To: Loren Brokaw, WDFW
Jason Griffith, Stillaguamish Tribe
Stan Walsh, SRSC
Steve Hinton, SRSC

From: Eric Beamer, SRSC

Date: April 5, 2016

Subject: North Leque Island tidal habitat and juvenile Chinook salmon carrying capacity analysis

BACKGROUND

WDFW is developing a restoration (or mitigation) project on the portion of Leque Island that is north of Highway 532. The project concept involves removing the remainder of the old levee to improve tidal flow and add channel connections to Skagit Bay and the old Stillaguamish River channel, to presumably benefit juvenile salmon rearing.

The area of North Leque Island is shown in Figure 1. Prior to approximately 2007 or 2008 this area was completely diked off and did not have tidal habitat. The area was drained by a tidegate located on the western edge of the parcel (Figure 1). The 2009 orthophotos first show the area with the tidegate removed. It is my understanding the tidegate failed and was never replaced. Currently, the parcel is influenced by tides and has marsh, channel, and impoundment habitat.

Loren Brokaw of WDFW has requested input on how beneficial such a project might be to juvenile Chinook salmon for this part of the Skagit and Stillaguamish River deltas. In order to answer Loren's request I worked through four steps for the North Leque Island area:

1. Calculate the current and predicted (after dike removal project) tidal habitat areas.
2. Calculate the current and predicted (after dike removal project) landscape connectivity values.
3. Calculate juvenile Chinook carrying capacity estimates for all habitat/connectivity combinations generated in steps 1 and 2 above.
4. Compare juvenile Chinook carrying capacity estimates to existing fish data where possible.

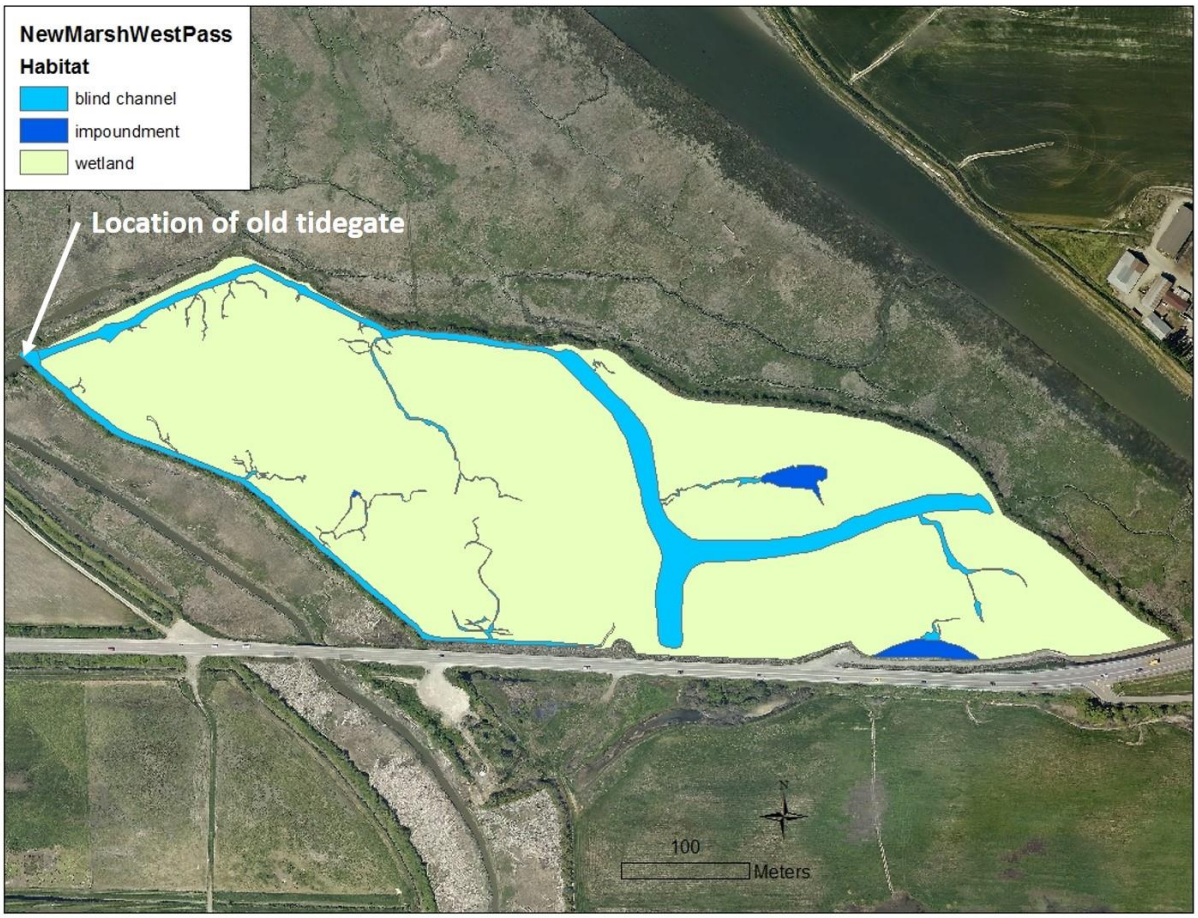

Figure 1. North Leque Island parcel tidal habitat conditions in 2013.

CURRENT & PREDICTED (AFTER DIKE REMOVAL) TIDAL HABITAT AREAS

To estimate the current tidal habitat condition for the North Leque Island parcel I used results from our most recent period of Skagit tidal delta habitat status and trends monitoring, which is year 2013 (Figure 1). In 2013 the total tidally influenced area of the parcel was 14.636 hectares, with 13.1076 ha in tidal marsh habitat, 1.3745 ha channel, and 0.1539 ha impoundment. Total 2013 tidal channel and impoundment quantities are compared to predictions derived from South Fork Skagit tidal delta reference sites based on Hood 2007 (Table 1).

