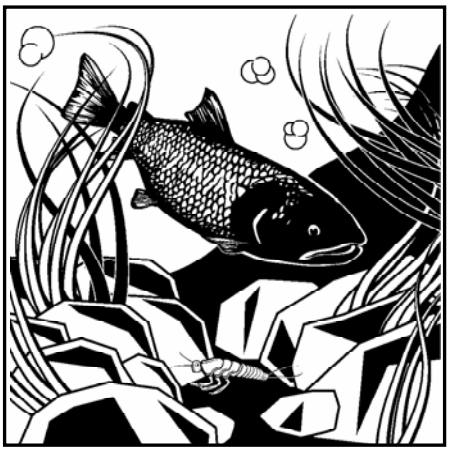
MANAGEMENT RECOMMENDATIONS FOR CITY OF BELLINGHAM POCKET ESTUARIES



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Management Recommendations for City of Bellingham Pocket Estuaries

Background

As part of the Shoreline Management Program update for the City of Bellingham, the City identified 'pocket estuaries' as a critical habitat. Once these features were identified it became necessary to formulate a management strategy for these habitats that would be incorporated into the revised Shoreline Management Program.

Report Objectives

In order for the City to address management decisions regarding pocket estuary habitats in the City of Bellingham and the Urban Growth Boundary, Northwest Ecological Services, LLC was engaged to complete the following tasks:

- Compile existing scientific documents that have been completed within the past year on pocket estuaries and adjacent shorelands.
- Identify essential functions of pocket estuaries.
- Identify essential functions within City pocket estuaries and provide management recommendations.
- Develop goals, policies, objectives and draft implementation actions for each pocket estuary to be managed.
- Draft a sub-designation section on pocket estuaries that can be blended into the existing draft shoreline designations.
- Identify areas and topics where additional regulations may be beneficial in managing pocket estuaries.

This report describes the methods used to perform the above referenced tasks. Information presented in this report includes: existing best available science on pocket estuaries; general pocket estuary functions; a brief summary of the general level of functions and estuary habitat features for each pocket estuary reviewed for this report; a description of each pocket estuary studied; general pocket estuary buffer functions; buffer width effectiveness; summary of key functions for each pocket estuary; and management recommendations for goals, objectives and buffer widths for each pocket estuary.

Methods

The literature review for this report resulted in locating very few studies specifically addressing pocket estuaries. The most current and local studies addressing pocket estuary function have been performed by Skagit System Cooperative Research Development whose work has focused on salmonid use of pocket estuaries (Beamer et al 2003). Other studies are limited to nearshore or general estuary review. Because the Best Available Science is limited for this specific habitat type the literature review for this analysis was extended into other similar habitats that have received more rigorous study, specifically marine nearshore and riparian habitats, and estuarine habitats. These habitats have large overlaps with each other and pocket estuaries, resulting in data that can be extended to pocket estuary analysis.

Existing Best Science on Pocket Estuary Habitat

Estuarine habitat is located in a transition zone between the land, freshwater and the sea. This zone is typically dynamic and influenced by a variety of physical, chemical and biological processes (Williams and Thom 2001). Within Bellingham City limits pocket estuaries are located at the mouths of drainages or within artificial impoundments created by the railroad. These habitats typically are, or have the potential to be, very productive. They often include habitat classes such as saltmarsh, mudflat or algae/eelgrass beds within them which are reported to be some of the most productive marine habitat types.

Pocket estuaries are small sub-estuaries within a larger estuary (Bellingham Bay) that form behind spits or barriers. Most pocket estuaries in this review are located behind human created barriers. Pocket estuaries are typically tidal lagoons with fringing unvegetated flats, saltmarsh and tidal channels. Pocket estuaries typically have: habitat types consistent with lower wave or long-shore current energy; and local freshwater inputs (surface or groundwater sources) where salinity is depressed during some part of the year (usually winter and spring) (Beamer et al 2003).

Six pocket estuaries were identified within the City of Bellingham and its Urban Growth Area (UGA) for this review: Chuckanut Creek estuary, Edgemore South pocket estuary, Edgemore North pocket estuary, Post Point Lagoon estuary, Padden Creek estuary, and Whatcom Creek estuary (Figures 1, 2 & 3). Squalicum Creek estuary was not included in this review because it lacks an impoundment separating it from the greater nearshore environment, although many of the discussions from this review could be extended to it. Whatcom Creek estuary has only a minimal separation, but appears to have sufficient elements matching the definition of a pocket estuary to be included in this review. The size of these estuaries ranges from 75 acres for Chuckanut Creek estuary to 0.7 acres for Edgemore South pocket estuary located at the base of the Edgemore bluffs. The average size of the reviewed pocket estuary was three acres. It could be argued that all of Bellingham Bay is a single estuary.

GENERAL POCKET ESTUARY FUNCTION

The literature indicates pocket estuaries provide similar functions to larger estuary systems and nearshore habitat, but become more valuable as overall estuary area is lost in a system. Changes to Bellingham Bay's waterfront over the past 150 years have resulted in a significant loss of estuary habitat. This loss has resulted in interruptions to migration pathways for salmonid, shorebird and other wildlife species occurring in Bellingham Bay on a seasonal and annual basis. Studies by the Waterfront Futures Group and Anchor Environmental have highlighted the disruption of aquatic habitat migratory pathways and its potential effects on salmonid populations. The remaining pocket estuaries functions appear to be significant in maintaining aquatic habitat for a variety of fish species, waterfowl, shorebird and terrestrial wildlife by providing links between fractured habitat corridors. The following section discusses specific potential functions of pocket estuaries.

- **Salmonid Habitat**

Research on the importance of estuary habitat to salmonids is well documented. However, specific research on pocket estuary functional is limited. The literature indicates that general estuary and nearshore habitat provides a range of important functions for all life phases of salmonids. Functions provided by estuaries and nearshore habitat include: migration of juvenile fish from freshwater to marine system; nursery habitat (particularly for chum and Chinook salmon juveniles); juvenile food production and feeding; adult food production; residence or refuge habitat for juveniles; and areas suitable for the physiological transition from freshwater to marine habitat (Williams and Thom 2001). Within Bellingham Bay pocket estuaries are important habitat links in a fractured aquatic habitat for out migrating juvenile salmon as refuge, forage areas, areas allowing for physiological adaptation to saltwater, food production for juvenile and adult fish. All salmonid species utilize estuary habitat at some point in their life cycle, but pocket estuary habitat appears to be particularly important to Chinook and chum salmon juveniles as they are the most estuarine dependent salmon species. These species feed and rear in these habitats for extended periods before moving to deeper water habitats (Williams and Thom 2001). Studies performed by the Skagit River Cooperative have demonstrated the significance of this habitat type to both Chinook and chum salmon populations (Beamer et al 2003).

