To: Jeff McGowen
Skagit County

From: Eric Beamer
Research Director
Skagit River System Cooperative

Date: May 14, 2015

Re: South Fork Dike Setback restoration project area

This memo:

1. Summarizes fish and environmental (DO) monitoring data collected at the South Fork Dike Setback restoration project area during 2012 and 2014 in order to provide context to predictions of juvenile Chinook salmon carrying capacity estimates for four restoration alternatives.
2. Presents juvenile Chinook carrying capacity estimates for alternatives described in the April 24, 2015 memorandum to Jeff McGowan from Susan Tonkin et al.

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## Fish and Local Environment Monitoring in 2012 &2014

The South Fork Dike Setback restoration project area is a riverine tidal wetland site located on the left bank of the South Fork of the Skagit River, approximately ¾ of a mile upstream from the town of Conway (Figure 1). The restoration project occurred in 2006. Restoration activities removed dike near the river and relocated it adjacent to an existing road. An existing blind tidal channel was reconnected to the river and extended into restored wetland area. Approximately 20 acres of a 40 acre parcel were reconnected to natural fluvial and tidal processes at this site.

The South Fork Dike Setback monitoring sites are within a blind channel system (Figure 1). A fyke trap was used at the blind channel mouth, spanning approximately 4.5 meters (m), narrowing to a width of roughly 2 – 3 m immediately upstream. Approximately 200 m upstream from the mouth, the channel opens to a three- lobed, cloverleaf-shaped, pond-like impoundment area. Because of hydraulic controls at the lower extent of the impoundment at the connection to the outlet channel, these pond-like areas retained water throughout tidal cycles and river fluctuations. Two of the three lobes or ponds were selected for beach seine sampling. Wetted area of the entire blind channel system was calculated based on field verification of GIS analysis using 2011 orthophotos and then verified in the field. Pond area was estimated at 2,494 $m^2$ while channel area was estimated at 869 $m^2$.

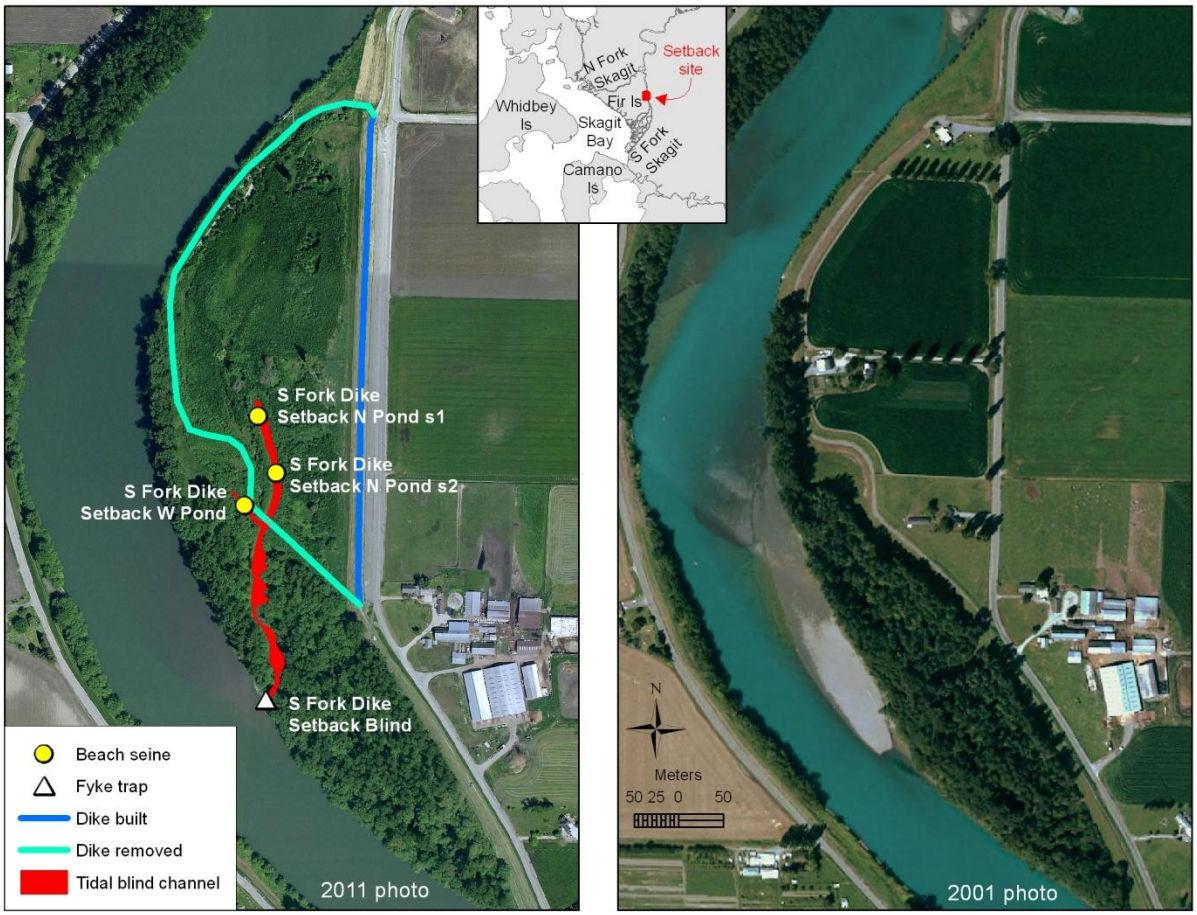



Figure 1. Aerial view of the South Fork Dike Setback restoration project site before (2001 photo) and after (2011 photo) restoration. The location of fish monitoring sites in 2012 are shown on the 2011 photo.

## *Fish assemblage*

Fish catch data from beach seining efforts in both years (2012 and 2014) are summarized in a table showing the total number of fish caught by species and their mean catch per effort.