Table 1. Predicted and actual habitat area (tidal channel and impoundment combined) for North Leque Island Parcel.

	Predicted (Hood 2007)	**Actual 2013**
Total Channel Area (hectares)		
Point estimate (95% CI)	0.31313 (1.25-0.078)	1.5284
Tidal Channel Count (number of outlets)		
Point estimate (95% CI)	10 (3-29)	1

<u>Conclusions and discussion related to habitat amount:</u>

1. Total tidal channel and impoundment amount in 2013 is greater than what is predicted using reference areas within the SF Skagit delta. Conditions in 2013 are five times higher than the predicted point estimate and 22% higher than the higher 95% confidence limit. This suggests that removal of the old levee will not increase tidal channel habitat within the North Leque Island parcel. Most likely - over time - habitat conditions within the parcel will migrate toward the SF Skagit delta reference site predictions.
2. Total channel count in 2013 is much lower than what is predicted using reference areas within the SF Skagit delta. Conditions in 2013 are a tenth of the predicted point estimate and one third of the lower 95% confidence limit. This suggests removal of the old levee will likely increase the number of tidal channel outlets connected to the parcel, which will improve the parcel's connectivity for fish and other natural estuarine biota and processes.
3. A parcel of this size likely has downstream (i.e., "outside the dikes") influence on tidal channel amount. Presumably this is already happening with the single dike breach at the location of the old tidegate. However, full levee removal could have different results. I did not estimate any outside the dike effects for this memo. A prediction could be made with additional effort.

CURRENT & PREDICTED (AFTER DIKE REMOVAL) LANDSCAPE CONNECTIVITY

I calculated landscape connectivity values based on 2013 fish migration pathways. This is an update to the fish pathways developed for the 2005 Skagit Chinook Recovery Plan described in Beamer & Wolf (2011). The 2013 fish pathways reflect changes within the Skagit tidal delta that occurred between the two periods. All landscape connectivity values are shown in Table 2. Landscape connectivity to the North Leque Island parcel in 2013 is via a single point: the location of the old tidegate failure (shown in Figure 1). I assumed landscape connectivity to the North Leque Island parcel after full dike removal would mainly be through two current blind channels: West Pass Upper and Blind Ch #506 (locations are shown in Figure 2). I also calculated landscape connectivity to two existing fish data sites (locations shown in Figure 2). Figures 3-6 (below) show the work of calculating landscape connectivity to each site listed in Table 2.

Table 2. Landscape connectivity values for the North Leque Island parcel.

Site	Landscape connectivity value
North Leque Island parcel in 2013	0.011781
North Leque Island parcel after full dike removal:	
West Pass Upper	0.013546
Blind Ch #506	0.013321
Fish data sites:	
West Pass Lower	0.014115
West Pass Upper	0.013546

<u>Conclusions and discussion related to landscape connectivity:</u>

1. Full dike removal will increase connectivity to the North Leque Island parcel (about 15% increase) for Skagit origin juvenile Chinook salmon.
2. There will an improvement in connectivity for Stillaguamish origin juvenile Chinook salmon if full dike removal at the North Leque Island parcel occurs. While I did not quantify landscape connectivity values for Stillaguamish origin fish, the benefit to Stillaguamish may be larger than for the Skagit. This is because the distance to the closest Stillaguamish River distributary (which is the closest source of Stillaguamish fish) is Old Stilly Channel. Under 2013 conditions, fish from Old Stilly Channel must swim approximately 5 miles from its junction at West and South Passes to access habitat within North Leque Island. After dike removal, fish from Old Stilly Channel would only need to swim about half a mile to access that same habitat.