Features that make pocket estuaries most functional for salmonids include the presence of eelgrass/algae beds, saltwater marsh, overhanging terrestrial vegetation, the presence of large woody debris, connectivity to other productive nearshore habitats, and a source of freshwater. These features provide the maximum potential for cover, food production, refuge, access and opportunity for physiological changes for juveniles adapting to the marine chemistry.

Estuaries reviewed that appear to provide these functions particularly well include: Chuckanut Creek and Edgemore North pocket estuaries. Post Point Lagoon, and Whatcom and Padden Creek estuaries have the potential to serve this function well, and currently provide it in a limited manner, but are limited by current land use practices. There is no fish access to the Edgemore South estuary.

- **Forage and Groundfish**

Estuary and nearshore habitat have been recorded to be important for refuge and rearing habitat for juvenile forage fish (e.g. surf smelt, herring, sand lance) and groundfish (e.g. flatfish, rockfish) (Williams and Thom 2001). These habitats provide for adult spawning, residence and migration of juvenile and adults, and juvenile rearing for Pacific herring, surf smelt, longfin smelt, and sand lance. Estuary habitat tends to be more significant for forage fish species than groundfish species, but there are some exceptions. Estuaries are most functional to juveniles in these taxa groups as the adults tend to be more pelagic. No specific information was located for Bellingham Bay with regards to these species and pocket estuaries, however surf smelt and sand lance both spawn within Bellingham Bay and several spawning areas occur near pocket estuaries. Based on supporting documentation illustrating the importance of estuary habitat to a wide variety of fish species Bellingham's pocket estuaries are most likely providing these functions as well. Features that make pocket estuaries most functional for forage fish and groundfish are similar those listed for salmonids.

All of the reviewed pocket estuaries have the potential to provide habitat for forage and groundfish, except the Edgemore South estuary which has no fish access. Habitat features and buffer conditions indicate that Chuckanut Creek and Edgemore North pocket estuaries have a high potential to serve this function. Post Point Lagoon, and Whatcom and Padden Creek estuaries have the potential to serve this function well, and currently provide it in a limited manner, but are limited by current land use practices and the disruption of aquatic migration pathways. Chuckanut Creek estuary also provides important shellfish habitat.

- **Wildlife**

Estuaries provide habitat for a variety of wildlife species. A study from King County lists 205 species are associated at sometime during their life with estuaries or the near shore habitat (King County 2001). No specific study was located that addressed wildlife usage of pocket estuaries, but it is expected to be similar as reported for general estuary and nearshore areas. Wildlife reported using pocket estuaries in the Bellingham Bay area include concentrations of wintering waterfowl (e.g. bufflehead, goldeneye, merganser, grebes, etc.), winter concentrations of dabbling duck and rocky shorebird species, important stopover foraging areas for migrating shorebirds, foraging for great blue herons, foraging habitat bald eagle and habitat for mustilid mammals (e.g. mink, river otter, weasel). The level of use of local pocket estuaries is dependent not only on in-water features within the estuary but also the condition and connectivity of the

surrounding upland buffer. Estuaries with the highest level of wildlife usage tend to be larger, have a variety of in-water features such as a variety of plant communities and large woody debris along the shoreline, and a connection to other upland habitats via a large forested upland buffer. In general, wildlife functions decrease as you move northward from Chuckanut Bay due to increasing levels of development that have left little to no vegetated buffers or connections to other habitat areas.

All of the reviewed pocket estuaries provide important wildlife habitat. Chuckanut Creek estuary has the greatest numbers of habitat features and supports the greatest diversity of wildlife species of all the reviewed sites. The two Edgemore pocket estuaries and Post Point Lagoon are all connected via shoreline habitat corridors to other significant habitats. Padden and Whatcom Creeks are located in more isolated positions from surrounding terrestrial habitat, but maintain some continuity via the associated steam corridors. Aquatic and shoreline habitat corridors for these two pocket estuaries are more fragmented.

Table 1. Summary of general level of function for pocket estuaries.

Pocket Estuary	General Level of Function							
	Salmonid	Forage/ground fish Habitat	Shellfish Habitat	Winter Water Fowl	Bald Eagle	Great Blue Heron	Mustilid Use	General Wildlife Use
Chuckanut Creek	H	M	H	H	H	H	H	H
Edgemore South	N/A	N/A	N/A	L	L	L	L	L
Edgemore North	M/H	M/H	M?	M	M	M	M	L/M
Post Point Lagoon	M	M	L	M	L	L	M	L/M
Padden Creek	M	L	L?	M	L	M	M	L/M
Whatcom Creek	M/H	L	L	L/M	L	L/M	M	L/M

H – High (Habitat is currently performing a given function well and appears to be sustainable over time.)
M – Medium (Habitat is currently performing a given function but the function is limited by a natural or human aspect. Sustainability of this function is at risk, but may be corrected through restoration actions.)
L – Low (Habitat is currently not performing a given function or the function is severely impaired. The sustainability of the function is at high risk of permanent failure.)
? – Level of function is difficult to assess. Listed function level is an approximation.
N/A – A given function is currently or historically not applicable to this habitat.

Table 2. Summary of estuary habitat features per pocket estuary.

Estuary	Buffer forested 100' or >	Mudflat	Cobble	Rock	Algae/eel-grass	Saltmarsh	Large woody material	Overhanging vegetation	Access for fish	Salmonid Stream present	Human Presence prominent	Forested corridor to other habitats
Chuckanut Creek	X	X	X	X	X	X	X	X Present on south side	X	X	O	X
Edgemore South	X	X	X	O	?	X Small fringe	O Limited	X	O	O	O	X
Edgemore North	O Partial	X	X	O	O	X Small fringe	X	X Present in areas	X	O	O	O Small area present
Post Point Lagoon	X just planted	X	O	O	X	O Small fringe	X Limited	O	X	O	X	X Broken forested corridor
Padden Creek	O	X	O	O	O, but near	X Present on west-south side, lacking on east side	X	O	X	X	X	X Present in areas but broken
Whatcom Creek	O	X	O	O	X	X	O Limited	X Present in areas	X	X	X	O Broken corridor

X – existing; O – non-existing; ? - unknown

X - Habitat is currently performing a given function and appears to be sustainable over time.
O - Habitat is currently not performing a given function or the function is impaired. The sustainability of the function is at high risk of permanent failure.
? - Level of function is difficult to assess.

POCKET ESTUARIES REVIEWED

The following section provides a review of the important features and functions of each of the pocket estuaries identified for this analysis. Tables 1 and 2 also provide a summary of functions and specific habitat features to be found in each of the estuaries.

