Task 4 Dungeness River Aquifer Recharge Habitat Technical Memorandum

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SUBJECT: Dungeness River Aquifer Recharge Habitat Effects

INTRODUCTION

Clallam County Environmental Health Services and their project partners, including Clallam Conservation District, Clallam PUD, City of Sequim, Washington State Department of Ecology, various irrigation districts/companies, and the Jamestown S'Klallam Tribe, are working cooperatively on a groundwater storage grant received from the Washington State Department of Ecology Water Resources Program in February 2006 to study the feasibility of aquifer recharge (AR) in the Dungeness watershed (Ecology Grant No. G0600342). The objectives for conducting AR in the watershed include storing peak surface water from the Dungeness River in local groundwater aquifers for: (1) augmentation of late-season flows in the lower mainstem Dungeness River and tributaries; (2) augmentation of adjacent small streams; and (3) maintenance or augmentation of groundwater levels.

The County retained the consulting team of Pacific Groundwater Group, Anchor Environmental, R2 Resource Consultants, Brown and Caldwell and Groundwater Solutions, Inc. to assist with the development of the feasibility study envisioned in the grant. One of the tasks inherent in the grant was the preparation of a technical memorandum describing the potential effects of surface water withdrawal on the freshwater habitats in the Dungeness River system during periods of the year when water is available. The task objective is to evaluate habitat impacts from AR diversion when the river discharge exceeds recommended instream minimums based on IFIM studies (Hiss and Lichatowich 1990, Wampler and Hiss

1991, Hiss 1993a,b), excluding the period from August through October. The TM uses the existing recommended instream flow levels, but recognizes these levels may change in the future. The Tribe has petitioned Ecology to review the monthly flow levels, especially as they relate to the abrupt transition from July 31st (475 cfs) to August 1st (180 cfs). The following technical memorandum (TM) addresses Task 4 of the Dungeness River AR Grant.

Project Layout Assumptions

Specific project details related to the timing, quantity, duration and location of proposed withdrawals have not been developed to date. For the purposes of this TM, it is assumed the withdrawal could occur at any of the irrigation district outtakes between River Mile (RM) 11.0 and 6.9. Several rates of diversion will be explored in the TM as discussed in the *Approach* section below. Water diverted for aquifer recharge purposes likely will be routed to infiltration ditches, infiltration ponds, or injection wells to recharge the groundwater system. The AR operation would likely be designed to facilitate return of a portion of the recharged water to the Dungeness River, tributaries, and small streams during periods of critical low flow (e.g. four months after the spring freshet).

The intended purpose of this Habitat TM is to assist the selection of model simulations in Task 3 and the Feasibility Assessment in Task 6 of the grant by describing potential habitat sensitivity to changes in river flow on an incremental basis for a series of diversion rates. The TM will help identify feasible withdrawal options based on potential habitat modifications in both the mainstem and side channel areas of the lower Dungeness River. AR benefits of groundwater return flow to the Dungeness River during the low flow season will be evaluated in a similar fashion during the Feasibility Assessment when predictions for return flows are available.

Following the introduction, the TM methodology is described in Section 2.0, ***Approach***. This section includes the description of the hydrologic records intended for use, the reference sites chosen for assessment as well as the habitat needs and periodicity of use for the anadromous fish species and life history stages of interest. Section 3.0, ***Result/Discussion***, includes a discussion of the results for both mainstem and side channel habitats and an assessment of the number of life history stages potentially influenced over time. Tables of habitat sensitivity to incremental flow modifications for various seasons are included. A summary of the findings is included in Section 4.0 ***Conclusions***. This working draft is intended for TAG review and comments. A final Habitat TM will be completed following receipt of comments.