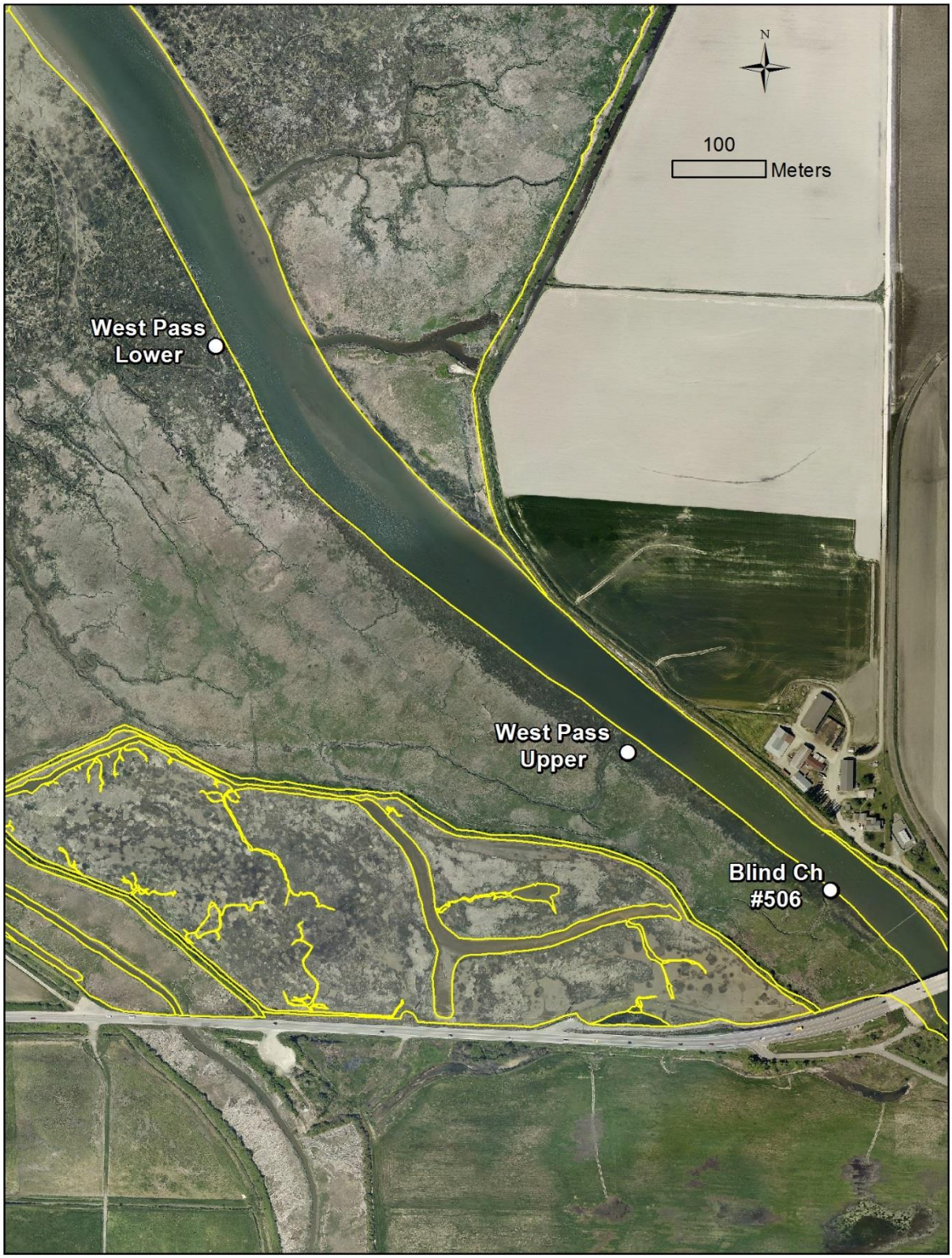

Figure 2. Location of blind channel sites used in landscape connectivity estimates for North Leque Island.

Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
Steamboat Sl to top of Tom Moore Sl	3	1.64484	4.934519
Steamboat Sl from Milltown N to Milltown S	3	0.486215	1.458646
Steamboat Sl from Isohis Sl to reunion with TM	4	0.143762	0.575047
"north fork" TM Sl from Isohis connector to merge	4	0.468306	1.873226
from TM Sl along Camano Is to Arrowhead	5	0.942198	4.710989
from Skagit Bay near Eng Boom south to West Pass	6	1.276023	7.65614
Steamboat Sl from Tom Moore Sl to Milltown N	3	1.87613	5.628389
SF from fork to dike setback blind	2	4.755857	9.511713
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
"north fork" Tom Moore Sl to Isohis connector	4	0.459895	1.83958
from "nf" TM Sl to reunion with "sf" TM Sl	5	1.859292	9.296459
Steamboat Sl from Milltown S to Boom Sl	3	0.615196	1.845589
Steamboat Sl from Boom Sl to Isohis Sl	3	0.044525	0.133574
Steamboat Sl from Boom Sl to Isohis Sl	3	0.187989	0.563967
Steamboat Sl from Boom Sl to Isohis Sl	3	0.330788	0.992364
Steamboat Sl from Isohis Sl to reunion with TM	4	0.489425	1.957701
Tom Moore Sl from Steamboat to bay fork	3	0.641316	1.923949
"north fork" TM Sl from Isohis connector to merge	4	0.434437	1.737748
"north fork" TM Sl from Isohis connector to merge	5	0.373296	1.866478
from "nf" TM Sl to reunion with "sf" TM Sl	5	0.522091	2.610454
from TM Sl along Camano Is to Arrowhead	5	0.831597	4.157984
from Skagit Bay near Eng Boom south to West Pass	6	0.374501	2.247007
"north fork" TM Sl from Isohis connector to merge	4	0.212061	0.848243
start of blind going towards new WP marsh	7	0.05395	0.377648
to new marsh dike breach at West Pass	7	1.713427	11.993989