Chuckanut Creek Pocket Estuary

The Chuckanut Creek estuary provides the highest level of functions of the pocket estuaries reviewed for this report (Table 1). The barrier separating this estuary from the marine nearshore is an artificial railbed berm located at the west end of the estuary. The berm has a restricted opening, but effectively reduces wave energy, separates the bay from longshore currents, and presumably reduces mixing with marine waters resulting in reduced salinity levels during the spring and winter. The primary freshwater source to this system is Chuckanut Creek. Secondary inputs include a small stream flowing through a saltmarsh and runoff from surrounding bluffs.

This estuary includes a variety of features that contribute to its high quality. It provides functions at a high level for all functions except forage fish and groundfish spawning, for which there is no data (Tables 1 and 2). Chuckanut Creek estuary includes extensive mudflats that are associated with softshell clam beds and that provide abundant winter waterfowl habitat, particularly for dabbling duck species (Table 2). Chuckanut Creek provides documented spawning habitat for chum, coho, sea-run cutthroat and steelhead. Saltmarsh habitat is present at the mouth of Chuckanut Creek and at the northwest terminus of Fairhaven Avenue, however regular fish access to this saltmarsh is unlikely due to a restricted culvert and reduced access during tidal cycles. The Chuckanut Creek estuary buffer is functioning at high level for all aspects and the buffer is well connected to other significant riparian and terrestrial habitats along Chuckanut Creek and Chuckanut Mountain.

The primary limitations and risks to the Chuckanut Creek estuary is water quality (fecal coliform) from failing septic systems in the Chuckanut Village area and upstream and from potential future development of private land that could reduce the quantity and quality of forested buffer and result in interruptions of wildlife travel corridors.

Edgemore South Pocket Estuary

A small pocket estuary is located immediately north of the railroad tunnel at Clark's Point. This feature may have been artificially formed by the railbed, which now completely encloses it. There is no visible opening to the marine system, but seepage through the berm ballast is likely. Incoming freshwater to this system originates from runoff from the surrounding uplands and possible groundwater inputs. The pocket is surrounded by steep sandstone bluffs, supporting a high quality Douglas fir forest intermixed with Pacific Madrone, which averages100 feet or

more in width. The uplands surrounding this pocket are currently being developed for single family residences.

The estuary appears to function more like a wetland due to the enclosed nature of the estuary. It is unclear if the system is affected by tidal cycles. Functions associated with fish habitat are non-existent due to a lack of access to the nearshore. There is little access to the public. The estuary maintains moderate functions for winter waterfowl, eagles and other wildlife species, but is somewhat limited by its small size. Additionally, future development around this estuary is likely to increase human related activities further reducing the wildlife function of this small system.

Edgemore North Pocket Estuary

A pocket estuary, enclosed by the railbed, is located immediately south of Post Point. Unlike the Edgemore South estuary, this system has an opening to the marine system, providing access to fish and tidal cycles. The freshwater input to this system is limited to the surface runoff from the surrounding uplands, mostly residential yards. The buffers are primarily deciduous trees and shrubs averaging about 75 feet wide. Some of the vegetation reaches over the banks, providing potential leaf litter and insects for fish. Some lawns extend to the edge of the estuary. No large trees are present, reducing its function for bald eagle foraging. The estuary includes cobble substrate and possible mudflat or algae beds (data was not present on these aspects). The estuary is small, but of sufficient size to provide habitat for fish and wildlife. Fish access is present and the estuary may provide important refuge, forage and rearing habitat for chum, Chinook and other forage fish and ground fish juveniles. It may serve as an important linkage and refuge area for all salmonid species when juveniles are moving from freshwater natal sites to more pelagic habitats. The estuary is regularly used by wintering waterfowl and is likely utilized by great blue heron, mustilid species and occasional bald eagles.

This pocket estuary is connected via a narrow vegetated strip to habitat to the north and south. Vegetation within the buffer is primarily lower deciduous shrubs and non-native shrub and herbaceous species. There is moderate connectivity along the nearshore, except for the railbed. This estuary has a number of features that provide it with moderate habitat diversity such as large woody material on the shore, more than one substrate type, connectivity with other habitats in both aquatic and nearshore habitats. The estuary receives light human use that is unlikely to disturb wildlife usage. There are possible water quality issues from diverted residential surface runoff that has been tight-lined to the toe of the bluff. Tight-lining negates the buffer's ability to provide water quality improvement.

Post Point Lagoon Pocket Estuary

Post Point Lagoon pocket estuary is located immediately west of the City of Bellingham sewer treatment plant. This estuary is also impounded by the railroad tracks and has a small opening

near the middle of the impoundment providing access to the marine nearshore. The main source of freshwater input to this estuary is a small seasonal stream that enters the lagoon near its southern end. Surface water runoff from the upland dog park is also directed into the estuary via culverts (this area is part of a City of Bellingham Park and is a designated off-leash area for dogs). Dog access to the buffer and estuary itself have resulted in significant damage to the vegetation and erosion of the shoreline. The buffer was dominated by grass until recently planted by the City of Bellingham with native trees and shrubs. Dog access has been restricted to a small area of the estuary and exposed soils have been mulched. The estuary is within 500 feet of a Great Blue Heron heronry located to the southeast.

Habitat features in the estuary include eelgrass (algae bed), a small saltmarsh habitat at the north end, and some limited mudflat. It has limited large woody debris (except what was recently brought in for enhancement) and no overhanging vegetation (expected when new plantings mature). The park is part of a disrupted, highly fragmented corridor that can be utilized by some wildlife species. The estuary receives high levels of human related disruption ranging from dog access, human presence, sewer treatment plant activities and trains. Despite the high level of disturbance, winter waterfowl regularly use the site and herons continue to nest nearby. The habitat may be significant to salmonids as well as other fish species. The estuary is located near a salmon spawning creek (Padden Creek) and eelgrass habitat, and may serve as an important migration linkage for juvenile salmonids during migration to more pelagic habitats.

Padden Creek Pocket Estuary

Padden Creek Estuary is located at the mouth of Padden Creek, south of the railroad tracks. This estuary has been impounded by the railed and has one outlet to the marine system near Padden Creek Boatyards. The primary freshwater input to this system is Padden Creek, a salmonid spawning stream. The estuary is located in a highly industrialized area. There is very little vegetated buffer around the estuary. The City of Bellingham enhanced the buffer on the west side of the estuary approximately 10 years ago. The enhanced area has a saltmarsh, upland system that averages about 50 feet. A narrow, grass dominated, buffer is present on south side along Harris Avenue. The remaining areas have impervious surface to the edge of the estuary. There is little to no overhanging vegetation over the shoreline and limited large woody material. This system does provide a relatively large mudflat habitat and is the largest area of this habitat type within the City limits north of the Chuckanut Creek estuary. Eelgrass beds are present outside the estuary.

