Lower Dosewallips River Reach Analysis

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Introduction

The SRFB application for the Dosewallips Estuary Restoration Project established three fundamental problems in the ecological function of the lower Dosewallips River:

1. Loss/isolation of distributary channel habitat
2. Loss/modification of tidal estuarine circulation
3. Riparian forest degradation
4. Loss/impairment of natural channel processes in the mainstem river (This problem has been identified post-application).

This reach analysis seeks to investigate current conditions and outline actions to remedy these problems. An exception may be problem 3 which, in some part, is a biological not physical problem.

Reach analysis or assessment is, in general, "An … 'objective procedure to characterize the present [or historic] state of a natural resource in a watershed and to diagnose resource impairment that can be remedied'[1]. In the context of stream habitat restoration, assessment is typically used to document current and historic conditions, identify and determine the extent of problems and habitat deficiencies, identify the causes of those problems and deficiencies, identify restoration opportunities and constraints, and to determine the dominant processes that create and maintain habitat within the stream corridor[2]."

Physical habitat assessment can be approached in a variety of ways. A purely quantitative analysis is a large undertaking associated with significant infrastructure and high risk to human and habitat values. Accurate physical measurements and numerical modeling are commonly the basis for such an analysis.

A qualitative approach uses expert opinion and readily obtained physical measurements associated with rural, low risk projects. A qualitative approach is employed in this study. The study area is the reach of the Dosewallips River mainstem downstream of the US 101 bridge as well as the adjacent flood plain and estuary.

Physical characteristics

Historical perspective

The Dosewallips estuary is delta-type estuary, as opposed to a drowned river valley-type estuary also common in Puget Sound. Deltas form when the amount of sediment produced by the watershed, and transported by the river, exceeds the volume of the valley and sea level rise[3]. The formation of the Dosewallips delta probably has its roots in the distant, more geologically active past when glacial processes led to significant releases of sediment to fill the glacially carved valley bottom.

Even though the delta is a depositional structure, the regional trend is one of subsidence. A recent study of the Duckabush and Hamma Hamma River estuaries (3 and 12 miles south of the Dosewallips, respectively) indicates that a combination of tectonic subsidence and sea level rise has lead to a lowering of the estuary 2.7 to 4 mm/yr in the last 100 years[4]. This is roughly twice the eustatic sea level rise in the last 1500 years.

Current morphology is dominated by episodic river floods, coarse sediment and a macrotidal range, much lower energy processes than those that formed the delta. The general shape of the delta, channel and distributaries has not changed substantially since the 1883 (U.S. Coast & Geodetic Survey T-sheet), **Figure 1**. The remnant channel running along the north edge of the delta clearly shows that the Dosewallips River once ran there, but it is not clear when this occurred, certainly longer than 120 years. Hydraulically, the remnant channel to the north is very attractive to the Dosewallips: it is a roughly 30% shorter route to the base elevation at Hood Canal and, as a result, much steeper with greater sediment transport capacity. The resistance of the delta to modern change may have one of several roots. We did not seek an answer in this study because, with the left bank dike, the development of Brinnon, and the US 101 road fill, it is unlikely that this northern route will be occupied soon.

Development of the estuary had already begun when the U.S. Coast & Geodetic Survey Topographic Sheet was drawn in 1883. This is true particularly in the area south of the main channel where there was an orchard in that year and which, in all the subsequent aerial photographs, is consistently cleared. The former orchard is now the site of State Park's day use area and a number of camp sites. This same area shows the greatest topographic simplification in our study area.

The currently wooded section, defined by the distributary we call N3 and the mainstem left bank, was probably the location of the mainstem sometime before 1883. A large sediment pulse could have been deposited here, forcing the river to the right. This section is rich with distributaries and flood swales. Analysis of aerial photographs shows that in 1957 it was the only portion of the estuary east of US 101 that supported a dense concentration of taller vegetation, and by 1965 is almost entirely treed.

Generally the area on the right bank, the side with the developed campgrounds, has been simplified over the years. Nineteen-thirty-nine aerial photography shows nearly featureless pasture or fields to the southwest of the main channel. Washington State Parks archives have records of dredging and diking from the earliest days of Parks ownership. A 1964 plan sheet shows dredging in the study area, primarily bar scalping. It is not indicated where the dredge spoils were placed, although it is easy to imagine them placed in the right bank area to increase its elevation.