Table 1. Total fish catch (and mean catch per beach seine set) by species at South Fork Dike Setback, 2012.

| | **Catch** | |
|---|---|---|
| **Salmonid species:** | Pond area | Fyke trap |
| Chinook salmon, unmarked subyearling *Oncorhynchus tshawytscha* | 599 (19.97) | 55 (5.00) |
| Coho salmon, unmarked subyearling *Oncorhynchus kisutch* | 35 (1.17) | 0 (0.00) |
| Coho salmon, unmarked yearling *Oncorhynchus kisutch* | 11 (0.37) | 1 (0.09) |
| Chum salmon, subyearling *Oncorhynchus keta* | 12 (0.40) | 2 (0.18) |
| Pink salmon, subyearling | 0 (0.00) | 1 (0.09) |
| Unidentified trout, subyearling *Oncorhynchus mykiss or clarki* | 0 (0.00) | 1 (0.09) |
| Whitefish, all ages *Prosopium williamsoni* | 65 (2.17) | 1 (0.09) |
| **Total salmonid catch** | **722** | **61** |
| | | |
| **Other freshwater or estuarine fish species:** | | |
| Threespine stickleback *Gasterosteus aculeatus* | 7,786 (259.53) | 47 (4.27) |
| Prickly sculpin *Cottus asper* | 6 (0.20) | 10 (0.91) |
| Peamouth chub *Mylocheilus caurinus* | 258 (8.60) | 0 (0.00) |
| Largescale sucker *Catosmus macrocheilus* | 870 (29.00) | 0 (0.00) |
| **Total other fish catch** | **8,920** | **57** |
| | | |
| **Total fish catch** | **9,642** | **118** |

Table 2. Total catch by species at South Fork Dike Setback sites February 20 through August 14, 2014. Mean catch per unit effort is in parentheses.

| Strata: | Beach seine | Fyke trap |
|---|---|---|
| **Salmonid species:** | | |
| Chinook salmon, unmarked subyearling *Oncorhynchus tshawytscha* | 494 (13.72) | 110 (10.00) |
| Chinook salmon, unmarked yearling *Oncorhynchus tshawytscha* | 1 (0.03) | 0 (0.00) |
| Chinook salmon, hatchery marked subyearling *Oncorhynchus tshawytscha* | 1 (0.03) | 0 (0.00) |
| Coho salmon, unmarked subyearling *Oncorhynchus kisutch* | 191 (5.31) | 0 (0.00) |
| Coho salmon, unmarked yearling *Oncorhynchus kisutch* | 26 (0.72) | 1 (0.09) |
| Pink salmon, subyearling *Oncorhynchus gorbuska* | 7 (0.19) | 4 (0.36) |
| Chum salmon, subyearling *Oncorhynchus keta* | 50 (1.39) | 12 (1.09) |
| Mountain whitefish, all ages *Prosopium williamsoni* | 7 (0.19) | 3 (0.27 |
| **Total salmonids:** | **777** | **130** |
| **Other fish species:** | | |
| Yellow perch, *Perca flavescens* | 41 (1.14) | 22 (2.00) |
| Prickly sculpin, *Cottus asper* | 5 (0.14) | 68 (6.18 |
| Three-spine stickleback, *Gasterosteus aculeatus* | 1,375 (38.19) | 39 (3.55) |
| Bass, unidentified species, *Micropterus* spp | 1 (0.03) | 0 (0.00) |
| Pumkinseed sunfish, *Lepomis gibbosus* | 5 (0.14) | 0 (0.00) |
| Peamouth chub, *Mylocheilus caurinus* | 681 (18.92) | 0 (0.00) |
| Redside shiner, Richardsonius *balteatus* | 1 (0.03) | 0 (0.00) |
| **Total other fish species:** | **2,109** | **129** |
| **Total fish catch:** | **2,886** | **259** |

## *Juvenile Chinook salmon*

### Monthly Density

There is a seasonal curve of juvenile Chinook salmon using South Fork Dike Setback habitat each year (Figures 2 and 3). Peak juvenile Chinook density was in March of both years. In both years, juvenile Chinook were not present in South Fork Dike Setback habitat in the months of July and August.

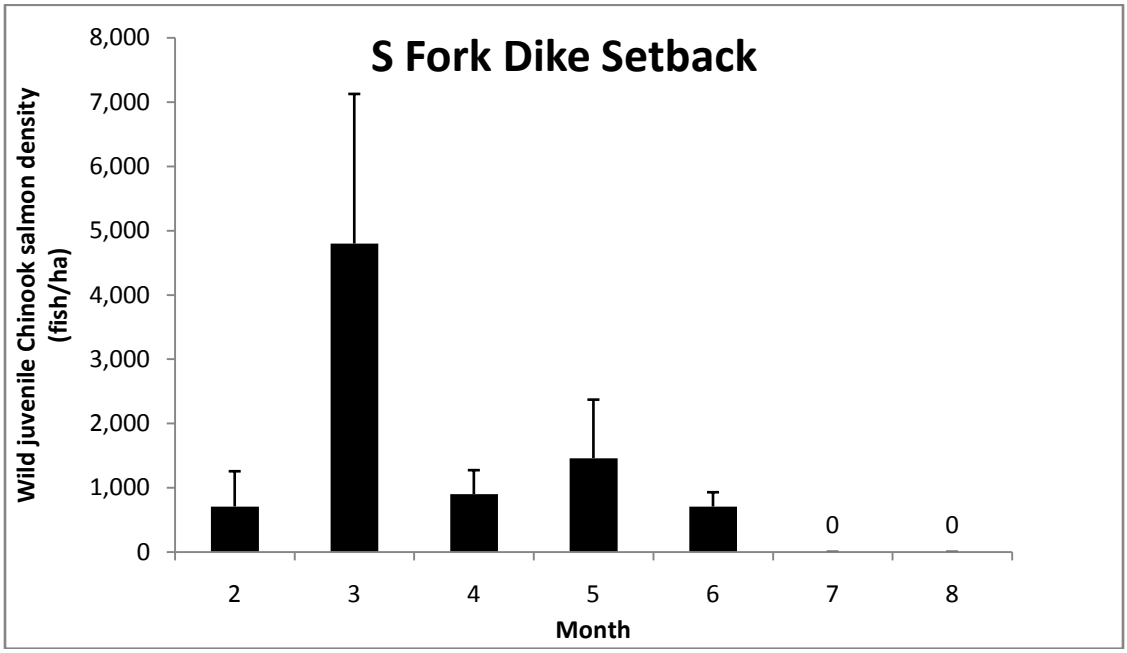



Figure 2. Weighted average monthly density of wild juvenile Chinook salmon caught in the South Fork Dike Setback restoration site in 2012. The four fish sampling sites shown in Figure 1 were weighted by habitat area (pond, tidal channel) and averaged. No Chinook salmon were caught in the months of July and August. Error bars are standard error.