APPROACH

The influence of several rates of diversion on habitat changes in the mainstem Dungeness River and selected side channels between November and July is addressed herein. Considered rates of diversion are based on the schedule of flows in excess of minimum instream flow requirements and reasonable assumptions of transmitting capacity for AR diversions. Changes in flow addressed in this report include reductions of 2, 5, 10, 15, 30, and 50 cfs during periods when these rates represent approximately 1 to 5 percent of the incoming flow at the USGS gaging station at RM 11.8. The highest diversion rates are associated with short-term withdrawals during peak runoff events. A representative site in the mainstem river that corresponds to a majority of the mainstem habitat conditions in the lower Dungeness River and several surface water connected side channels characteristic of the area are assessed.

As a surrogate for habitat influences on the mainstem, the assessment uses the existing documentation from the upper in-stream flow (IFIM) study site at RM 4.2, that represents unconfined, braided channel conditions (Hiss 1993a,b). Anticipated changes for each life stage and species originally run in the model, including Chinook, coho and pink salmon, steelhead trout and native char, are depicted. The periodicity of life-history stage use of these species in the lower river is used to prioritize habitat effects given the time period anticipated for AR diversions. The influence of diversion rates on Instream Flow Incremental Method (IFIM) spawning and rearing Weighted Useable Area (WUA) indices are put into qualitative context with other habitat factors that might be affected by reductions in seasonal peak flows.

The work of Daraio et al. (2003) is used to assess flow and habitat conditions for the various side channels downstream of RM 11.0, when each of the channels is connected to the mainstem river. This Bureau of Reclamation study offers flow/habitat relationships in selected key side channels in the lower river for various fish species, including all of the species evaluated in the IFIM study. The surface water-connected side channels with developed habitat/flow relationships downstream of RM 11.0 include the Kinkade East, Kinkade middle, Kinkade West, Dawley, Lower East Railroad Bridge, Stevens/Savage and Anderson side channels. The anticipated mainstem flow range that preferred habitat is available in the side channels is calculated for each of the identified rates of diversion. Although river flow and habitat characteristics for individual side channels are dynamic in nature, it is assumed the observed habitat trends in the Daraio et al (2003) study are representative of the other side channels in the lower watershed and that the trend in habitat conditions with mainstem river flow will be maintained on average, over time, across the many side channels downstream of RM 11.0.

RESULTS/DISCUSSION

Hydrology

For the purposes of establishing reference conditions, hydrologic data for three specific locations in the Dungeness River are compared as follows:

- The USGS gaging station #12048000 Dungeness River near Sequim, WA located at RM 11.8.
- The upper IFIM study site on the Dungeness River mainstem at RM 4.2.
- Washington Department of Ecology gaging station ID 18A050, at the Schoolhouse Bridge, RM 0.75.

The USGS site occurs upstream of all existing and proposed diversion sites. It represents the longest period of flow record in the watershed and the base control site for hydrology in the watershed.

The upper Instream Flow Incremental Methodology (IFIM) study reach represents hydrologic conditions from a braided reach. It was used in combination with a lower study site at RM 2.8 that represents a single, confined channel reach in setting the current flow regime for the lower river (Hiss 1993). There is no flow measurement station at either RM 4.2 or 2.8. Stream flow at the upper IFIM study site at RM 4.2 is a function of: (1) surface water inflow at the USGS gage (RM 11.8); (2) the amount of water withdrawn for irrigation purposes between RM 11.0 and 6.9; (3) the natural flow in the channel gained or lost to groundwater between RM 11.8 and 4.2; and (4) tributary surface water inflow. It is likely the observed natural seepage losses in the lower river are offset by tributary inputs such that river discharge at RM 4.2 is commensurate with measured streamflow data described below for the Schoolhouse Bridge.

Ecology's gaging station at the Schoolhouse Bridge (RM 0.75) will likely be the measurement point for future compliance with the minimum instream flow levels in the lower river (Caldwell, B. Washington Department of Ecology, pers. comm. Oct 12, 2006 TAG Habitat Subgroup meeting). Flow availability for AR diversions at the Schoolhouse Bridge will be further performed as another portion of Task 3. Seasonal minimum instream flow recommendations based on the IFIM study results are 575 cfs from November through March, 475 cfs April through July and 180 cfs August through October, as shown if Figure 1.