Habitat associated with juvenile and adult salmonids is likely the most significant habitat in the Padden Creek estuary. The estuary generally drains completely at most low tides, resulting in minimal refuge and forage functions except during higher tides. The mudflats are utilized as foraging habitat for great blue herons, dabbling ducks, Canada geese and occasional shorebirds. Mustilid species may use it on occasion. Other wildlife utilization is limited by a lack of well

connected forested corridor to other systems. A corridor is present up Padden Creek, but it is fragmented and impacted by surrounding development.

Whatcom Creek Pocket Estuary

Whatcom Creek Estuary is located at the mouth of Whatcom Creek. This estuary is partially impounded by the Holly Street bridge crossing. The Whatcom Creek Estuary does not meet the definition of a pocket estuary in the strictest sense, but the restriction resulting from the Holly Street bridge appears to allow it to function in a similar manner and therefore it will be included in this discussion.

The primary freshwater source to this system is Whatcom Creek. The estuary is located in a highly developed portion of the downtown business district in Maritime Heritage Park. The Whatcom Waterway (a federally maintained waterway) dominates the nearshore environment west of the estuary. The Maritime Fish Hatchery is located on the northern bank of the estuary and Whatcom Falls forms the upstream end of the estuary. Whatcom Creek supports a number of salmonid fish species, most originating from the hatchery. The estuary recently underwent major restoration work during a remediation project to the historic landfill that covers the former tidelands. The restoration increased estuary area and included saltmarsh and riparian plantings that are doing well. The City of Bellingham Parks Department, in conjunction with the Nooksack Salmon Enhancement Association and other volunteers, planted a corridor, up to one hundred feet wide, of native trees, shrubs and associated plantings along the upland buffer. The area maintains moderate to heavy use by pedestrians and seasonal fishermen.

Habitat features include new saltmarsh plantings, riparian plantings, moderate large woody debris, and mudflats. Despite a forested corridor in the vicinity of the Maritime Heritage Park, this system is functionally isolated from any surrounding terrestrial or nearshore habitat due to constrictions and disconnections upstream. Despite its isolation, the area is utilized by a number of avian species and is likely important mustilid habitat. Aquatic linkages to other habitats are also limited, an issue that has been discussed in conjunction with the success of salmonid populations. There have been a number of proposals to provide aquatic connections to other habitat types.

POCKET ESTUARY BUFFER FUNCTIONS

Literature specifically addressing buffer protection for pocket estuaries was not located and research on buffers for estuarine and marine systems is limited. Much of the material for this review comes from a summary of the best available information on marine and estuarine riparian function (Brenner and Culverwell 2001). Brenner and Culverwell (2001) theorize that marine riparian zones function in a similar manner as freshwater riparian zones. The following

summary is the result of information from estuary and nearshore reviews addressing riparian function for estuary and nearshore habitats.

To provide maximum opportunities to protect critical areas it is important to include other regulatory tools besides buffers. Buffers are just one of a palette of tools available to help protect shorelines and aquatic habitat including: comprehensive plan designations; zoning and associated land use density requirements; performance standards for different activities (e.g. stormwater, erosion control, noise, glare); best management practices; and monitoring and enforcement of project conditions. Buffers are not always the most effective manner to protect function in a system. Landscape requirements may be more effective in restoring an area or stormwater features maybe more effective in developed and developing areas. Two stormwater outfalls are planned to be rerouted in this area.

Buffer Effectiveness

Buffers surrounding the reviewed pocket estuaries range from relatively undisturbed to highly impacted buffers that are nearly non-existent. It is important to keep in mind that buffers are only one mechanism used to protect sensitive areas.

The following sections provide a brief discussion of the functions buffers can provide in protecting estuarine and nearshore processes and habitat.

- **Water Quality/Sediment Removal**

Filtering and removing sediments that may enter a stream, lake, or marine water system is one of the most commonly identified functions of a vegetated buffer. The main functions are removing pollutants and providing soil stability. In marine systems with limited circulation, sediment can increase turbidity and adversely affect marine habitat and aquatic life. The removal of fine sediments is of particular importance because of the negative effect of suspended sediments on aquatic organisms and the degradation fine sediments have on substrate habitat (gravels). A buffer that is characterized by dense and woody vegetation reduces the velocity of runoff flow, stabilizes soils, takes up nutrients and other contaminants, and reduces siltation – all of which protect water from contamination (Desbonnet et al 1994; Brennan and Culverwell 2004). The effectiveness of a vegetated buffer depends upon its width, slope, soil type and vegetation species (Brennan and Culverwell 2004).

- **Nutrient Removal**

Vegetated buffers can be effective at removing and filtering nutrients, thus controlling inputs to surface water (Desbonnet et al 1994; Pentec 2001). Nitrogen is a limiting nutrient within marine systems that results in excessive outbreaks of algae and diatoms that can have adverse affects to the marine environments. Nutrient inputs may be of particular concern in systems such as pocket estuaries because they have limited circulation and tend to accumulate nutrients.

Nutrient inputs, particularly nitrogen, are often associated with runoff from residential yards where fertilizers are commonly used. Pocket estuaries located near residential uses such as Chuckanut Creek Estuary, and the north and south Edgemore pocket estuaries appear to be at the greatest risk from nutrient enrichment. Padden and Whatcom Creek estuaries could also be at risk from nitrogen sources carried from upstream sources. Buffers designed to reduce nutrient levels in surface runoff can be utilized to help protect systems, but the buffers need to be applied within the entire watershed and not just adjacent to the pocket estuaries. Other aspects of infrastructure may be equally beneficial, such as requiring stormwater treatment in new developments and retrofitting old developments lacking such systems.

- **Bacterial Removal**

Vegetated buffers can be effective in controlling fecal coliform levels (Pentec 2001). The reduction of fecal coliform is dependent upon precipitation, temperature, infiltration, soil characteristics, bacterial die-off, run-off and the characteristic or condition of the buffer (*Id.)*. Fecal coliform often adheres to and is transported on sediment particles. Buffers and Best Management Practices that are effective for sediment control can be effective for controlling fecal coliform transport. Bacterial contamination sources can originate from range of sources: failing septic systems, agricultural activities with livestock, pets, and wildlife. Failing septic systems have been an issue in the Chuckanut Creek estuary. The off-leash dog park at the Post Point Lagoon could be another potential source. Engineered water quality treatment systems may be useful in addressing issues at the Post Point Lagoon. Again more comprehensive engineered stormwater treatment on a drainage wide basis could be effective in reducing bacterial contamination in these and other marine and freshwater systems.