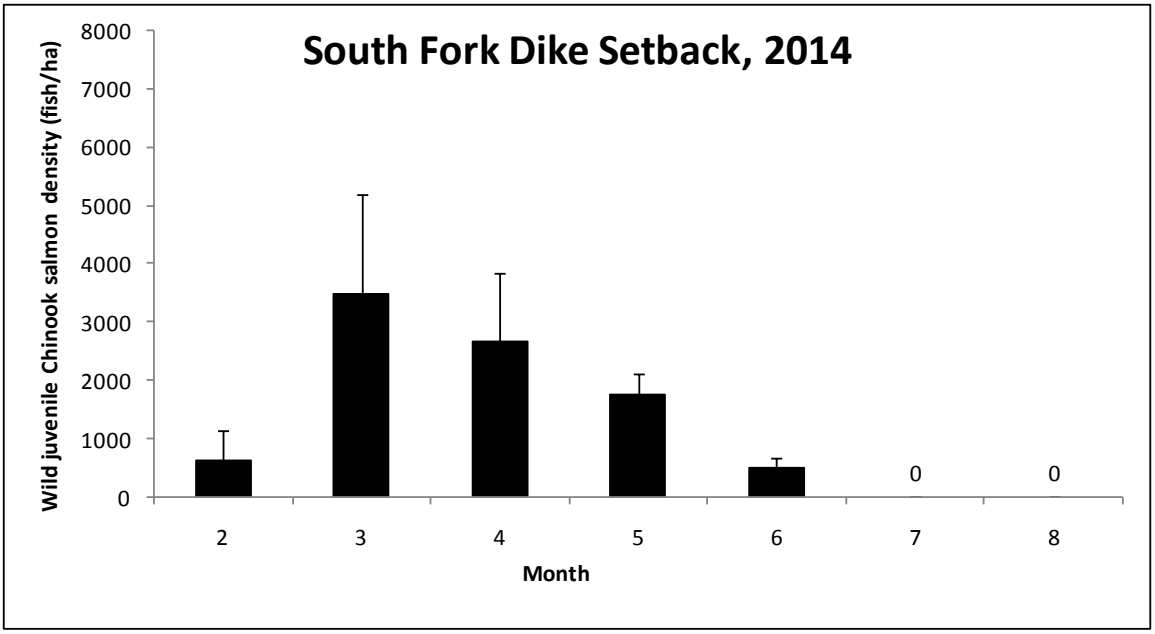



Figure 3. Weighted average monthly density of wild juvenile Chinook salmon caught in the South Fork Dike Setback restoration site in 2014. The four fish sampling sites shown in Figure 1 were weighted by habitat area (pond, tidal channel) and averaged. No Chinook salmon were caught in the months of July and August. Error bars are standard error.

## Annual Abundance

Juvenile wild Chinook salmon abundance estimates were made to determine the number of fish that reared in restored habitat of the South Fork Dike Setback in 2012 and 2014 compared to model-generated carrying capacity estimates for juvenile Chinook salmon. Fish abundance was calculated as: fish density multiplied by the wetted area of South Fork Dike Setback during the time of sampling.

Fish abundance was calculated for each beach seine or fyke trap set on each sampling date because juvenile Chinook salmon catches varied by site and time of year. Ponded areas were beach seined and the outlet channel was fyke trapped. Pond area was estimated at 2,494 $m^2$ while channel area was estimated at 869 $m^2$.

Individual fish abundance estimates were averaged by pond (beach seine) and channel (fyke trap) habitat for each year (2012 and 2014), resulting in average daily juvenile Chinook salmon abundance for the entire monitoring period (February through mid-August = 195 days) for each area in each year. Average juvenile Chinook salmon abundance was multiplied by the 195-day period, yielding an estimate of fishdays, then divided by the average resident time (35 days) of individual juvenile Chinook salmon rearing in Skagit River tidal delta habitat (Beamer et al. 2000). This calculation procedure is an estimate of the population of juvenile Chinook salmon that used Wiley and Teal Slough lobes during the 2012 and 2014 monitoring periods.

Table 3. Population estimate of individual juvenile wild Chinook salmon that used habitat within the South Fork Dike Setback during the 2012 and 2014 monitoring period (February through mid-August, 195 days) based on expansion of juvenile wild Chinook density results from four sites with South Fork Dike Setback (Figure 1). Results are based on 41 and 47 beach seine and fyke trap sets made in 2012 and 2014, respectively.

| **Year** | **Seasonal Chinook abundance in fishdays**<br><br>**Point estimate (upper & lower 95% CI)** | **Average Chinook delta residence period (days)** | **Juvenile Chinook population**<br><br>**Point estimate (upper & lower 95% CI)** |
|---|---|---|---|
| 2012 | 262,052 | 35[a] | 7,487 |
| 2014 | 275,377 | | 7,868 |

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

95% confidence intervals not calculated yet. They will be wide.

## Comparison to other Skagit sites

In this section we answer the fish monitoring question: *How does seasonal juvenile Chinook salmon density in South Fork Dike Setback compare to reference sites throughout the Skagit estuary in 2012?*

Landscape connectivity, or large-scale connectivity, refers to the relative distances and pathways that salmon must travel to find habitat over a very large area. As this concept is applied in the Skagit River delta, landscape connectivity is a function of both the distance and complexity of the pathway that salmon must follow to specific habitat areas (e.g., sites within South Fork Dike Setback habitat). Connectivity decreases as complexity of the route the fish must swim increases and the distance the fish must swim increases. Within the delta, the complexity of the route fish must take to find habitat is measured by the distributary bifurcation order and distance traveled. Habitat that is less connected to the source of fish has lower densities of fish. By determining landscape connectivity to various sites, comparisons of juvenile Chinook salmon usage results from South Fork Dike Setback fish sampling sites with that of other sites throughout the Skagit River tidal delta can be made in order to determine whether South Fork Dike Setback project is functioning consistently with the rest of the Skagit River delta.

