	4	0.75	
Harbor seals	3	1	4	4					12	4	0.75	6.1
Terrestrial-Marine												
Organic material / invertebrate import / export	3	1	0		4	1	2	4	15	7	0.535714286	
Sediment Input					4	1	0	4	9	4	0.5625	
River otter					4	1	2	4	11	4	0.6875	
Riparian birds					4	1	2		7	3	0.583333333	
Great blue heron					4	1	2		7	3	0.583333333	3.0

Total Unit Score 9.00