The literature shows that buffer effectiveness to improve and protect water quality is dependent on number of factors, chief among them are slope and the physical character of the vegetation (Desbonnet et al 994). Gentle slopes are more effective at slowing runoff velocities allowing sediments to be trapped and nutrients and other pollutants to be taken up by vegetation. Grass and herbaceous dominated buffers are superior at improving water quality for a number of parameters, but woody material provides separate and equally important features. A buffer with a low slope, that includes both herbaceous and woody plants, is most effective for a range of buffer functions.
Existing buffers around the Padden Creek and Whatcom Creek estuaries are located in areas of heavy development. Surface water in these areas may not have the opportunity to flow through vegetated buffers even if provided. Existing stormwater may be redirected into the City stormwater system or into individual stormwater systems as redevelopment occurs. Proposed buffer requirements should include these factors when determining the final width.

Table 3. Summary of sediment and pollutant removal effectiveness and wildlife habitat value based on buffer width (Desbonnet et al 1993, 1994)

Buffer Width	Pollutant Removal Effectiveness	Wildlife Habitat Value
16ft (5m)	Approximately 50% or greater sediment and pollutant removal	Poor habitat value, useful for temporary activity of wildlife.
32ft (10m)	Approximately 60% or greater sediment and pollutant removal	Minimally protects stream habitat, poor wetland habitat, useful for temporary activity of wildlife.
49ft (15m)	Greater then 60% sediment and pollutant removal	Minimum general wildlife and avian habitat value.
66ft (20m)	Greater then 70% sediment and pollutant removal	May have use as a wildlife travel corridor for some species as well as minimal to fair wildlife habitat.
98ft (30m)	Approximately 70% or greater sediment and pollutant removal	May have use as a wildlife travel corridor for some species as well as minimal to fair wildlife habitat.
164ft (50m)	Approximately 75% or greater sediment and pollutant removal	Minimum to fair general wildlife habitat value.
264ft (75m)	Approximately 80% or greater sediment and pollutant removal	Fair to good general wildlife and avian habitat value.
328ft (100m)	Approximately 80% or greater sediment and pollutant removal	Good general wildlife and avian habitat value; may protect significant wildlife habitat value.
656ft (200m)	Approximately 90% or greater sediment and pollutant removal	Excellent general wildlife and avian habitat value; likely to support diverse community.
1,968ft (600m)	Approximately 99% or greater sediment and pollutant removal	Excellent general wildlife and avian habitat value; likely to support diverse community; protection of significant species.

The literature indicates a vegetated buffer of 50 feet provides up to 60% removal of sediments; whereas a 98 foot buffer removes approximately 70% of the sediment. Increasing the buffer to 300 feet would provide an increase removal by a mere 10% (Desbonnet et al 1993, 1994). Table 3 provides a summary of buffer widths and their associated effectiveness in controlling sediment and pollution in surface water.

- **Shoreline Stabilization**

In the marine system, vegetation is only minimally effective at stabilizing slopes against tides and storm surges (Pentec 2001). However, vegetation can be effective at controlling toe of slope erosion. Vegetation provides effective erosion control and increases slope stability by reinforcing soils with root systems and by reducing soil moisture through evapotranspiration, reducing velocity of surface runoff, reducing erosion by spreading runoff water over a wide area, and promoting absorption and infiltration through the leaf layer and underlying soils (Brennan and Culverwell 2004). Soils, slope height and angle, drainage, and other factors are also important in determining risk of erosion. Native vegetation is particularly important in areas where bluffs are steep and eroding (Pentec 2001). Excessive erosion can increase sedimentation in the nearshore aquatic zone, resulting in decreased water quality. However, sediment input from eroding shores is also an important source of material for beach nourishment, formation and maintenance, particularly since most of the shoreline in the City of Bellingham has been separated from the nearshore by the railroad. This function would not be a limiting factor in pocket estuary protection.

- **Shade/Temperature Moderation**

Solar radiation exposure, which causes higher temperatures and desiccation, is a limiting factor for upper intertidal organisms (Brennan and Culverwell 2004). The degree of solar exposure has an affect in determining distribution, abundance, and species composition. How shade affects the nearshore in Puget Sound is not well understood. However, until more data can be gathered, it is important recognize that shade provided by shoreline vegetation can be a limiting factor and its importance should not be totally discounted. In particular, studies have shown that surf smelt (*Hypomesus pretiosus)* egg mortality is significantly higher on unshaded beaches.

- **Microclimate**

Temperature and moisture regulation, tidal inundation, wind exposure, and salt spray all contribute to microclimates in the nearshore marine, aquatic and terrestrial, and plant and animal communities (Brennan and Culverwell 2004; Pentec 2001). In turn, the marine environment is affected by upstream riparian conditions. The biggest effect at the marine/upland interface is temperature moderation; along the marine shoreline, uplands are cooler in the summer and warmer in the winter. Terrestrial temperature and moisture is also regulated by the density of vegetation. All these factors contribute to microclimates that support

a variety of fish, invertebrate, and wildlife species. Removing vegetation increases solar exposure and decreases organic matter, resulting in increased run-off rates, increased water temperature entering marine systems, desiccation of soils, and increased stress for animals dependent upon cool, moist conditions.

Studies are varied, but a study conducted by Brosofske et al (1997) indicated that buffer distances of 102 to 155 feet are required to maintain natural microclimate conditions in forested systems. These buffer widths may be difficult to achieve in urban settings such as Padden and Whatcom Creeks.

- **Large Woody Debris Contribution**

Large woody debris (LWD) provides many functions in aquatic ecosystem, including, habitat structure and bank stabilization (Brennan and Culverwell 2004). Coarse wood debris is an important segment of estuarine and ocean habitats. Many of the functions documented for LWD in the freshwater systems are analogous to similar functions in the marine system. Structurally, LWD provides roosting, nesting, refuge, and foraging opportunities for wildlife; foraging, refuge, and spawning substrate for fish; and foraging, refuge, spawning, and attachment substrate for aquatic invertebrates and algae in the marine/estuarine environment. It is also important in the development and maintenance of some saltmarsh communities. A lack of this material has a direct affect on the level of function provided to the system.

The literature recommendations vary for buffer width requirements to maintain a natural contribution of large woody debris to systems. No specific reference was directed to estuary large woody debris requirements. Most of the reviews are for streams. The literatures indicates forested buffers ranging between 50 and 100 feet may provide sufficient recruitment to meet system large woody debris requirements (Pentec 2001).