The season-long density of juvenile Chinook salmon at all South Fork Dike Setback monitoring sites and at other long-term monitoring sites located throughout the Skagit River tidal delta was estimated. This fish density statistic is termed *cumulative Chinook salmon density*. Cumulative Chinook salmon density was estimated for the periods February 1 through August 15 for timing curves of juvenile Chinook salmon in Skagit River tidal delta habitat. The exact start and end dates used for all data (South Fork Dike Setback Slough sites and Skagit long term monitoring sites) is based on the start and ending dates of sampling at Wiley and Teal Sloughs. Cumulative Chinook salmon density (C) (fish*days*ha$^{-1}$) was calculated as:

$$C = \sum_{m=F}^{L} D_m n_m$$

where $D_m$ is the average monthly density, $n_m$ is the number of days in the month, and $F$ and $L$ are the first and last months ($m$) sampled, respectively.

The cumulative Chinook salmon density by landscape connectivity was plotted to graphically determine whether juvenile Chinook salmon are using the habitat in the South Fork Dike Setback project area at different densities than at natural tidal channel sites within the Skagit tidal delta.

Landscape connectivity (LC) for each site is calculated:

$$LC = \frac{1}{\sum_{j=1}^{j_{end}} (O_j * D_j)}$$

where $O_j$ = distributary channel order for channel segment $j$, $D_j$ = distance along segment $j$ of order $O_j$, $j$ = count (1...$j_{end}$) of distributary channel segments, and $j_{end}$ = total number of channel segments at destination or sample point.

We calculated landscape connectivity to fish sampling sites (see Appendix 1) and then averaged the landscape connectivity values for sites by year (2012 or 2014). The average landscape connectivity value was then plotted with cumulative Chinook salmon density and shown in Figure 4.

There is a positive relationship between seasonal wild juvenile Chinook salmon density and landscape connectivity for the long term monitoring sites throughout the Skagit River delta in 2012 (Figure 4). In 2012, landscape connectivity explains 85% of the variation in seasonal juvenile Chinook salmon density at the Skagit River delta long-term monitoring sites. We are unable to make the same plot for 2014 data because results for long term monitoring sites are not yet available.

The South Fork Dike Setback result for 2012 plots lower than the relationship between seasonal wild juvenile Chinook salmon density and landscape connectivity for other Skagit River delta long-term monitoring sites. In fact, the South Fork Dike Setback results is nearly 7 times lower in seasonal Chinook density than its closest reference site with respect to landscape connectivity (Figure 4). A possible explanation for this result is:

1. recent sedimentation in the channel reducing fish access to the habitat within South Fork Dike Setback, and
2. lower than ideal dissolved oxygen levels (see next section of memo) which are also likely related to a lack of connectivity with the river.

We recommend future restoration at this site should include a design that improves fish access and DO through a better connection with riverine (and tidal) processes.

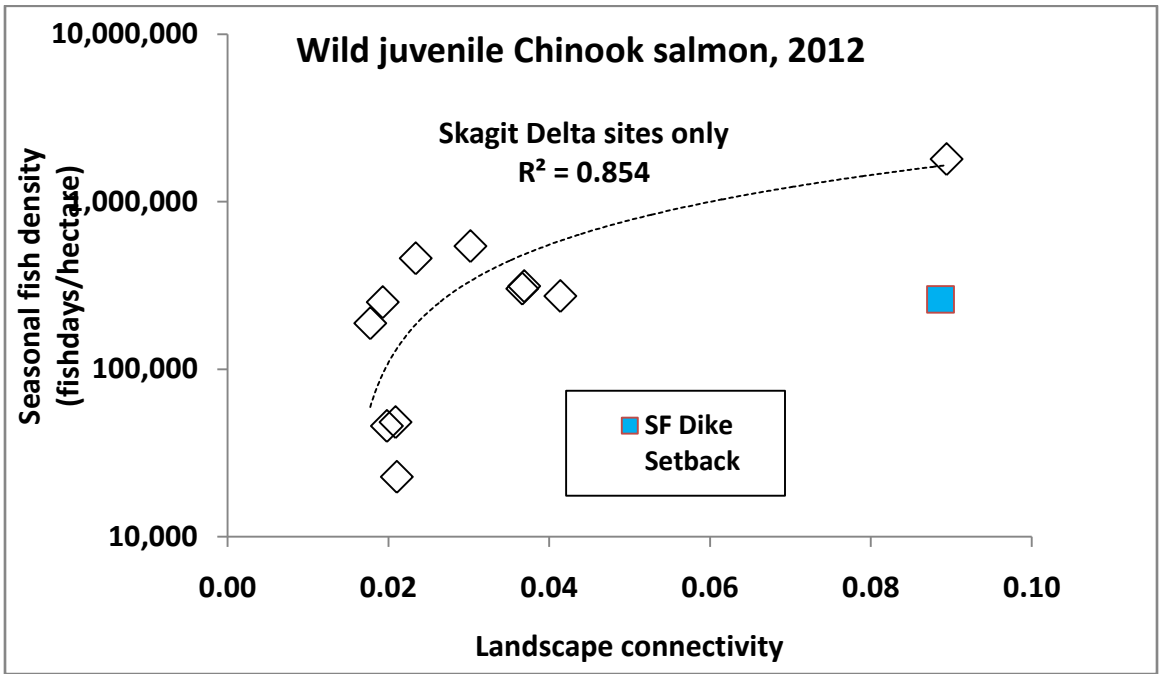



Figure 4. Relationship between landscape connectivity and seasonal Chinook salmon density for Skagit River delta long-term monitoring sites and South Fork Dike Setback monitoring sites, 2012.