In 1968 bank protection occurred along the right bank and further dredging in the main channel with the note that "material to be used as fill behind bank protection." By 1978 the right bank was largely rip rapped, although it is difficult to tell exactly which proposed construction activities were actually done and which weren't. The distributary mouths, N1 and N2 (**Figure 4**), were cleared of debris at least once in 1978. It is assumed that this was done to decrease flood elevations in the mainstem.

Focusing on the current alignment downstream of US 101, the main Dosewallips channel runs down the center of a prograding delta cone, **Figure 3**. This morphology is a common condition when the river alignment is constrained (in this case by the US 101 road fill and bridge) and not allowed to move laterally across the face of the delta. The typical delta is fan-shaped and the delta front moves out as sediment is added episodically across the conical surface[5]. In an unconstrained condition, the lower Dosewallips river would abandon the current alignment for one that flowed to the north or south, around the aggraded delta cone, seeking a more efficient route to salt water. Those familiar with JimmyComeLately Creek will see that pattern.

JimmyComeLately Creek; avulsion of a prograded delta cone

The Dosewallips Delta topography has been determined in a rough way using Lidar data from the Port Gamble S'Klallam tribe and a limited amount of ground survey. We understand the general shape of the area below US 101, but not exactly (see **Figures 2 and 3**, and the cross sections).

Channel characteristics

The channel is confined at the bridge and unconfined at the estuary. The US 101 bridge and approach fill limit the down-valley movement of flow over the flood plain. The effective width of the bridge (compensating for the skew of 40° and eliminating the State Parks access roadway) is 345 feet, the flood prone width. The average bankfull width upstream of the bridge is approximately 230 feet , which makes the entrenchment ratio in the bridge section 1.5, or moderately entrenched. Entrenchment indicates a channel with high shear stress, high efficiency and a lack of flood plain storage. Downstream of the bridge the flood prone width extends for an indeterminate distance since the flood plain is a conical surface, falling away laterally. The meaning of this term is stretched in this context, but we could say that it is unconfined.

Sinuosity in the study reach is essentially 1.0. At low channel slopes we expect high sinuosity (>1.4), although diked channels and those on alluvial fans tend to be straight.

This channel could move laterally at any point downstream of the bridge so that the entire area should be considered the channel migration zone. Bank armoring on the right bank hinders movement, as does a developed riparian on the left bank.

Water, sediment and wood discharge

While the USGS gage was in operation, 37 years of flow data were accumulated with the following peak flow statistics (**Table 1).**

Table 1

USGS station 12053400 (1931-1968)

Recurrence Interval, yr.	Dosewallips R. peak discharge, cfs
1.01	1,362
1.25	2,852
2	4,335
5	6,586
10	8,194
50	12,021
100	13,762

The bankfull channel in this reach can contain a 4000 cfs 2 year flood. Flows in excess of this cover the flood plain to a greater or lesser extent. Distributary flow from the bridge to roughly 2100 feet downstream may account for up to 2000 cfs. The 5 major distributaries carry a maximum of about 400 cfs each. This may be overoptimistic since 3 of the 5 combine into one channel. These channels flow only within a few feet of bankfull elevation, depending on the elevation of the sediment at the inlet. When flow goes overbank, distributary flow likely increases as the width and depth of these channels increases with distance from the mainstem.

The elevation of the area north of the wooded riparian, the Bloomfield property, is substantially lower than the bankfull elevation at the channel. The flood path between the bank top at the bridge and bank top of Sylopash Slough drops 7 feet, and the lack of heavy riparian vegetation along this path makes it very prone to avulsion.

The wood that enters the study reach is either pressed against the riparian vegetation by overland flow and distributary flow, or it ends up the end of the channel, about MHHW, at the head of the new distributaries. Very little of the wood is retained in the mainstem channel and cannot be considered a significant factor in channel morphology or habitat formation. Key piece size for a channel this size is minimum of one quarter of the bankfull width long and one half to three quarters of the bankfull depth in diameter[6]. This is equivalent to a log about 40 feet long and 2.5 to 3.75 feet average diameter, with root wad. In his survey of in-channel wood in the lower half of the river, Labbe, *et. al.*, found the majority (99%) was smaller than key piece size[7].

Stream bed, bank and general soil characteristics

Bank soils are generally sand and finer materials. The sort of soil to be expected on a flood plain. In themselves, these soils are sensitive to lateral channel movement. Along the main channel on both banks large cottonwoods, alders and conifers have become established, as well as various species of native and non-native brush, to create a root mass that is relatively resistant to erosion. In approximately 1968, Washington State Parks installed rip rap bank protection all along the right bank from the US 101 bridge to 1800 ft downstream. This was done to stop the lateral movement of the lower Dosewallips River into park property. This rock has now become embedded in roots and is quite resistant to erosion. Visual inspection does not reveal the original extent of the installation, although historical photographs show a well-armored bank.