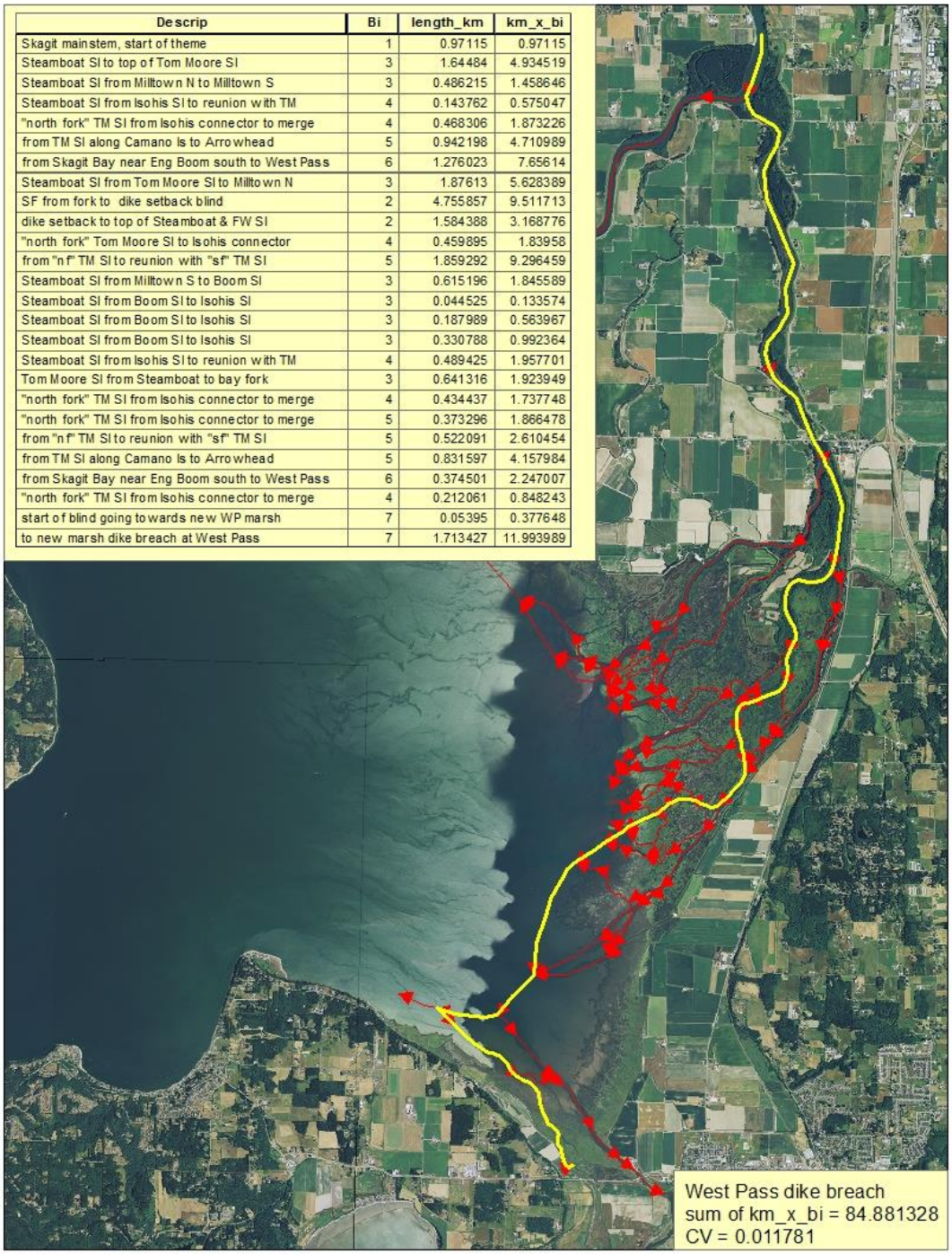

Figure 3. 2013 Landscape Connectivity and pathway to North Leque Island to the old tide gate site.

Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
Steamboat Sl to top of Tom Moore Sl	3	1.64484	4.934519
Steamboat Sl from Milltown N to Milltown S	3	0.486215	1.458646
Steamboat Sl from Isohis Sl to reunion with TM	4	0.143762	0.575047
"north fork" TM Sl from Isohis connector to merge	4	0.468306	1.873226
Steamboat Sl from Tom Moore Sl to Milltown N	3	1.87613	5.628389
SF from fork to dike setback blind	2	4.755857	9.511713
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
"north fork" Tom Moore Sl to Isohis connector	4	0.459895	1.83958
from "nf" TM Sl to reunion with "sf" TM Sl	5	1.859292	9.296459
Steamboat Sl from Milltown S to Boom Sl	3	0.615196	1.845589
Steamboat Sl from Boom Sl to Isohis Sl	3	0.044525	0.133574
Steamboat Sl from Boom Sl to Isohis Sl	3	0.187989	0.563967
Steamboat Sl from Boom Sl to Isohis Sl	3	0.330788	0.992364
Steamboat Sl from Isohis Sl to reunion with TM	4	0.489425	1.957701
Tom Moore Sl from Steamboat to bay fork	3	0.641316	1.923949
"north fork" TM Sl from Isohis connector to merge	4	0.434437	1.737748
"north fork" TM Sl from Isohis connector to merge	5	0.373296	1.866478
from "nf" TM Sl to reunion with "sf" TM Sl	5	0.522091	2.610454
from TM Sl along Camano Is to Arrowhead	5	0.831597	4.157984
from Skagit Bay south thru West Pass	6	0.861568	5.16941
from Skagit Bay south thru West Pass	5	0.189494	0.947472
from Skagit Bay south thru West Pass	6	0.413537	2.481224
"north fork" TM Sl from Isohis connector to merge	4	0.212061	0.848243
from Skagit Bay south thru West Pass	5	0.808952	4.044761
to West Pass Lower	6	0.050956	0.305738