## *Local Environment*

Environmental conditions at fish sampling sites were generally at levels known to be suitable for juvenile salmon rearing, with one exception: dissolved oxygen (DO) within pond area in summer months. In pond area monthly average DO varied from a high of 11.17 mg/L in February to a low of 0.73 mg/L in July (Figure 5). During the sampling in July 2012 we found a new sand bar created from deposition at the mouth of the channel, and we found the water in the pond area had become stagnant. During the sampling in August 2012, there was a little more river flow, and the dissolved oxygen levels had increased to 3.78 mg/L in the pond area. Both the July and August average values are below the 1 day Washington State Dissolved Oxygen Standard of 6.5 mg/L established for freshwater waters where juvenile salmon are rearing or migrating through.

Jeff – didn't have time to write a paragraph for 2014, but the overall pattern is the same as 2012. Poorer DO in July and August in the pond areas (less connected to the river).

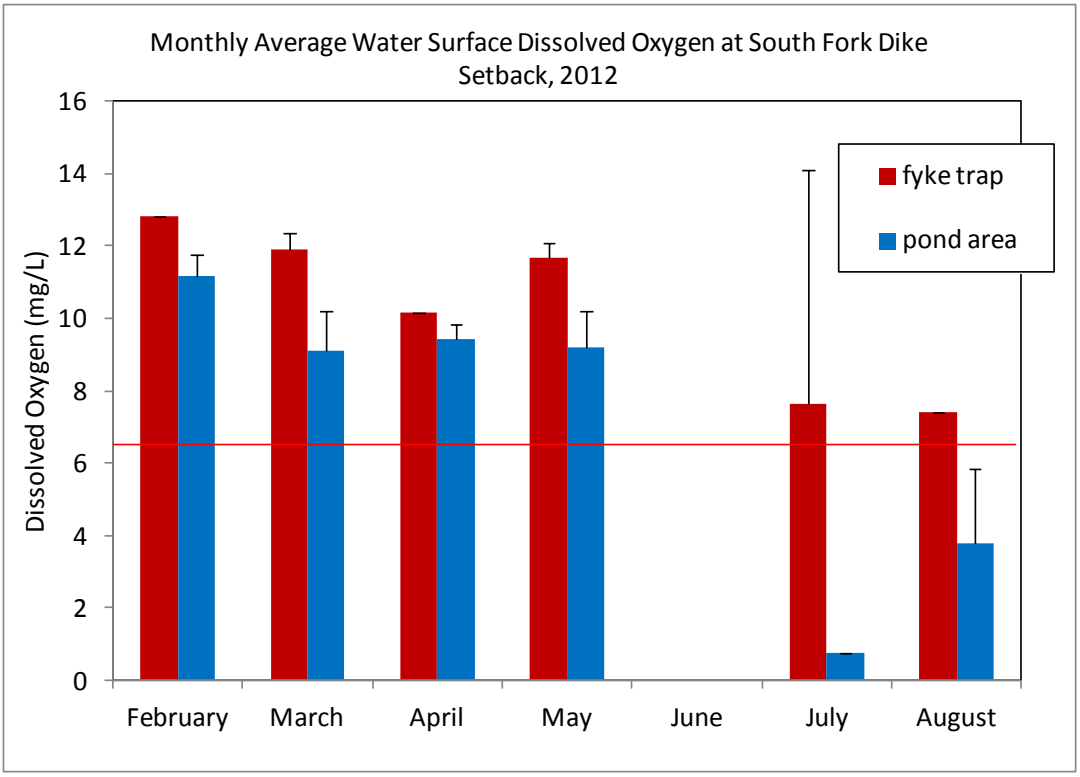



Figure 5. Monthly average dissolved oxygen (DO) measured at the water surface in South Fork Dike Setback, 2012. The error bars are one standard deviation. The horizontal red line is the threshold line for DO (6.5 mg/L, Washington State 1 day minimum water quality standard for juvenile salmonid rearing and migration in fresh waters). Values below the threshold are considered unhealthy for juvenile salmon. There were no DO data collected in June.