The stream bed material consists of gravel and cobble, with the occasional boulder-sized particle. Pebble counts[8] were done at three locations in and upstream of the study reach. One at a point 2644 feet downstream of the US 101 bridge. This location is the "end" of the channel at about mean higher high water, where sediment transport stops as the channel is backwatered at high tides. It was chosen to represent the sort of material transported through the reach creating the emerging delta cone. Below is table of the sediment distribution.

Table 2 Particle size distribution, Dosewallips River mainstem, 2644 ft downstream of US 101.

Percent finer	Particle size, ft	Particle size, mm
16	0.03	8
35	0.09	26
50	0.16	48
84	0.30	92
90	0.37	112
100	0.60	183

The second and third pebble counts were done upstream of the US 101 bridge. These samples were taken on the face of bars representing the coarsest bedload transported by the Dosewallips river in this reach.

Table 3 Particle size distribution, Dosewallips River mainstem, 360 ft upstream of US 101.

Percent finer	Particle size, ft	Particle size, mm
16	0.02	7
35	0.08	24
50	0.15	47
84	0.36	110
90	0.39	120
100	0.70	213

Table 4 Particle size distribution, Dosewallips River mainstem, 1200 ft upstream of US 101.

Percent finer	Particle size, ft	Particle size, mm
16	0.02	6
35	0.10	30
50	0.21	64
84	0.40	122
90	0.47	143
100	0.70	213

Channel profile

The **Table 5** below shows the hydraulic properties of the cross sections along the main channel profile downstream of US 101.

Table 5 Dosewallips River mainstem hydraulic conditions

Xsec	Distance D/s US 101 ft.	Low flow WS slope ft/ft	BFelev Avg. ft.	Depth Avg. ft.	Discharge Bankfull cfs	Width Bankfull ft.	Shear Stress Bankfull lbs/ft^2
6	0		18.0	5.8	7174	207	1.0
5	278	0.38%	17.1	5.9	6157	185	0.9
4	817	0.14%	14.6	4.2	4248	175	0.8
3	1316	0.35%	13.1	4.4	3399	130	0.9
2	1753	0.29%	11.9	4.5	4159	150	0.9
1	2151	0.18%	8.8	2.1		112	
0	2697	0.04%	8.8	2.3			

The lower river is at an overall water surface slope of 0.19%, over the entire reach from the US 101 bridge to the terminus of the channel where it breaks off into multiple distributaries. Low flow water surface slope varies along this profile, with a maximum of 0.38% downstream of the bridge, to a minimum of 0.04% in the last 500 feet.

At bankfull flow, water surface slope is approximately 0.3%, the value used in bankfull hydraulic computations for this study.

As one moves downstream, the hydraulic capacity of the main Dosewallips channel decreases, indicated by the decrease in the average depth of the channel (in this instance the difference in the elevation between the average bankfull elevation and the low flow water surface), the bankfull width, and consequently the bankfull discharge. This decrease in main channel capacity is compensated by an increase in the number of distributaries, overflow channels, and general overbank flow.