Streamflow at USGS Gage Site at RM 11.8

England (1999) provides flow duration curves for this site during the period-of-record, up to the time of his report [1923 – 1930; 1937 – 1998]. According to England (1999), the peak flow exceedance probabilities (the percentage of time a flow is equaled or exceeded on an annual basis) and return intervals for the USGS Dungeness River gaging station at RM 11.8 are shown in Table 1.

Table 1. USGS Flood Frequency Statistics for Station No. 12048000; Dungeness River near Sequim, WA.

Exceedance Probability	Peak Flow Return Interval	Discharge (cfs)
50%	2-yr.	2,990 ± 13%
10%	10-yr.	5,780 ± 13%
4%	25-yr.	7,120 ± 17%
2%	50-yr.	8.060 ± 22%
1%	100-yr.	8,960 ± 27%

Source: England (1999); Statistics range at the 95% confidence interval

Most fluvial bedload materials [coarse sediment layers associated with the channel bed] move during peak flow events. Ecologic and geomorphologic functions related to forming a hydrologic equilibrium with channel banks and side channels, refreshing spawning gravels and moving pool forming elements in streams are a function of peak flows on the order of the 1.5- to 2-year return interval and greater (Dunne and Leopold 1978; Castro and Jackson 2001). It is desirable to maintain river flows of this nature, often referred in the scientific literature as 'flushing' flows, for habitat formation and renewal. Thus, AR target diversion flows focus on the range of instream flows between the seasonal recommended instream flows and the flushing flows, which we select as a discharge at the USGS station of 2,650 cfs [the lower 95^{th} confidence interval range of the estimate for the 2-yr. peak flow event]. Flows below the instream flow requirements are not considered for AR diversions. Based on opinions expressed by TAG members at the habitat meetings dated October 12, 2006 this analysis assumes AR diversions also will not occur during flushing flows. However, it was recognized during the April 25, 2007 TAG meeting that diversions in the range of 2 to 50 cfs

(0.08 to 1.9 percent) at 2-yr flood return intervals in the river would be unlikely to exhibit an adverse influence on the ability of the river to form and refresh habitat. Incremental increases in diversion rates for AR were discussed at the meeting once a threshold flushing flow was exceeded. Regardless, habitat versus flow data for the mainstem and side-channels are only projected up to 750 cfs in the river (Hiss 1993a,b and Daraio et al. 2003), so discussion of habitat influences at flow levels above this point are qualitative in nature.

Mean-daily flow statistics for three seasons in the watershed including winter precipitation, spring snowmelt runoff and summer low flow seasons are shown in Table 2 (England 1999).

Table 2. Mean Daily Flow Duration Statistics for Station No. 12048000; Dungeness River near Sequim, WA.

Season	90% Exceedance (cfs)	50% Exceedance (cfs)	10% Exceedance (cfs)
November – March	137	269	672
April – July	244	465	858
August – October	109	177	357

Source: England (1999)

The accuracy of the USGS streamflow data is dependant upon the stability of the stage-discharge relation, the frequency of discharge measurements, and the accuracy of observations of stage, measurements of discharge, and interpretations of records. According to the USGS, the degree of accuracy for the Dungeness River station at RM 11.8 is “Good,” indicating about 95 percent of the daily discharges are within 10 percent of the true value.

The availability of river flows in excess of the minimum instream flow levels will be addressed in Task 3 of the grant. PGG has developed an initial estimate of flows at the Schoolhouse Bridge under half buildout of the Sequim-Dungeness Water Users Association Comprehensive Water Conservation Plan based on flow correlations between the Schoolhouse Bridge and USGS gages, and 35 years of flow data from the USGS gage. The synthetic flows were then compared to proposed minimum instream flow requirements to calculate associated flow exceedences (Figure 1). While the analysis of flow availability will be updated in Task 3, Figure 1 provides a reasonable representation of the general magnitude, duration, and exceedance probabilities of water in excess of the IFIM seasonal recommended flows for the overall purposes of this habitat analysis.