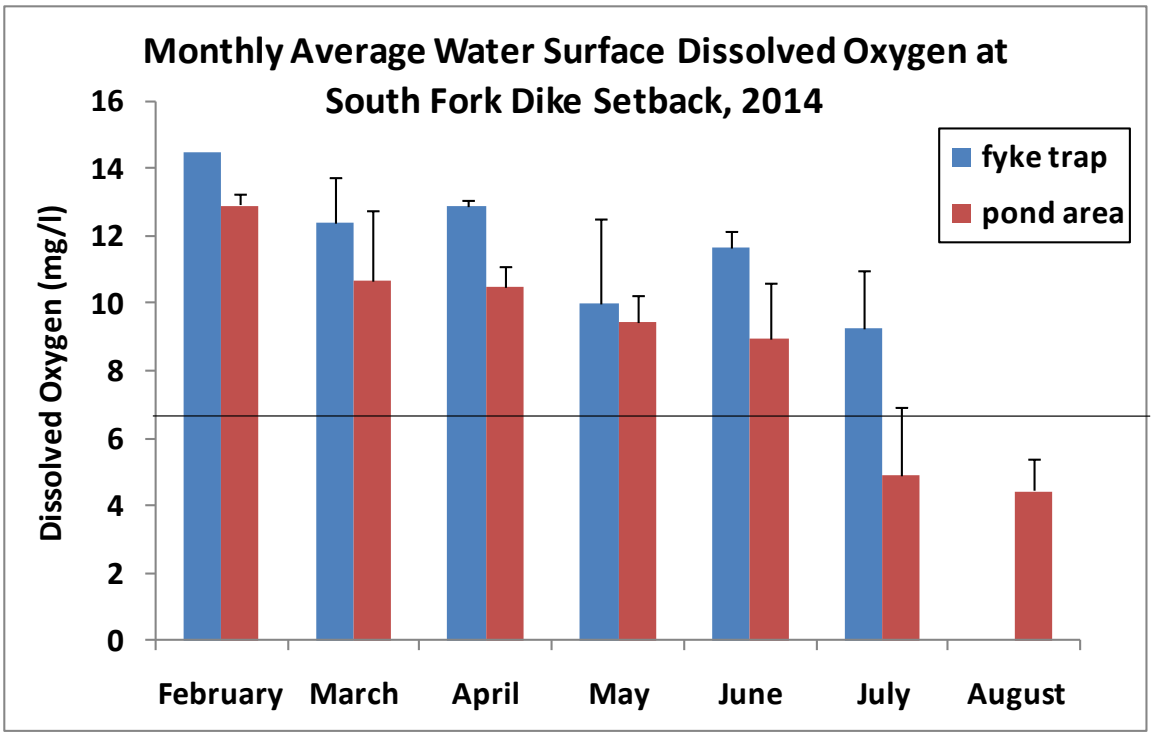



Figure 6. Monthly average dissolved oxygen (DO) measured at the water surface in South Fork Dike Setback, 2014. The error bars are one standard deviation. The horizontal red line is the threshold line for DO (6.5 mg/L, Washington State 1 day minimum water quality standard for juvenile salmonid rearing and migration in fresh waters). Values below the threshold are considered unhealthy for juvenile salmon. There were no DO data collected in August from the Fyke Trap.

## Juvenile Chinook Carrying capacity estimates

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).

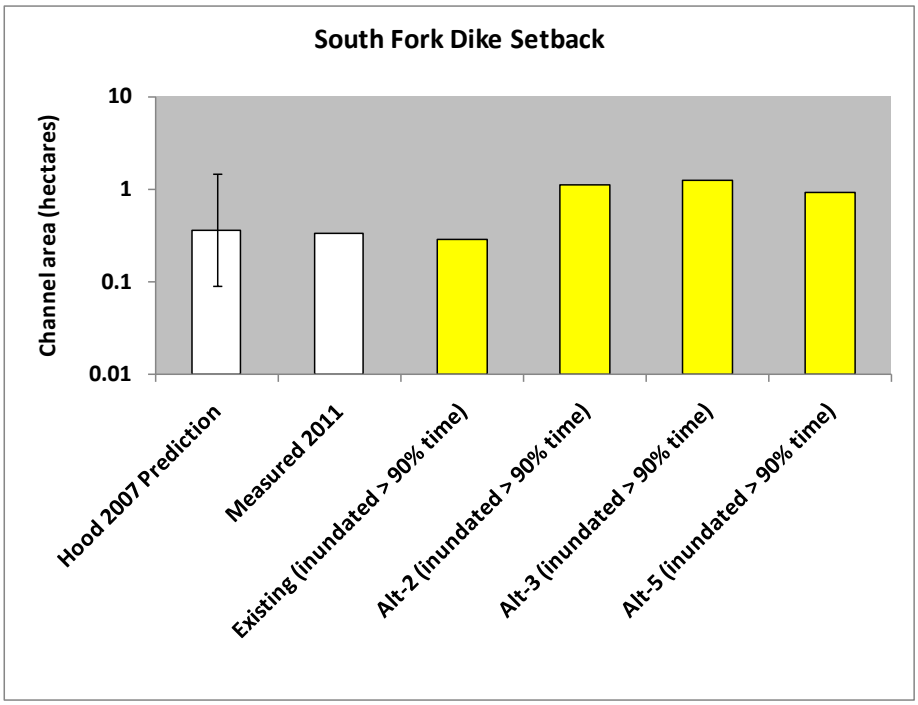
Table 4. Juvenile wild Chinook salmon carrying capacity model results for South Fork Dike Setback. Landscape connectivity is from Appendix 1. Wetted areas are from April 24, 2015 memorandum to Jeff McGowan from Susan Tonkin et al..

| **Alternative** | **Landscape connectivity** | **Habitat Area (ha) Type** | **Smolts annually** |
|---|---|---|---|
| Existing (inundated > 90% of time) | 0.08865 | 0.2832 | 12,136 |
| Alternative 2 (inundated > 90% of time) | | 1.1331 | 48,543 |
| Alternative 3 (inundated > 90% of time) | | 1.2545 | 53,744 |
| Alternative 5 (inundated > 90% of time) | | 0.9308 | 39,875 |

## Sustainability of wetted habitat area within South Fork Dike Setback

Sustainable channel conditions are reached after natural hydrologic and sedimentation processes achieve a balance at the site. Equilibrium channel area for the South Fork Dike Setback area is 0.365 hectares (0.091-1.461, 95% CI) based on allometric analysis of reference sites in the adjacent South Fork Skagit delta (after Hood 2007). In 2011, we measured 0.3363 hectares of channel and ponded habitat that fish were using which is close to the point estimate based on Hood 2007. However, in the two years of fish monitoring we found evidence of channel filling which suggest the 2011 amount of habitat is not sustainable. We provide these results (Hood based estimate of equilibrium channel area, our 2011 estimate) to provide context to the wetted area estimates from the alternatives described in the April 24, 2015 memorandum to Jeff McGowan from Susan Tonkin et al.

In general, the measured conditions in 2011 coincides with estimates in the April 24, 2015 memorandum to Jeff McGowan from Susan Tonkin et al. for Existing Condition. Alternatives 2, 3, and 5 fit within the upper 95% confidence interval of the norm from Hood 2007. However, we see evidence that current conditions are not sustainable so recommend caution against building more habitat within the site without a plan for maintaining that amount of habitat.