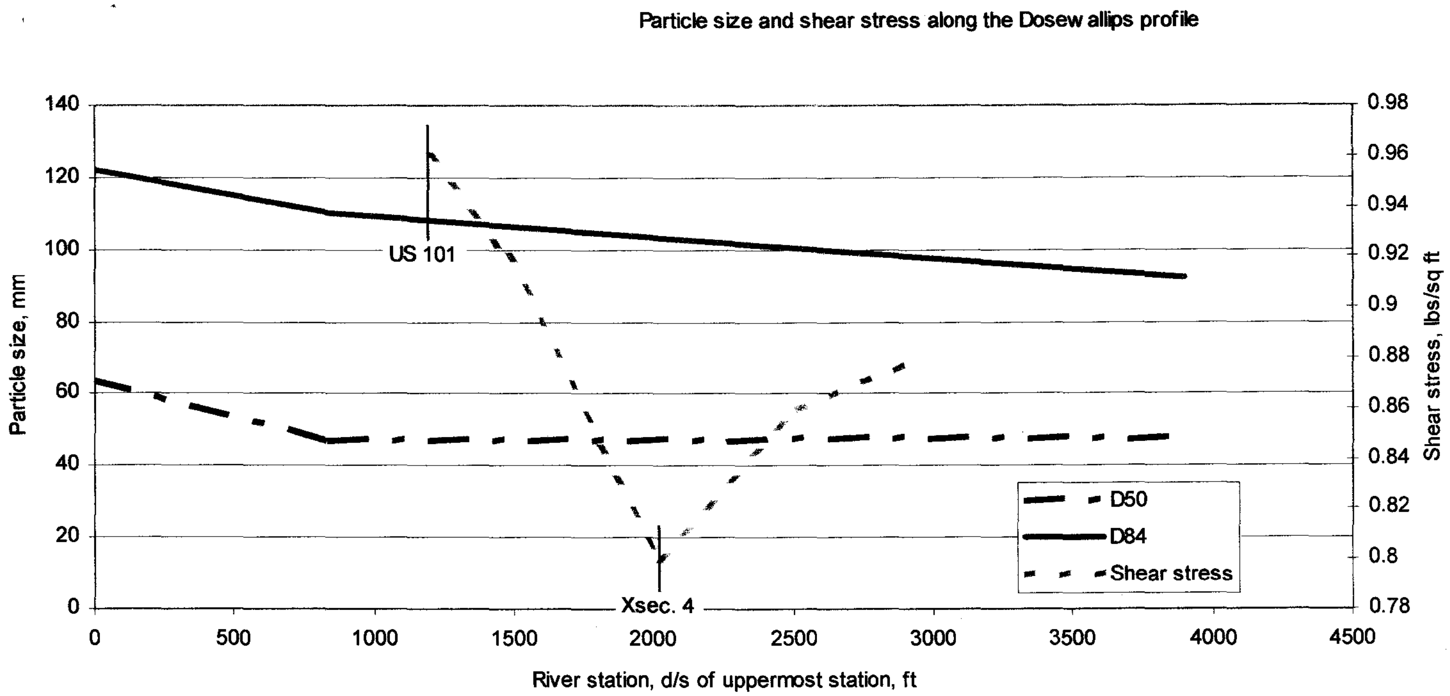
It is somewhat difficult to hydraulically model a channel which is "leaking" all along its length. A one dimensional backwater model would require multiple water diversion points along the profile to prevent the water surface elevation from "building up" progressively downstream. For this study each cross section was treated individually to determine the theoretical flow at bankfull stage. Flows in excess of the cross section's capacity is assumed to flow overbank or down distributary channels. Hydraulic computations were done with the aid of WinXsPro[9], a normal flow cross section analysis program.

The main channel type is pool riffle, although this is drowned out by sediment deposition, with the channel tending to a plane bed through most of the reach. Low flow water depths in the cross sections did not exceed 2.5 feet, except in the backwatered lower section. This rather low pool depth for this size of channel indicates a lack of hydraulic diversity. The lower 600 feet is backwatered at low flow by the terminus of the channel. At tides greater than MHHW, the backwatered area extends further upstream.

Channel stability and equilibrium

As the main channel lengthens with delta progradation (6 ft/yr) and the average elevation of Hood Canal increases with eustatic sea level rise (1 to 2 mm/yr.), channel slope decreases (providing the upstream channel is generally in equilibrium). The consequence of this decrease in slope is, among other things, reduced sediment transport capacity and subsequent aggredation, leading to channel avulsion (abandonment of the current mainstem). All else remaining equal, if the channel continues to prograde, a threshold will be reached where an avulsion becomes imminent.

Since the 1960s the slope of the channel in the reach downstream of the bridge has decreased. The 1968 USCOE Dosewallips River flood model plotted an "observed water surface" in the reach roughly 1200 feet downstream of the US 101 bridge. Slope of this observed surface was 0.43%. In 2004 the low flow water surface slope was 0.28%, a decrease of 34%. From this data it is assumed that this portion of the channel is aggrading at a rate greater than the reach immediately upstream. The rate of this increase is greater than that predicted by delta progradation and sea level rise and likely results from more local aggredation in this reach.



The chart above pictures the change in particle sizes and shear stress along the Dosewallips River profile starting from a point 1200 feet upstream of the US 101 bridge. The particle size data is from **Tables 2, 3 and 4**, representing 2 pebble counts upstream of the bridge and one at the terminus of the channel. Shear stress data is from **Table 5**.