- **Wildlife Habitat**

Riparian and wetland habitats are some of the most diverse for animals if a system is undisturbed. The 'edge effect' between different plant assemblages, water regimes and physical structures provides more diverse and quantifiable habitat niches – thus providing a broader spectrum of habitats that support a wider variety of aquatic organisms, mammals and bird species (Pentec 2001). Vegetated buffers provide refuge from predation and weather, and habitat for nesting and feeding. Many species rely upon buffers for their entire life cycle, while others are dependent upon terrestrial areas for specific life stages such as seasonal migrations (Brennan and Culverwell 2004). Generally, vegetated buffer widths that support full wildlife habitat are greater than for other functions. Larger buffer widths are typically needed for species that are more sensitive to disturbance (Desbonnet et al 1994). In addition, connectivity of the buffer to adequate corridors and large forested areas determines the extent of functional wildlife habitat, particularly when evaluated for specific species. The effectiveness of vegetated

buffer for wildlife habitat is dependent upon buffer width, vegetation type (native vs. non-native) and vegetation diversity (more diverse vegetation promotes biodiversity) (*Id.)*.

Forested 100 foot buffers provide adequate buffer functions to maintain common songbird, small mammal and amphibian populations. Larger buffers specific for identified species are required to protect more sensitive species needs. See Table 3 for recommendations for wildlife habitat buffer widths.

- **Screening Noise, Light, Disturbance**

Buffers can protect wildlife by reducing or limiting the amount of noise, light and physical disturbance from human activities (Pentec 2001). All wildlife respond to human disturbances, however, the degree to which wildlife are affected by disturbance is dependent upon many factors including, intensity of the disturbance, duration, species, and the life-cycle stage of the species (*Id.)*. Losses in reproduction and overall population sizes can result from disturbance during nesting, breeding, feeding and resting. Screening functions are very limited at Post Point Lagoon, Padden Creek and Whatcom Creeks. Screening within portions of the Maritime Heritage Park provide this function at a higher level, although the north side of the park is still limited for these functions. A 50 foot buffer can be effective for this function.

- **Nesting, Feeding, Breeding**

Greater structural and vegetation diversity provides more habitat niches for nesting, feeding and breeding. Vertical complexity and diverse vegetation provides many strata for foraging wildlife. Surface water associated with vegetated buffers provides hydration and feeding opportunities for waterfowl, birds of prey, fish, mammals, and amphibians and reptiles (Pentec 2001). Post Point Lagoon, Padden Creek and Whatcom Creek currently do not have sufficient buffer widths to support these functions.

- **Travel Corridors**

Many species use riparian areas, wetlands, and undeveloped open spaces for travel, dispersion and migration (Pentec 20010). These habitat corridors become increasingly important as urbanization occurs. Padden Creek and Whatcom Creek have poor connections to travel corridors.

- **Leaf Litter/Insect Fall**

Leaf litter and insect fall is both an indirect and direct energy source for streams and rivers. Leaf litter adds organic matter to the system. Insect fall provides a food source for juvenile salmonids. The greatest recruitment of insects to the water surface is immediately adjacent to the waters edge or from over-hanging vegetation. Many insects consumed by fish in estuaries are produced in marsh vegetation that is below ordinary high water; and it is likely that shoreline shrub and forested areas are also important for insect production (Pentec 2001). Moist

microclimates that are created by riparian vegetation can be favorable to the production of prey resource insects for juvenile salmon (Brennan and Culverwell 2004).

Buffers of 50 to 75 feet provide appear to meet full litter and insect fall function (Pentec 2001). Post Point Lagoon, Padden Creek and Whatcom Creek currently fall below this threshold, but native plantings at Post Point Lagoon and areas of the Whatcom Creek estuary are expected to improve these functions over time.

BUFFER WIDTH RECOMMENDATIONS

Chuckanut Creek Pocket Estuary

***Summary of Key Functions*:**
This system provides high quality estuarine habitat with multiple habitat features that support significant wildlife and shellfish populations. Existing buffers are providing high water quality, shoreline protection, and all wildlife habitat functions. Water quality issues from Fecal coliform have been documented for this system.

Goals

- Preserve and protect existing shoreline natural resources including the estuary, beaches, shorelines, fragile ecological areas, fish and wildlife habitats, native vegetation, associated critical areas and buffers. Due to the quality of the habitat in this estuary, the Chuckanut railroad pocket estuary should have the highest priority for preservation.
- Preserve and protect the connectivity between the Chuckanut estuary and Chuckanut Creek by protecting habitat corridors.
- Improve water quality with emphasis on control of bacterial contamination.

Objectives

- Protect critical areas and shoreline ecological processes and functions through regulatory and non-regulatory means, which may include, acquisition of key properties, regulation of development, and incentives.
- Manage and treat stormwater and wastewater properly. This may include extending the City sewer to serve areas currently without service.
- Maintain wildlife function within buffers and estuary.

Buffer Recommendation

- Wildlife Function: Maximum width [200 feet where available, not less than 150 feet] – should be applied to sites where forested or naturally vegetated buffer is present.
- Water Quality Function: 50 feet on gently sloping sites and 100 on sites with moderate to steep slopes (should be applied to sites where the buffer has already been decreased to less than 100 feet). There should be no pesticides, herbicides or fertilizer application allowed in the buffer. Un-groomed native vegetation should be encouraged.

Edgemore South Pocket Estuary

***Summary of Key Functions*:**
This pocket estuary is more functionally a wetland than an estuary. The feature provides moderate to high quality wildlife habitat for avian and terrestrial wildlife species, but lacks fish access. Buffer functions are currently moderate to high for most functions, but the properties adjacent to this feature are currently under development for single family homes. Current development site preparation includes vegetation removal and significant areas of bare ground. No erosion control features other than a thin layer of mulch are present. Erosion of sediment into the estuary could occur under current conditions and during construction of houses.

Goals

- Preserve and protect estuary and buffer functions. The buffer of this wet pocket is very steep and vegetated with native trees and shrubs. The maximum buffer distance should be maintained.
- Preserve and protect the connectivity with the Chuckanut estuary and Clark's Point.
- Preserve existing water quality of the estuary.

Objectives

- Protect critical areas and shoreline ecological processes and functions through regulatory and non-regulatory means, including buffer setbacks, regulation of development, and incentives.
- Improve water quality by eliminating tight-line drainages from residential development.
- Regulate the use of pesticides, herbicide and fertilizers in residential yards.

Buffer Recommendation (due to steep bluff this should be measured from top of bank)

- Wildlife associated emphasis: 100 feet
- Water Quality: 50 feet (in areas where the native vegetation community is disturbed)

Edgemore NorthPocket Estuary

***Summary of Key Functions*:**
This pocket estuary provides moderate wildlife habitat for avian and terrestrial wildlife species and excellent fish resources. Buffers are currently functioning at moderate levels for most functions, but have been degraded by removal of shrubs and trees. Conifer trees are essentially absent from the buffer. The estuary appears to be well linked to other important fish habitat and is likely an important habitat for salmonid, forage fish and ground fish species.

Goals

- Preserve and protect existing shoreline natural resources including the estuary, beaches, shorelines, fragile ecological areas, fish and wildlife habitats, native vegetation, associated critical areas and buffers.
- Restore degraded buffer habitat.
- Improve and protect existing water quality in the estuary.