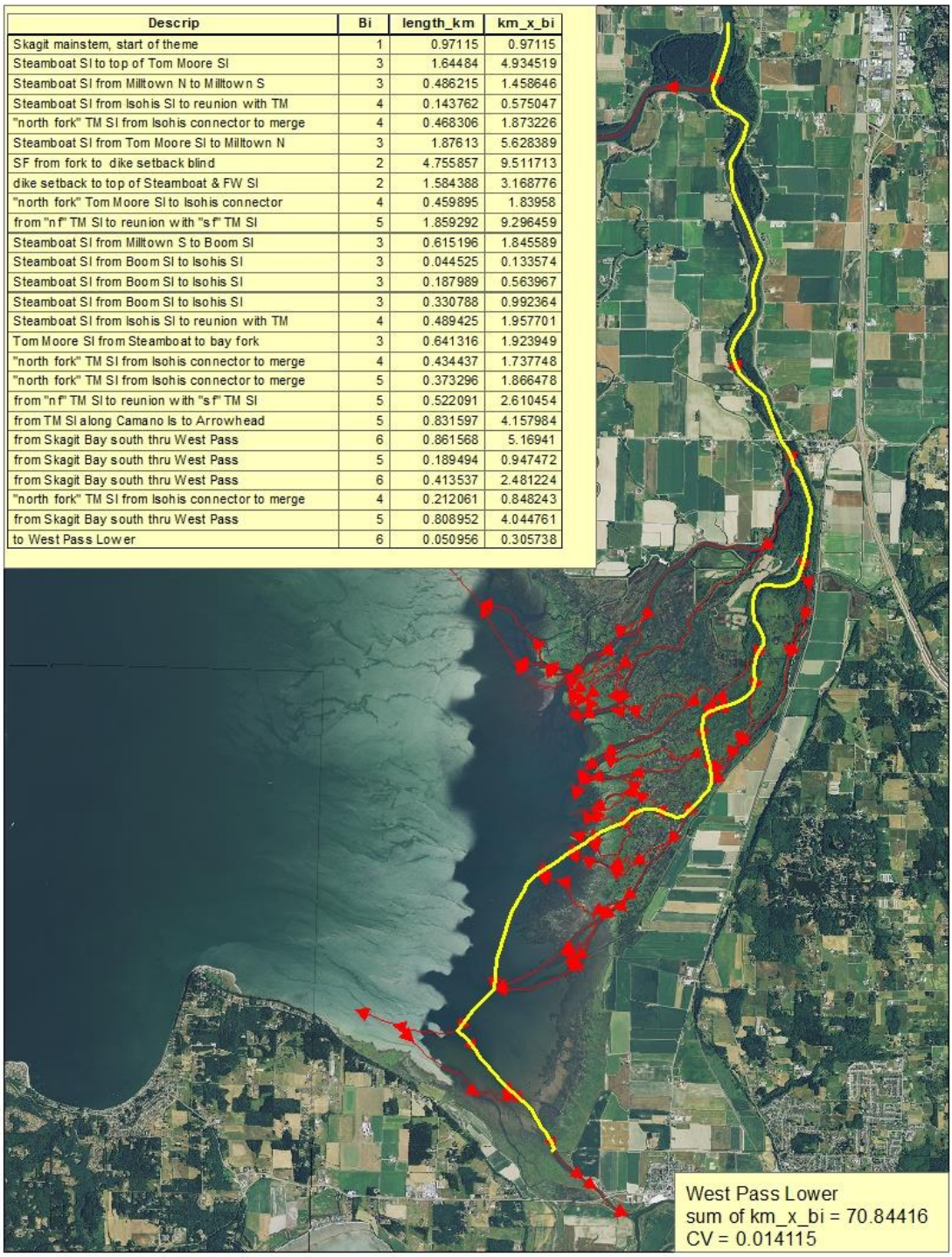

Figure 4. 2013 Landscape Connectivity and pathway to West Pass Lower.

Descrip	Bi	length_km	km_x_bi
"north fork" TM Sl from Isohis connector to merge	4	0.468306	1.873226
Steamboat Sl from Tom Moore Sl to Milltown N	3	1.87613	5.628389
SF from fork to dike setback blind	2	4.755857	9.511713
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
"north fork" Tom Moore Sl to Isohis connector	4	0.459895	1.83958
from "nf" TM Sl to reunion with "sf" TM Sl	5	1.859292	9.296459
Steamboat Sl from Milltown S to Boom Sl	3	0.615196	1.845589
Steamboat Sl from Boom Sl to Isohis Sl	3	0.044525	0.133574
Steamboat Sl from Boom Sl to Isohis Sl	3	0.187989	0.563967
Steamboat Sl from Boom Sl to Isohis Sl	3	0.330788	0.992364
Steamboat Sl from Isohis Sl to reunion with TM	4	0.489425	1.957701
Tom Moore Sl from Steamboat to bay fork	3	0.641316	1.923949
"north fork" TM Sl from Isohis connector to merge	4	0.434437	1.737748
"north fork" TM Sl from Isohis connector to merge	5	0.373296	1.866478
from "nf" TM Sl to reunion with "sf" TM Sl	5	0.522091	2.610454
from TM Sl along Camano Is to Arrowhead	5	0.831597	4.157984
from Skagit Bay south thru West Pass	6	0.861568	5.16941
from Skagit Bay south thru West Pass	5	0.189494	0.947472
from Skagit Bay south thru West Pass	6	0.413537	2.481224
"north fork" TM Sl from Isohis connector to merge	4	0.212061	0.848243
from Skagit Bay south thru West Pass	5	0.808952	4.044761
from Skagit Bay south thru West Pass	5	0.616332	3.081659
to West Pass Upper	6	0.033634	0.201804