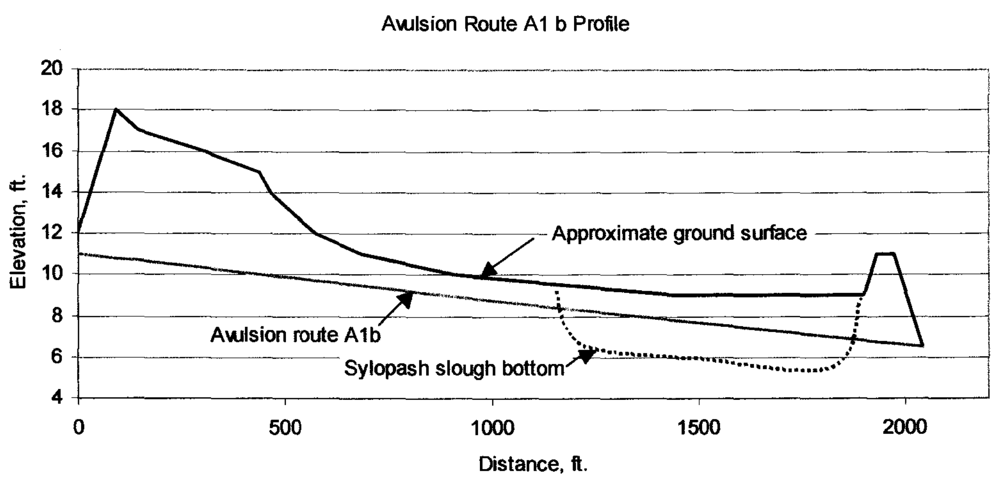
The size of D_{50} is virtually unchanged through the study reach, indicating that this size particle is readily transported under the shear stress present at all cross sections. The size of D_{84}, on the other hand, decreases, indicating a deposition of the coarser fraction within the reach. The dip in shear stress at cross section. 4 means that this is a likely location for deposition. As we have seen, there has been a reduction in slope since the 1960s in this reach. The reach containing cross section 4 will tend to aggrade forcing high backwater elevations which lead to more overbank flow and an increase in the likelihood of channel avulsion.

While we can never know exactly when or where an avulsion will occur, the threat needs to be evaluated. **Figure 6** shows a number of possible avulsion routes. They begin at points in the main channel of known elevation and proceed out perpendicular to contour lines and roughly along existing distributary alignments. They are not all *likely* routes, but offer a basis for comparison. Lateral channel changes are often stopped by wood racking against the inlet when it is in a forested riparian, blocked by a deposit of sediment in the inlet, or by trees falling into the newly enlarged channel as it passes through a forested riparian. Routes A2-5 are not likely avulsion paths for these reasons. Although an avulsion could be forced by removing trees, if other factors are favorable. Routes A1 and A6 are not forested and do not surfer these controls.

Another factor in the occurrence of avulsions is the relative stream energy after the event occurs. If the stream energy is in a lower state after the change occurs, it is more likely to happen. This can be thought of a lowering of the water surface at the upstream end of the avulsion route. What follows is an analysis to determine the change in water surface elevation after an avulsion.

The slope of the avulsion routes was taken from the existing channel, taking into consideration the concave-up shape to the profile of a channel approaching a level pool. The point was made earlier that the slope of the existing channel is measurably lower than it was just a few decades ago and it would seem prudent to assume a greater slope. The main difference between then and now is that the current channel is much longer. This increased length accommodates a low gradient reach directly above tidal influence, in addition to a transition to the higher gradient and coarser channel just above it.

Hood Canal establishes a base elevation for any stream entering it. This simple observation is complicated by the fact that it is macrotidal and that the base elevation will be variable depending on the stream energy entering it and the size and abundance of sediment transported into the interface. Rather than trying to solve this rather complicated problem, we can use existing conditions at the mouth and make the assumption that base elevation of any high order, sediment-carrying, channel will be similar to what we find at the end of the existing channel. The bed elevation at the mouth was measured at 6.5 feet. This is somewhat higher than the elevation of the tidal channels and distributaries (approximately 5 feet, MSL is 4.1 feet) at the same relative location on the delta front. These channels do not carry a coarse sediment load that would be deposited at a much



higher elevation than the generally fine material present in tidal channels.
The profile for A1 b is shown above. It assumes a base elevation of 6.5 feet and a slope of 0.22%. It does not follow the elevation of the Sylopash slough bottom since the river flow that would establish this hypothetical channel would be carrying sediment that

would be deposited under the influence of backwater from Hood Canal. The upstream end has a final elevation approximately 1.1 feet below the current channel elevation. This is the only profile, of the ones shown in **Figure 6,** that offers any decrease in relative stream energy and this only occurs if the shore bar is breached and the main channel enters the Canal toward the north east, rather than following Sylopash out to the east.