Objectives

- Protect critical areas and shoreline ecological processes and functions through regulatory and non-regulatory means, including buffer setbacks, regulation of development, and incentives.
- Regulate the use of pesticides, herbicide and fertilizers in residential yards.
- Protect and restore native buffer vegetation by removing of non-native vegetation and replacing with native trees and shrubs.
- Improve water quality by eliminating tight-line drainages from residential development.
- Limit disturbances to aquatic habitat – restrict the use of boats and docks in the estuary.

Buffer Recommendations

- Wildlife associated emphasis: If existing buffer is dominated by native vegetation, buffer should be 150 feet.
- Water Quality: 50 feet from top of bank.

Post Point Lagoon Pocket Estuary

***Summary of Key Functions*:**
This estuary currently has the potential to provide important fish and wildlife habitat functions, but has been limited by past uses. It is located near an active heronry and is used lightly by wintering waterfowl. The habitat is somewhat isolated from other terrestrial habitat, but there is a narrow habitat corridor for terrestrial species along the shoreline. The estuary appears to be well linked to other important aquatic habitats and is likely important to salmonid, forage fish and ground fish species.

The existing buffer is in poor condition, but is part of a recent City enhancement project that includes extensive planting of native plants and fencing. The Post Point Lagoon has experienced significant impacts associated with an off-leash dog park where dogs access the lagoon. Free access to the lagoon has resulted in a lack of ground cover and sediment being carried into the lagoon along with potential bacterial contamination from dog feces. The City has recently revegetated much of the buffer around the lagoon and restricted dog access to a limited portion of the lagoon shoreline. However, dog activity could still result in wildlife disturbance within the lagoon and associated buffer reducing its overall potential wildlife function. Impacts to aquatic life within the lagoon from dog access to the lagoon is unclear. Runoff from the adjacent off-leash areas continues to enter to lagoon and is a potential source of sediment and bacterial contamination.

Goals

- Preserve and protect existing shoreline natural resources including the estuary, beaches, shorelines, fragile ecological areas, fish and wildlife habitats, native vegetation, associated critical areas and buffers.
- Enhance and restore protect estuary and buffer functions.
- Improve water quality.

Objectives

- Maintain and improve estuary and buffer functions.
- Improve habitat and water quality by restricting use of estuary and adjacent buffer by domesticated animals.
- Maintain freshwater input to estuary.
- Improve water quality in fresh water tributary by implementing buffer and vegetation enhancement and preservation up-stream; improve stormwater treatment.
- Restore and enlarge salt marsh habitat.

Buffer Recommendations

- Wildlife associated emphasis: 200 feet
- Water Quality: 50 feet (including the following features: estuary ordinary high water mark, freshwater tributary, culvert(s) which drain the off-lease dog park)

Padden Creek Pocket Estuary

***Summary of Key Functions*:**
Padden Creek estuary currently has the potential to provide important fish and wildlife habitat functions, but is limited by surrounding development. The habitat is somewhat isolated from other terrestrial habitat, but has linkages to the Padden Creek riparian corridor. There is little to no connection by terrestrial habitat along the shoreline to other shoreline habitats. The estuary appears to be moderately well linked to other important aquatic habitats and is connected to a salmonid spawning stream. Fish residence within the estuary is likely limited, since the estuary drains regularly with the tides. Mudflat habitat is well represented and utilized by birds year round.

Padden and Whatcom Creeks offer the most estuary area for improvement and or restoration, with Padden having more area. Due to existing conditions, Padden currently offers better habitat opportunities. Padden should receive priority for habitat restoration and overall preservation.

Goals

- Restore and maintain the Padden Creek delta as a viable urban marsh/estuary that supports diverse wildlife habitat.
- Enhance and restore estuary and buffer functions.
- **Improve water quality by determining runoff sources and treat prior to entering lagoon.**

Objectives

- Improve water quality in Padden Creek by implementing buffer and vegetation enhancement and preservation up-stream; improve stormwater treatment throughout watershed.
- Maintain and improve estuary and buffer wildlife functions with a particularly emphasis on habitat connectivity, and screening functions.
- Encourage lower impact urban land uses and technologies adjacent to estuary and buffer.

- Provide development incentives for buffer area increases and habitat improvements.
- Protect and improve riparian vegetation up-stream**.**

Buffer Recommendations

- Wildlife and water quality – 50 feet minimum.

Whatcom Creek Pocket Estuary

***Summary of Key Functions*:**
Whatcom Creek Estuary has been studied more extensively than any other estuary system in the City. This estuary has undergone extensive enhancement within the buffer and aquatic habitats over the past 15 years. The estuary continues to function well for both fish and wildlife despite the estuary's location within a highly developed area. Fish habitat has been the issue of much study for this system and could benefit greatly by construction of aquatic habitat islands in the adjacent marine system to provide more continuity and connectivity for juvenile fish.

Goals

- Preserve and protect estuary and buffer functions.
- Improve habitat connectivity between estuary and other habitats in Bellingham Bay.

Objectives

- Maintain and improve estuary and buffer function through plantings and installation of habitat features (completed).
- Provide habitat refuge and connectivity within Bellingham Bay via habitat islands.
- Provide terrestrial habitat corridors along shorelines to other significant habitats.
- Continue to work on remediation of old landfill sites. Remediation work associated with the Holly Street landfill has been completed. Work associated with Roeder Street Landfill still remains to be performed.

Buffer Recommendations

- Wildlife and water quality – 50 feet minimum.

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Figure 1. Vicinity Map
Southside Pocket Estuaries