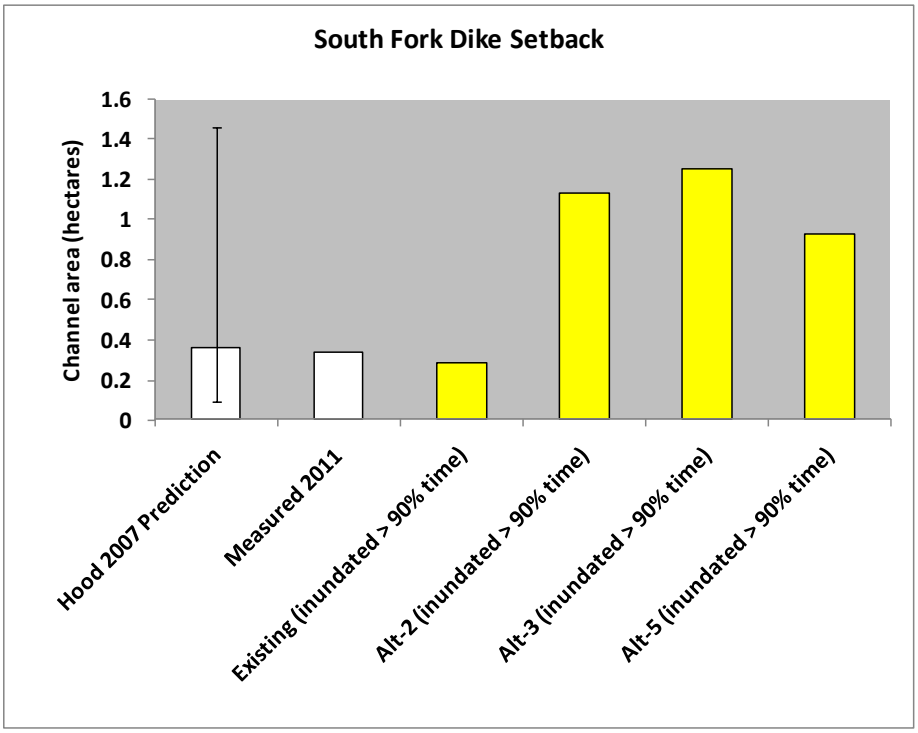




Figure 7. Wetted habitat areas for the South Fork Dike Setback area by various methods. Top panel is log scaled. Bottom panel is not log scaled.

# Appendix 1: Landscape connectivity calculations

**S Fork Dike Setback Restoration Project: Landscape Connectivity Calculation**

**Date**: May 2015

**By**: Karen Wolf, Skagit River System Cooperative

**Purpose and Calculation Methods:**
Within the delta and nearshore ecosystems of the Skagit River, Beamer et al. (2005) used habitat connectivity as an attribute to help predict the use of specific habitats for Chinook salmon recovery planning.

Landscape connectivity was defined as a function of both the length and the complexity of the pathway that juvenile Chinook salmon must follow to certain types of habitats, like blind tidal channels in the Skagit delta or pocket estuaries in adjacent nearshore areas. Habitat connectivity decreases as the complexity of the route fish must swim increases and as the distance the fish must swim increases. Within the Skagit delta, the complexity of the route fish must take to find key habitat was measured by the delta distributary channel bifurcation order and distance traveled. Beamer et al. (2005) show results from 2003, which had an outmigration population size of 5,500,000 juvenile Chinook salmon. In this year, landscape connectivity explained 68% of the variation in seasonal density of Chinook salmon at monitored sites within the Skagit estuary (see pages 20-21 of Beamer et al. 2005).

An ArcMap data layer, *fish_direction*, was created in GIS to calculate landscape connectivity values for specific places within the Skagit tidal delta or pocket estuaries within adjacent nearshore areas (e.g., Skagit Bay or Padilla Bay). *Fish_direction* reflects the pathways through which juvenile Chinook salmon are expected to move through the delta channel network and along the nearshore to find and colonize habitat. It includes quantification of 'Bi' (index bifurcation order) by creating GIS-based rules for the methods described in Appendix D.V, page 79 of Beamer et al. (2005). Pathway location and direction outside of the tidal delta is based on drift buoy results (Appendix D.VI, page 81 in Beamer et al. 2005) and low tide channel locations visible on orthophotos. The following attributes are included in the *fish_direction* GIS theme and are included in tables below for each Landscape Connectivity calculation.

**<u>Definitions of Table Attributes</u>**

| | |
|---|---|
| Bi | Index bifurcation order |
| Length_km | Length of arc in kilometers |
| Km_x_bi | Kilometer length multiplied by Bi |
| Sum | Sum of all Km_x_bi values for a specific pathway |
| Landscape Connectivity | 1/Sum |

**Results:**
I calculated values of Landscape Connectivity for the fyke and beach seine sites within the S Fork Dike Setback Restoration area (Figure 1, Tables 1-4).

## Reference

Beamer, E., and coauthors. 2005. Delta and nearshore restoration for the recovery of wild Skagit River Chinook salmon: Linking estuary restoration to wild Chinook salmon populations. Skagit River System Cooperative, Appendix D to the Skagit Chinook Recovery Plan, LaConner, WA. Available at www.skagitcoop.org.