The **Table 6**, below, shows the average slope of the existing mainstem river beginning at the delta front. The assumption is that given the sediment gradation of the current bedload, similar flood events and the effect of tidal backwater, these are the slopes the bed would normally assume. The slope increases as one moves upstream. These are average slope for the lengths given, which are applied to similar length channels in the hypothetical avulsion routes.

Table 6

Cross section	Distance from Canal	Average slope
0	0	
1	546	0.04%
2	944	0.11%
3	1381	0.17%
4	1880	0.21%
5	2419	0.22%
6	2697	0.23%

The **Table 7** below shows the results of the analysis that was described above. For each avulsion route with given length and slope (from **Table 6**), the final elevation at the existing main channel is determined. As can be seen, in only one case will river energy be decreased, A1 b. In all other cases the routes are just too long to result in any substantial decrease in stream energy, and are therefore less like to occur.

Table 7

Avulsion Route	Length	Slope[1]	Existing[2] Chan. Elev	Avulsion[3] Chan. Elev
A1	3000	0.23%	12.1	13.4
A1 a	2510	0.22%	12.1	12.1
A1 b	2080	0.22%	12.1	11.0
A2	2300	0.22%	10.8	11.5
A2 a	1900	0.21%	10.8	10.6
A3	1800	0.21%	10.1	10.2
A3 a	1240	0.15%	10.1	8.3
A4	1200	0.14%	8.8	8.2
A5	880	0.10%	7.4	7.4
A6	2700	0.23%	12.1	12.7

[1] Average slope of channel with similar length. See text.

[2] Elevation of the existing channel at the beginning of the avulsion route.

[3] Elevation of the beginning of the avulsion channel when projected up from elev. 6.5 feet at the slope given slope[1].

In the early stages of the reach analysis, it appeared that an avulsion was a likely event in the lower Dosewallips. It now appears that conditions have not reached the threshold past which an avulsion is imminent. Conditions can change rapidly and this threshold exceeded rapidly. Such a condition would be a significant flood accompanied by a large release of sediment and wood. Such an event could increase the elevation of the bed downstream of US 101, deposit one or more significant log jams, or extend the length of the current channel. If this were to happen, an avulsion would likely occur.

Cross Sections

Six cross sections were established in the study area, **Figure 2**. The cross sections are a combination of ground surveys and Lidar aerial surveys. In areas where vegetation does not obscure the ground surface, Lidar data was used without correction. In high marsh areas, Lidar data was corrected with spot ground elevations. In areas of higher vegetation, brush and trees, a ground survey was done. These two methods were merged together to give the estuary-wide cross sections. The distance measurement begins at the intersection with US 101, on the southern end of the cross sections. This results in plots of these cross sections looking upstream, opposite the more conventional downstream-looking cross section. This means that channel right is on the left hand side of the plots. Unfortunately this was built into the analysis from the beginning and has not been changed.

In a number of cases where the cross sections intersect the main channel and distributaries obliquely, they have been modified to show true width to accurately estimate hydraulic conditions.

Cross section 5

The plot of elevation as a function of distance from the southern edge of the study area shows a marked drop in elevation as one moves north from the main channel. The slope of this line is somewhat greater than the slope of the channel, creating conditions conducive to lateral flow. Without the robust left bank riparian vegetation, northerly channel movement would have already occurred.

The gradient between the left bank at the US 101 bridge to the bottom of Sylopash slough, a distance of approximately 1014 ft, is 0.9%. This is three times the bankfull slope of the mainstem and offers a very attractive route for overbank flow. A significant flood, greater than the 10 year event, may begin to cut a permanent distributary channel here and may be the site of a future avulsion.

The N3 distributary is the most upstream channel to leave the mainstem in this reach. Bankfull flows at the bridge are 7000 cfs N3 only has the capacity to contain flows of 200 to 300 cfswhich amounts to roughly 4% of the main channel discharge at this stage. During higher recurrence interval storms, discharge may be significantly higher. Shear stress in this channel during a 5 year flood in the mainstem is sufficient to move the general bedload found in the main river (a pebble count was not done in any of the distributaries). This means that relatively frequent floods will keep this distributary scoured, providing that wood does not plug the mouth or a bar does not develop just inside the mouth. Water also enters the distributary from overland flow and, in part, accounts for the general downstream increase in width.