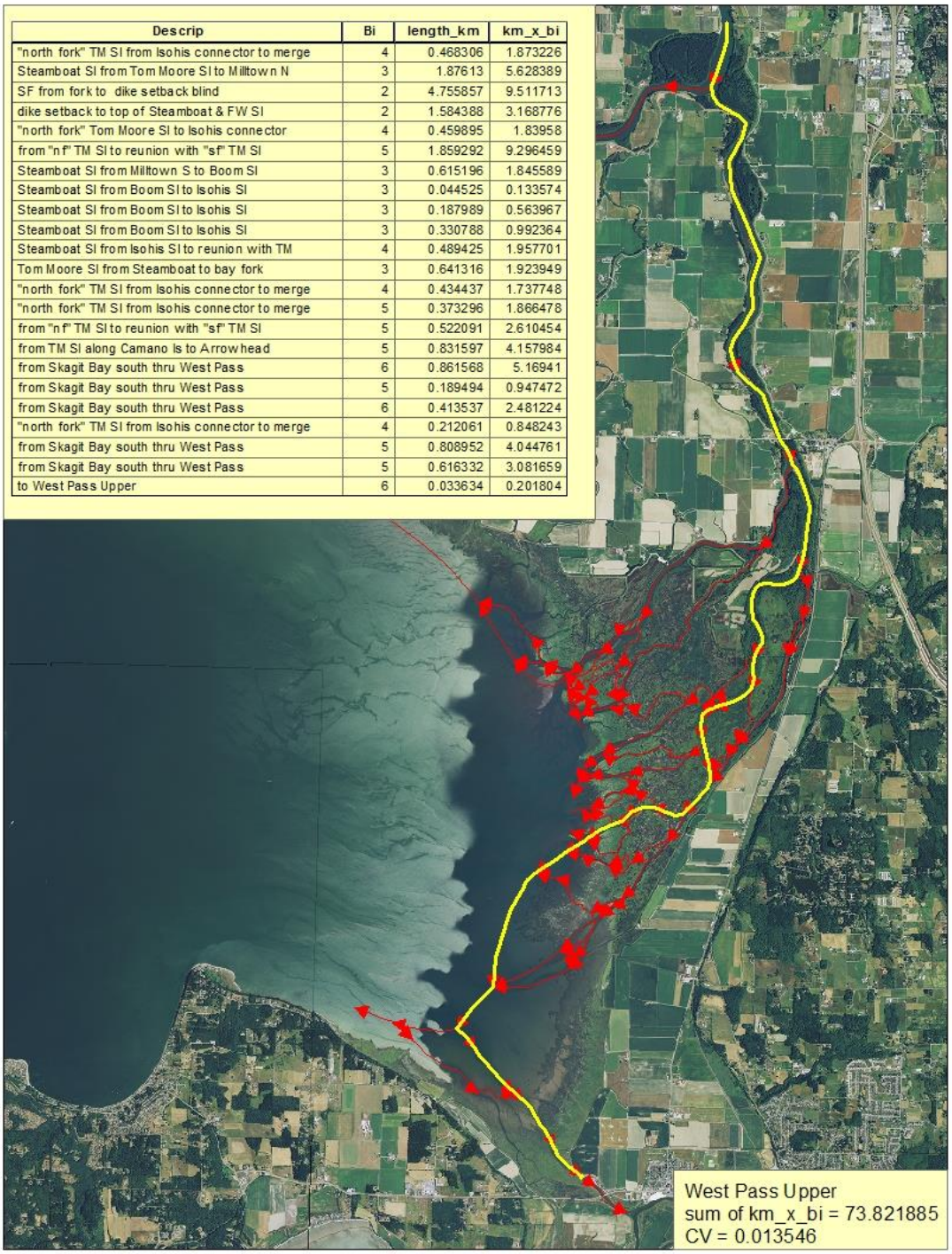

Figure 5. 2013 Landscape Connectivity and pathway to West Pass Upper.

Descrip	Bi	length_km	km_x_bi
"north fork" TM Sl from Isohis connector to merge	4	0.468306	1.873226
Steamboat Sl from Tom Moore Sl to Milltown N	3	1.87613	5.628389
SF from fork to dike setback blind	2	4.755857	9.511713
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
"north fork" Tom Moore Sl to Isohis connector	4	0.459895	1.83958
from "nf" TM Sl to reunion with "sf" TM Sl	5	1.859292	9.296459
Steamboat Sl from Milltown S to Boom Sl	3	0.615196	1.845589
Steamboat Sl from Boom Sl to Isohis Sl	3	0.044525	0.133574
Steamboat Sl from Boom Sl to Isohis Sl	3	0.187989	0.563967
Steamboat Sl from Boom Sl to Isohis Sl	3	0.330788	0.992364
Steamboat Sl from Isohis Sl to reunion with TM	4	0.489425	1.957701
Tom Moore Sl from Steamboat to bay fork	3	0.641316	1.923949
"north fork" TM Sl from Isohis connector to merge	4	0.434437	1.737748
"north fork" TM Sl from Isohis connector to merge	5	0.373296	1.866478
from "nf" TM Sl to reunion with "sf" TM Sl	5	0.522091	2.610454
from TM Sl along Camano Is to Arrowhead	5	0.831597	4.157984
from Skagit Bay south thru West Pass	6	0.861568	5.16941
from Skagit Bay south thru West Pass	5	0.189494	0.947472
from Skagit Bay south thru West Pass	6	0.413537	2.481224
"north fork" TM Sl from Isohis connector to merge	4	0.212061	0.848243
from Skagit Bay south thru West Pass	5	0.808952	4.044761
from Skagit Bay south thru West Pass	5	0.616332	3.081659
from Skagit Bay south thru West Pass	5	0.254531	1.272657
to blind for 'no-dike' West Pass marsh	6	0.029064	0.174384