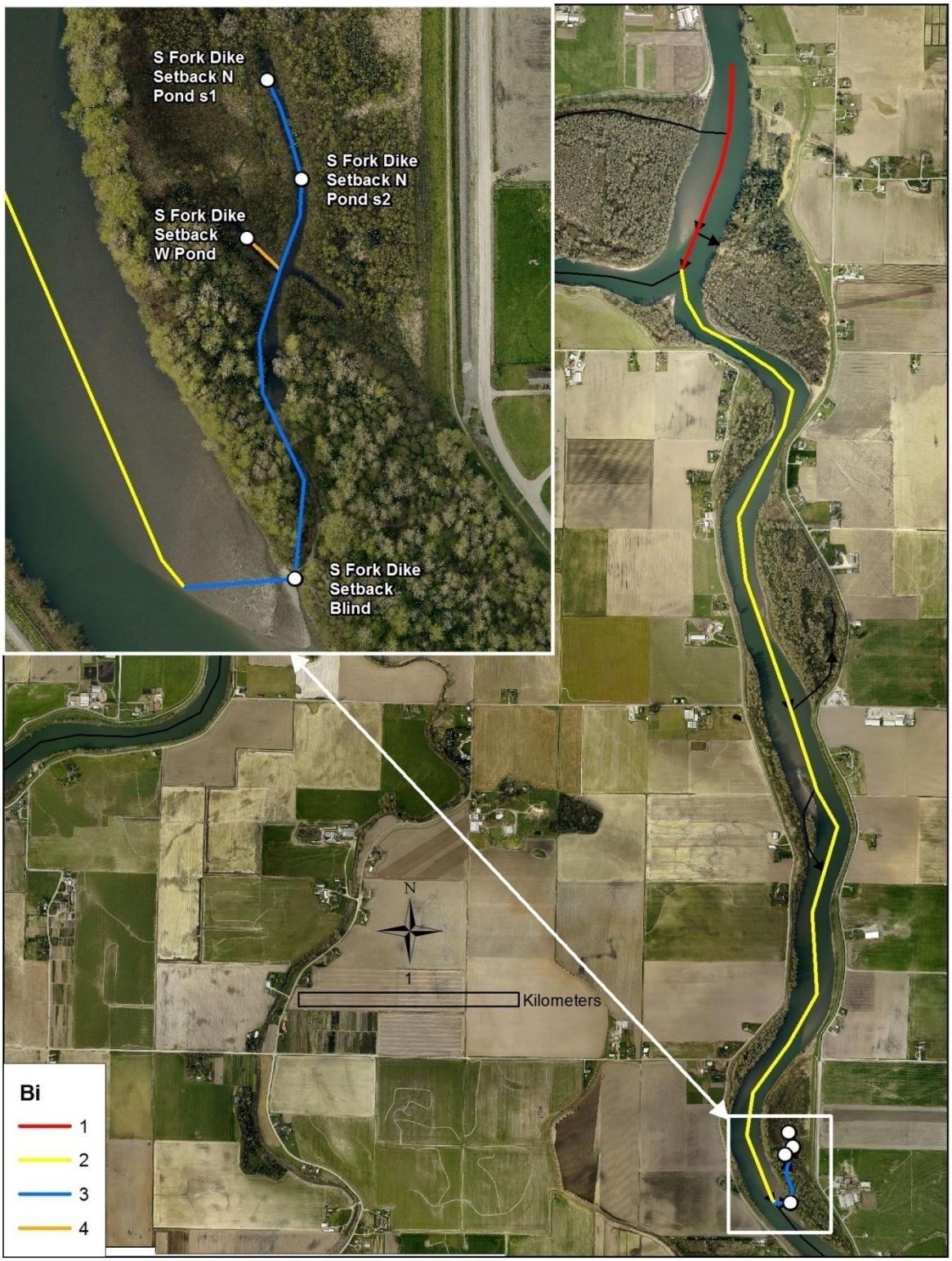



Figure 1. Pathways used to calculate Landscape Connectivity to S Fork Dike Setback sites. Thin black arcs with arrows are from the GIS theme *fish_direction*. Thicker arcs show the pathways chosen for calculating Landscape Connectivity to these sites and are colored by their Bi value.

Table 1. Worksheet showing calculation of Landscape Connectivity to S Fork Dike Setback Blind site. Arcs are listed in order from mainstem to sampling site.

| Order | Comments | Bi | length_km | km_x_bi |
|---|---|---|---|---|
| 1 | mainstem, start of theme | 1 | 0.78575 | 0.78575 |
| 2 | mainstem to fork | 1 | 0.18540 | 0.18540 |
| 3 | SF from fork to SF Off Chan | 2 | 2.33017 | 4.66034 |
| 4 | from SF Off Chan to dike setback blind | 2 | 2.41108 | 4.82215 |
| 5 | to SF Dike Setback Blind | 3 | 0.07042 | 0.21125 |
| | **Sum** | | | **10.66489** |
| | **Landscape Connectivity** | | | **0.09377** |

Table 2. Worksheet showing calculation of Landscape Connectivity to S Fork Dike Setback W Pond site. Arcs are listed in order from mainstem to sampling site.

| Order | Comments | Bi | length_km | km_x_bi |
|---|---|---|---|---|
| 1 | mainstem, start of theme | 1 | 0.78575 | 0.78575 |
| 2 | mainstem to fork | 1 | 0.18540 | 0.18540 |
| 3 | SF from fork to SF Off Chan | 2 | 2.33017 | 4.66034 |
| 4 | from SF Off Chan to dike setback blind | 2 | 2.41108 | 4.82215 |
| 5 | to SF Dike Setback Blind | 3 | 0.07042 | 0.21125 |
| 6 | up blind chan towards SF Setback seine sites | 3 | 0.20440 | 0.61321 |
| 7 | to Setback W Pond | 4 | 0.02886 | 0.11544 |
| | **Sum** | | | **11.39355** |
| | **Landscape Connectivity** | | | **0.08777** |

Table 3. Worksheet showing calculation of Landscape Connectivity to S Fork Dike Setback N Pond s2 site. Arcs are listed in order from mainstem to sampling site.

| Order | Comments | Bi | length_km | km_x_bi |
|---|---|---|---|---|
| 1 | mainstem, start of theme | 1 | 0.78575 | 0.78575 |
| 2 | mainstem to fork | 1 | 0.18540 | 0.18540 |
| 3 | SF from fork to SF Off Chan | 2 | 2.33017 | 4.66034 |
| 4 | from SF Off Chan to dike setback blind | 2 | 2.41108 | 4.82215 |
| 5 | to SF Dike Setback Blind | 3 | 0.07042 | 0.21125 |
| 6 | up blind chan towards SF Setback seine sites | 3 | 0.20440 | 0.61321 |
| 7 | to SF Setback N Pond s2 | 3 | 0.05948 | 0.17844 |
| | **Sum** | | | **11.45655** |
| | **Landscape Connectivity** | | | **0.08729** |

Table 4. Worksheet showing calculation of Landscape Connectivity to S Fork Dike Setback N Pond s1 site. Arcs are listed in order from mainstem to sampling site.

| Order | Comments | Bi | length_km | km_x_bi |
|---|---|---|---|---|
| 1 | mainstem, start of theme | 1 | 0.78575 | 0.78575 |
| 2 | mainstem to fork | 1 | 0.18540 | 0.18540 |
| 3 | SF from fork to SF Off Chan | 2 | 2.33017 | 4.66034 |
| 4 | from SF Off Chan to dike setback blind | 2 | 2.41108 | 4.82215 |
| 5 | to SF Dike Setback Blind | 3 | 0.07042 | 0.21125 |
| 6 | up blind chan towards SF Setback seine sites | 3 | 0.20440 | 0.61321 |
| 7 | to SF Setback N Pond s2 | 3 | 0.05948 | 0.17844 |
| 8 | to SF Setback N Pond s1 | 3 | 0.06683 | 0.20050 |
| | **Sum** | | | **11.65705** |
| | **Landscape Connectivity** | | | **0.08579** |