Cross section 4

Cross section 4 clearly shows the aggredation of material in the vicinity of the channel. The difference in elevation between the Dosewallips River left top-of-bank and the flood plain surface 200 hundred feet north from the main channel is about 2.5 feet lower. That amounts to 57% of the bankfull depth.

Cross section 3

Cross section 3 shows that the main channel is significantly narrower at this point than where the previous cross sections intersected the channel. This channel cross section has the least hydraulic capacity of any of the sampled channel cross sections, and as a result of the limited channel capacity here, the adjacent flood plain is scarred with overflow channels. This cross section shows that the area on the right bank has been built up, possibly with dredge spoils.

In the table below are tidal statistics at Quilcene bay, converted to the study datum, NAVD 88.

Table 8 Quilcene Bay tidal statistics.

	NAVD
MEAN HIGHER HIGH WATER (MHHW)	8.7
MEAN HIGH WATER (MHW)	7.9
MEAN SEA LEVEL (MSL)	4.1
MEAN LOW WATER (MLW)	0.3
MEAN LOWER LOW WATER (MLLW)	-2.6

All of the channel thalwegs, mainstem and distributary, have a very similar elevation at this point in the estuary, with the exception of Sylopash Slough and the channel that runs along the base of US 101. Cross section 3 is the first point measured where the influence of tide begins to be felt, backwatering up the channel and forcing sediment deposition. All the channel thalwegs are below MSL, indicating that they are dewatered half the time and experience normal flow capable of scour from overbank flow. But they are backwatered by tide 10 to 20 percent of the time, forcing deposition.

Surface texture patterns on the left bank flood plain along this cross section are complex. Some patches with no signs of recent deposition or scour are at the same elevation as similar, nearby patches with significant signs. It is the nature of cross sections to miss features that occur between them. This complexity, and the inability of the methods to discern it, is not considered important for this study.

Cross section 2

Most of cross section 2 is under the influence of tide. All but the wooded area right along the banks of the main channel is salt marsh with an elevation of approximately 9 ft. Lidar shows a slightly higher and more variable surface than actual ground elevation.

delta progradation rate of 6 feet per year is at all representative of the past, the delta front was back at the entrance to N3 roughly 440 years ago.

N1, N2, and N3 are all blind channels. They do receive scouring flow during flood events. The lowermost entrance to N3, the site of the cabled cottonwood log, has only recently been reestablished and is not continuous. Considering how rapidly these old distributary mouths become blocked with wood and sediment, the removal of debris and sediment in order to increase the frequency of active flow should not be part of a long term habitat restoration plan.

Habitat

There are a number of habitat types in the study area. The primarily types are

- mud flats
- shallow water habitat below MHW with a coarse texture
- tidal channels
- salt marsh
- freshwater marsh
- distributary rearing
- distributary spawning
- main channel rearing
- main channel holding
- main channel spawning
- main channel edge

A detailed evaluation of the area and condition of these habitats will not be a part of this report. While we might benefit from such an analysis, it is likely that it will not change the restoration activities recommended.

Land use, land cover, and infrastructure influence habitat in a number of ways in the study area, but primarily it affects channel evolution. Sinuosity has been reduced to a minimum in the lower Dosewallips. This was accomplished by diking and dredging over the last 50 years, and possibly for some time before that. As far as we can tell, the channel sinuosity was never very high. Sinuosities greater than 1.4 can be found in broad, flat, and fine-grained coastal estuaries. This coarse-grained high gradient delta would naturally have a relatively straight main channel, diversity primarily formed by bars, distributaries, and islands of deposited sediment pulses. The 1883 T sheet shows a channel that is relatively straight for 2500 feet and then bifurcates around an island. The current channel travels straight from the US 101 bridge to about MHHW (2644 feet), where it splits into a number of distributaries, basically falling off the deposited sediment wedge.

Edge habitat on the right bank main channel has been severely impacted. This bank was formed by a rip rap dike in 1978, significantly simplified compared to the more natural left bank. Vegetation is minimal, large wood nearly absent, and the bankline straight and uniformly steep. There is some overhanging vegetation and a few large trees, but this would be considered minimal.