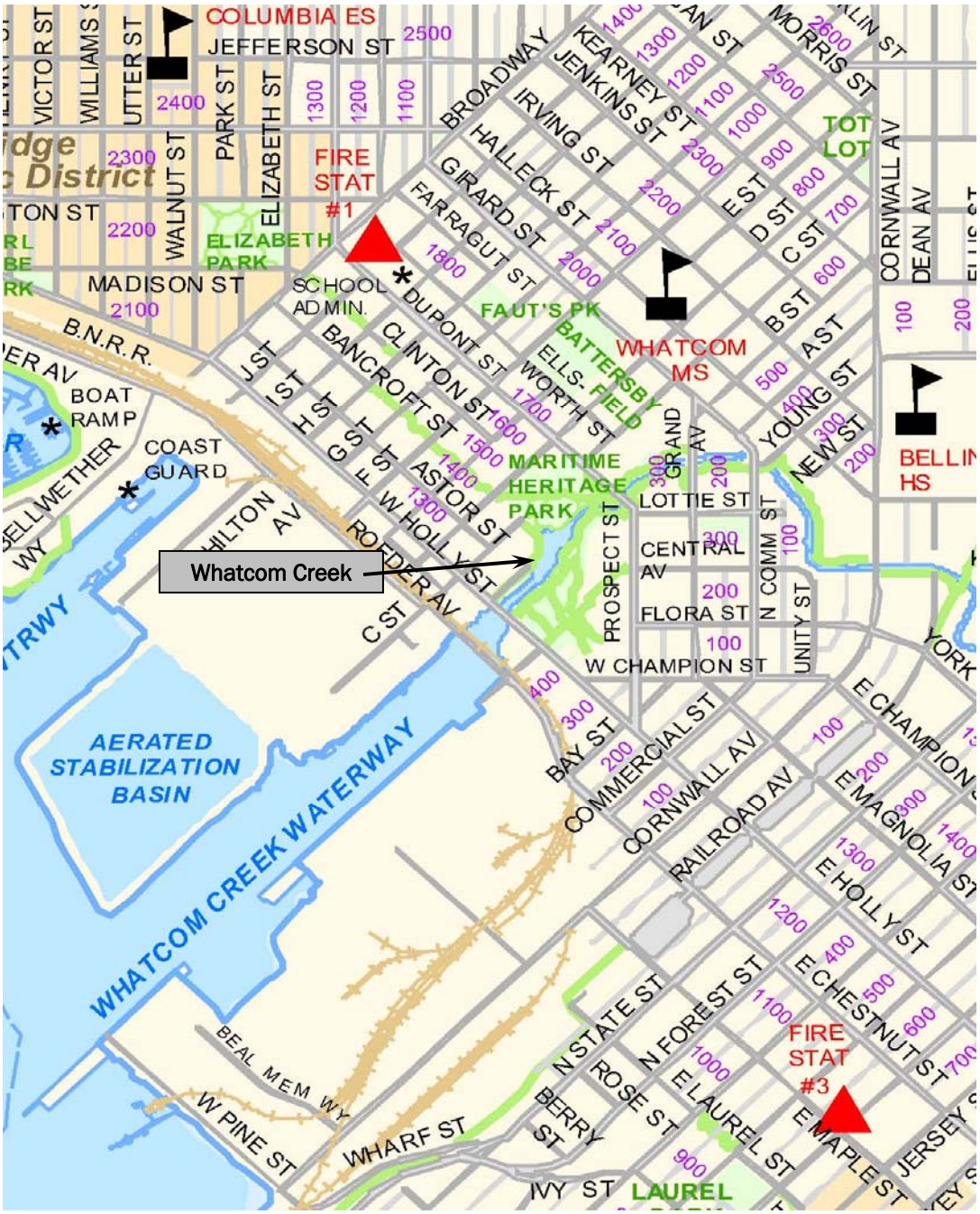

Figure 2. Vicinity Map
Central City Pocket Estuaries

Figure 3A. Chuckanut Creek Pocket Estuary

Figure 3B. Edgemore South Pocket Estuary

Figure 3C. Edgemore North Pocket Estuary

Figure 3D. Post Point Lagoon Pocket Estuary

Figure 3E. Padden Creek Pocket Estuary

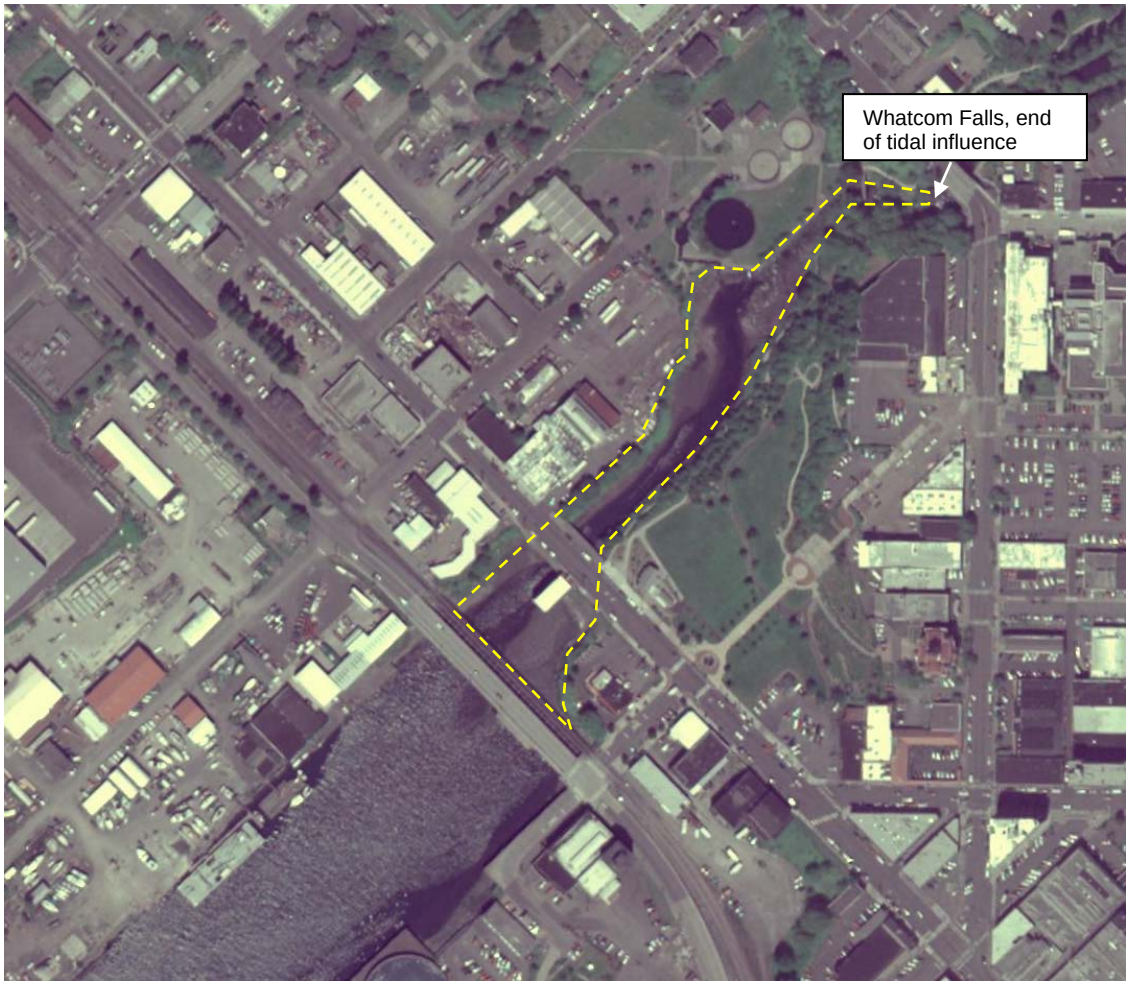

Figure 3F. Whatcom Creek Pocket Estuary