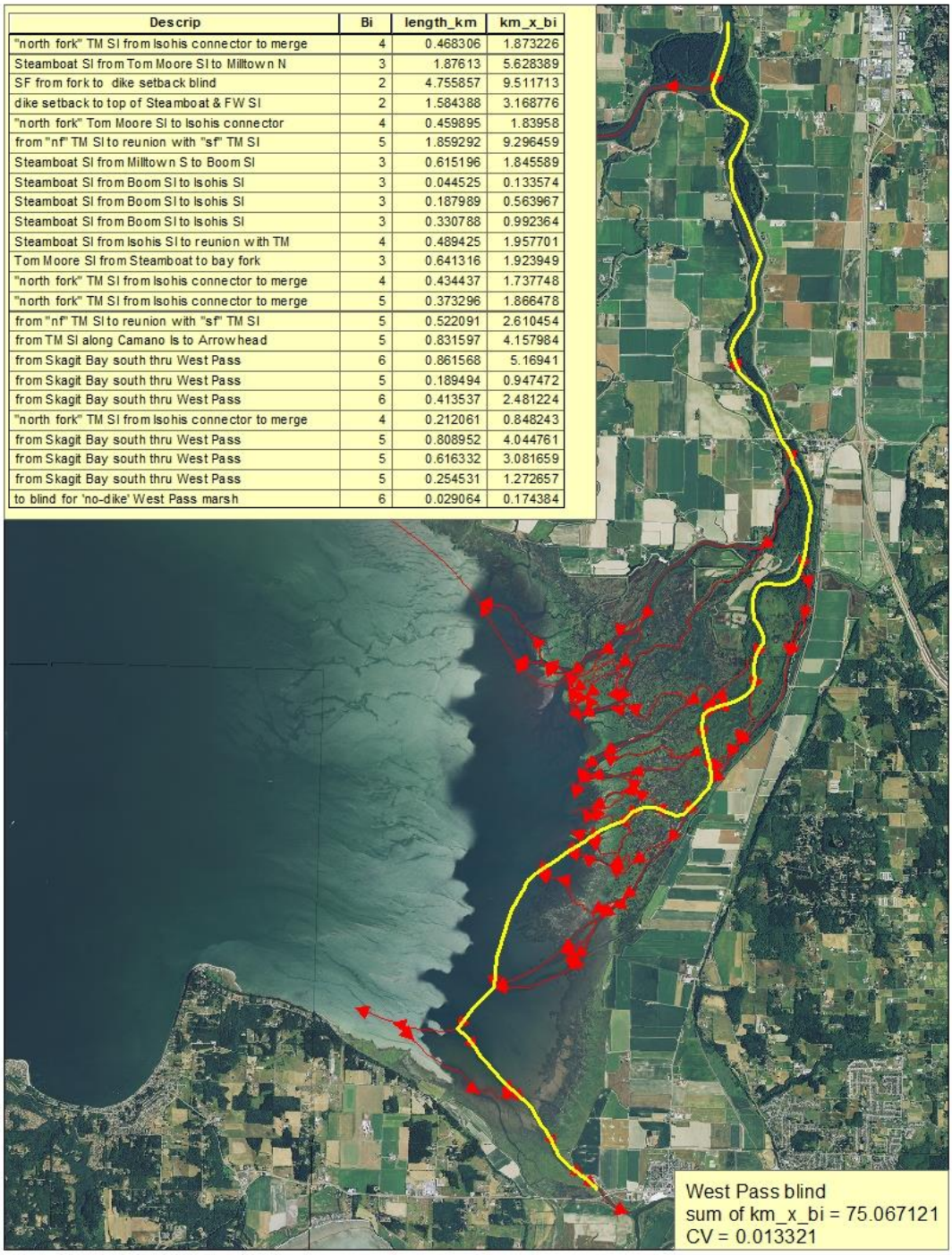

Figure 6. 2013 Landscape Connectivity and pathway to Blind #506.

JUVENILE CHINOOK SALMON CARRYING CAPACITY

Juvenile Chinook salmon carrying capacity is based on two variables: 1) wetted area available to fish; and 2) landscape connectivity. Both variables are positively correlated with juvenile Chinook abundance (i.e., larger habitat areas and higher connectivity values result in higher estimates of juvenile Chinook carrying capacity). The methods are described in Beamer et al. (2005) (page 89), which is the model developed for the 2005 Skagit Chinook Recovery Plan. I estimated juvenile Chinook carrying capacity for all habitat/connectivity combinations generated in steps 1 and 2 (above). To make the estimates, I assumed the North Leque Island area after dike removal was accessed through new pathways via two channels: West Pass Upper and Bind Ch #506. I averaged their connectivity values. Carrying capacity estimates are shown in Table 3.

Table 3. Juvenile wild Chinook salmon carrying capacity model results for North Leque Island parcel.

Alternative	**Habitat area (hectares)**	**Landscape connectivity**	**Smolts annually**
2013 conditions	1.5284 (from Table 1; not predicted to be a sustainable number)	0.011781 (from Table 2)	8,532
Full dike removal		0.013434 (averaged, from Table 2)	9,741

<u>Conclusions and discussion related to juvenile Chinook carrying capacity:</u>

1. A dike removal project that improves landscape connectivity for Skagit origin juvenile Chinook results in approximately a 1,200 fish per year increase over existing conditions in 2013.
2. While not quantified, there should also be an improvement for Stillaguamish origin juvenile Chinook salmon (see discussion in Landscape Connectivity section).

EXISTING JUVENILE CHINOOK DATA FROM NEARBY SITES

As a reality check, I compared the carrying capacity predictions to existing juvenile Chinook density data from two nearby sampling sites. These density data are from Beamer et al. (2009) and the sites are shown as West Pass Upper and West Pass Lower in Figure 2. Both sites are blind channels and were fyke trapped in 2007 and 2008, however only data from 2008 were used because the trapping period (February 2008 through June 2008) more completely captured the juvenile Chinook salmon rearing period. I also used juvenile Chinook density data provided by Jason Griffith. Jason's site is in West Pass just north of the highway bridge. Results are shown in Table 4. The methods used for Table 4 are identical to methods used to evaluate how many juvenile Chinook used the restored areas of the Wiley Slough and Fisher Slough restoration projects as part of their fish effectiveness monitoring effort (Beamer et al 2015; Beamer et al 2014).

Table 4. Population estimate of individual juvenile wild Chinook salmon that used habitat near the North Leque Island parcel. Results are standardized to represent one hectare of habitat. Ninety-five percent confidence intervals were not calculated.

Site and year	**Seasonal Chinook in fishdays per hectare of channel/impoundment** **Point estimate**	**Average Chinook delta residence period** **(days)**	**Juvenile Chinook population per hectare of channel/impoundment** **Point estimate**
Jason Griffith data, 2004-2007	18,458	35[a]	527
West Pass Lower, 2008	3,772		108
West Pass Upper, 2008	558		16

a – based on juvenile Skagit Chinook salmon otolith results reported in Beamer et al. (2000).

Because of the North Leque Island parcel's proximity to both the Skagit and Stillaguamish Rivers it is useful to interpret juvenile Chinook salmon results in the context of the juvenile Chinook populations for both rivers. Beamer et al. (2009) presents some genetic results from juvenile Chinook collected in West Pass sites suggesting ~70% of the juvenile Chinook using the area are from the Skagit, with ~15% from the Stillaguamish River. Thus, it is logical to think fish from both rivers use the North Leque Island parcel. However, one river typically produces millions of outmigrants while the other river produces 10s to 100s of thousands of migrants.

The number of juvenile Chinook outmigrating the Skagit River (and therefore having the potential to be caught within the estuary) in 2008 was only 1.7 million fish. For context, the recent 10-year average juvenile Chinook outmigration for the Skagit River is ~3.4 million, and Beamer et al. (2005) calculated full estuary juvenile Chinook carrying capacity is achieved at a Skagit River outmigration of 5.1 million subyearlings. The juvenile Chinook outmigration for the Skagit River for years 2004-2007 averaged 4.1 million. In contrast, juvenile Chinook outmigration for the Stillaguamish River for years 2004-2007 averaged 236,000 which is about 40% higher than the Stillaguamish River's recent 10-year average.