The 1978 dike has also eliminated the possibility of distributary development on the right bank. At the point where dike ends, the distributary S1 begins. Land use on the right bank, Dosewallips State Park, generally precludes channel development, either as increased sinuosity, distributary development or avulsion of the main channel to the south. Depending on Park's attitude toward natural systems, there may still be opportunities to foster channel complexity. The history of Park ownership has been one of manipulating the river for specific human needs, so a change in attitude would be necessary. There are portions of this reach that have been built up over the elevation of the adjacent natural flood plain. Cross section 3 shows where fill has elevated the original flood plain between stations 700 and 900. Excavation of this fill is not likely. A first step is to remove rip rap in selected areas and establish a vegetated buffer with a low natural slope.

Table 9 Main Dosewallips River distributaries and blind channels.

	Approximate area in acres				
Distributary	**Total area**	**Non-tidal**	**Tidal**	**Connected**	**Blind**
N1	0.8		0.8		0.8
N2	3.4	0.7	2.7		3.4
N3	3.6	1.0	2.6		3.6
N3 trib	0.3		0.3		0.3
N4	1.9		1.9		1.9
S1	1.2		1.2	1.2	
Sylopash slough*	4.2		4.2		4.2
New distributaries	1.6		1.6	1.6	
	0.9		0.9	0.9	
	0.7		0.7	0.7	
Totals	18.6	1.7	16.9	4.5	14.1

*Sylopash slough has not been a distributary for at least 120 years.

The restoration goals specifically state that the loss or isolation of distributary channel habitat is a problem. **Table 9** gives the area of the various channel habitats on the Dosewallips delta shown in **Figure 4**. Of the 18.6 acres of tidal and distributary habitat, only 24% is connected distributary habitat and of this only S1 conveys out-migrating juveniles to adjacent salt marsh habitat. Juveniles must go out to the delta front to move north to the adjacent salt marsh habitat, exposing themselves to deeper water and increased predation at an early age. We have discussed the reactivation of the distributaries and how they are quickly occluded by natural mechanisms.

There is a substantial amount of tidal channel habitat in the Dosewallips estuary, although much of it is not connected to the river, and not likely to be through maintenance-free restoration techniques.

The role and risks of large wood in the main channel is a complex problem in this reach. The reach is simplified and one of the primary benefits of large wood is complexity, although that complexity is accompanied by some risks. Significant accumulations of wood create backwater, increase flooding, and produce turbulence and local scour. At this conceptual stage in the design process, and without doing sophisticated modeling, an estimate of acceptable wood loading is given here. Gippel[11] found that the measurable backwater threshold for wood is 0.0056 ft^3/ft^2, which for this reach is about 142 ft^3/W_{ch}, or about one key piece per 2.7 channel widths. This is a relatively small amount, considering that for a jam to be stable it must be composed of a number of key pieces and a still greater number of functional ones. Another threshold is that wood structures should not exceed a blocking ratio of greater than 0.1[12]. The blocking ratio is the proportion of the channel cross section blocked by the wood structure. Clearly, if wood structures are proposed, a better analysis of the hydraulic consequences should be done.

Depending on which bank the wood is located and its reach scale effects, scour may affect Park activities and/or infrastructure, and could increase the risk of avulsion.

Key piece size for this reach of the Dosewallips has a volume of roughly 380 ft^3 (10.75 m^3), from Martin Fox's recommendation cited in the Stream Habitat Restoration Guidelines[13]. Abbe[14] suggests that, in large alluvial channels, the ratio of log length to bankfull width should be greater than 0.25, and the ratio of average log diameter to bankfull depth should be from 0.5 to 0.8, with root wad. This leads to a log roughly 40 feet long and 2.5 to 3.75 feet in diameter, which has a volume of 195 to 443 ft^3 without a root wad.

Conclusions

Physical habitat deficiencies that critically limit fish, wildlife, and plant productivity within the lower Dosewallips stream corridor in the study reach are few, but they are large scale. Generally, water quality is good, sediment is abundant, much of the immediate upland and estuary are left to develop naturally.

- As the east Olympic peninsula subsides and sea level rises, the north half of the original Dosewallips estuary will sink without sediment input. The location of the US 101 bridge constrains the lateral movement of the river and limits the range of sediment deposition to the southern estuary.
- Channel avulsion is an inevitable consequence of delta progradation. At the rate of 6 feet per year, providing the upstream channel elevation remains the same and including sea level rise of about 300 mm in that time, progradation will lower slope by about one third in the next 100 years. This is more than enough to halt sediment transport in the main channel and force an avulsion at some point upstream.
- In addition to the gradual increase in channel length mentioned in the previous point, there is also the possibility of a catastrophic change in the channel downstream of US 101 due to a major flood accompanied by a release of sediment and wood. Rather than a gradual build-up to an avulsion threshold,