In order to accommodate the low and varying number of juvenile Chinook salmon outmigrating the years representing results in Table 4, I standardized the results as a "percentage of estuary carrying capacity." These results are shown in Table 5. If juvenile Chinook salmon were using habitat in the vicinity of North Leque Island scaled to the number of outmigrants leaving the Skagit River, you'd expect to see a 1:1 correspondence between the number of fish that used habitat in the North Leque Island area with the number of outmigrants. However, Table 5 and Figure 7 clearly show habitats in the vicinity of North Leque Island in 2008, and averaged over 2004-2007, vastly under-performed in terms of juvenile Chinook abundance when compared to the number of outmigrants.

Table 5. Juvenile Chinook salmon abundance estimates expressed as "percentage of estuary carrying capacity" for habitats nearby to North Leque Island along with Skagit River outmigration estimates.

Site and year	**Juvenile Chinook population using 1 hectare of estuarine channel / impoundment** (from Table 4)	**N. Leque Island area** (from Table 1)	**Expanded # of juvenile Chinook** (column 2 x column 3)	**N. Leque Island carrying capacity** (from Table 3)	**Expanded # of juvenile Chinook** (expressed as % of estuary carry capacity)	**Skagit subyearling Chinook outmigrants** (expressed as % of estuary carry capacity)
Jason Griffith data, 2004-2007	527	1.5284 ha	805	9,741	8%	4.1 million / 5.1 million = 80%
West Pass Lower, 2008	108		165		2%	1.7 million /5.1 million = 33%
West Pass Upper, 2008	16		24		0.2%	1.7 million /5.1 million = 33%

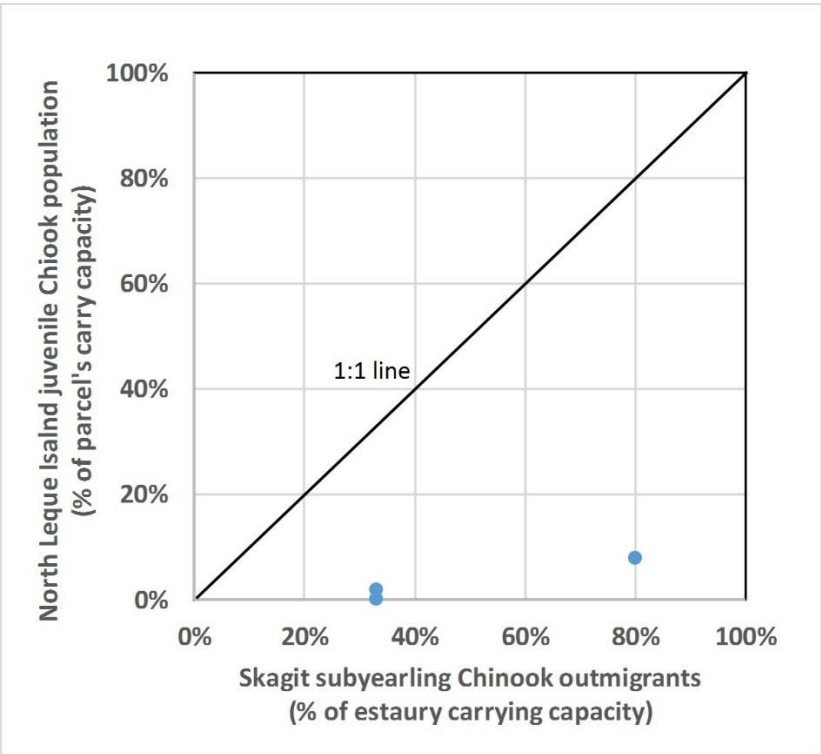

Figure 7. Relationship of juvenile Chinook salmon abundance in habitats nearby to North Leque Island as a function of Skagit River juvenile Chinook outmigration.

Conclusions and discussion related to existing juvenile Chinook monitoring data from sites nearby to North Leque Island:

1. Monitoring found juvenile Chinook present at all sites sampled nearby to North Leque Island suggesting juvenile Chinook are likely present in the North Leque Island tidal channels and would benefit from increased connectivity if the levees were removed.
2. However, juvenile Chinook abundance at the monitored site was very low compared to estimates for juvenile Chinook carrying capacity even when scaled by the number of outmigrants suggesting the benefit might not be very large in outmigration years not approaching estuary system level carrying capacity.
3. Are the results in Table 5 and Figure 7 really giving the correct picture for the number of juvenile Chinook that would use the North Leque Island area? My simple answer is that I don't know. It has not been the norm for restoration projects further upstream in the Skagit tidal delta. Many restoration project have higher than predicted number of fish using them (Wiley Slough, Beamer et al 2015; Fisher Slough, Beamer et al 2014). Some projects have about what is predicted (Swin Channel fill removal, SRSC unpublished data) while other are somewhat underperforming (SF Dike Setback, memo to Jeff McGowen from me) but I've not seen any results as low as what Table 5 and Figure 7 seems to indicate. I can think of several reasons why the results may be misleading:
    a. One possible reason is the Chinook carrying capacity model didn't utilize data from sites as far away as Leque Island so the model may over predict carrying capacity for areas with very low landscape connectivity values. In this case, the carrying capacity estimates are off and the monitoring data is more realistic.
    b. Fish monitoring around North Leque Island was not as extensive as what was used to make the Chinook Model or was used to for the fish effectiveness monitoring for the restoration projects mentioned above. The less extensive sampling effort may be leading to low juvenile Chinook abundance estimates because of the gaps in sampling. The Chinook model used data from sites sampled twice a month during February through August over a 10-year period. Restoration project effectiveness monitoring has mimic the twice per month, February through August pattern. Multiple years are the norm too. However, the fish data from nearby North Leque Island sites in Beamer et al 2009 was only monthly sampling February through June, and only a single year. I believe Jason's monitoring effort was only monthly sampling too, but was averaged over a 3-year period.

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