The periods with the highest probability of exceeding the recommended instream flow levels include mid-November through January and from May through July, annually. These two periods are used to represent the likely conditions during winter seasonal precipitation events and spring snowmelt runoff periods for the habitat assessment. Flow availability during winter precipitation is more sporadic than during spring snowmelt, but can occur at higher rates. Use of sporadic, instantaneous flows during winter would require capability to control the short-term timing and rate of diversions. These periods correspond in a general sense with the seasonal flow assessment provided by England (1999) in Table 2.

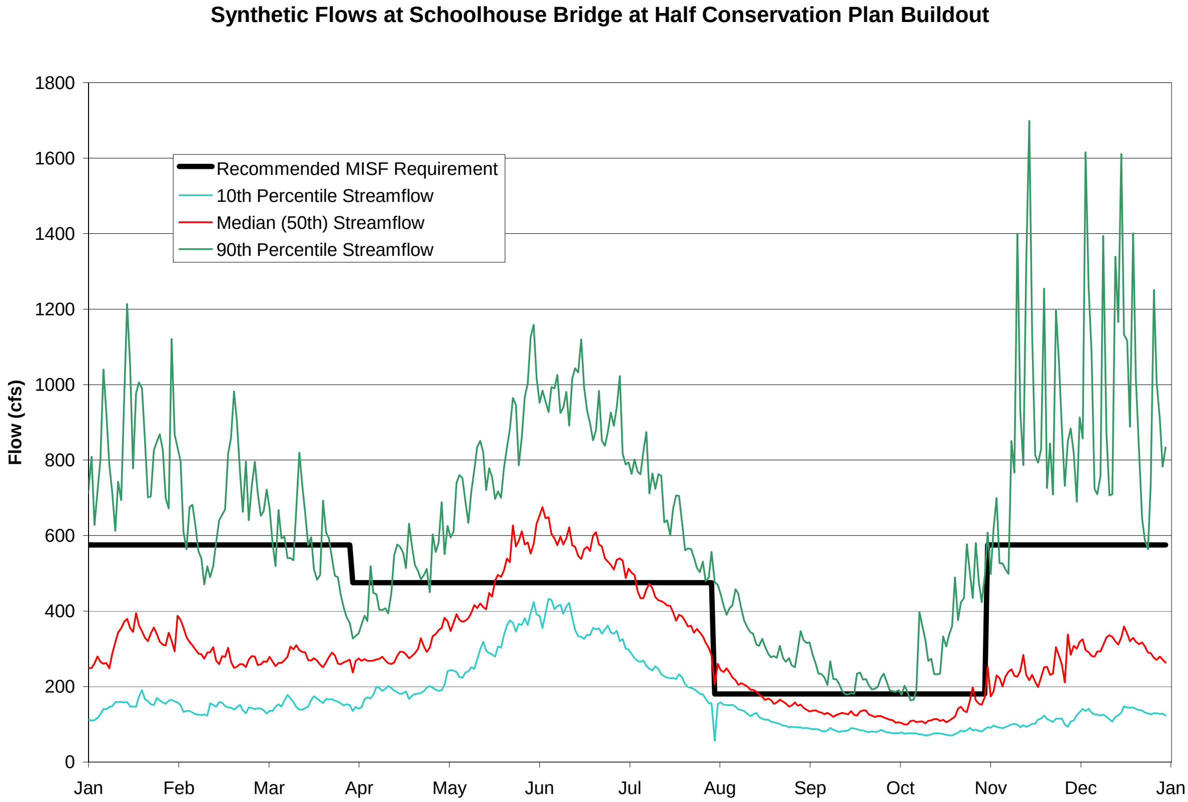


Figure 1. Synthetic Daily Flow Exceedance Probabilities at the Schoolhouse Bridge Gage (RM 0.75) based on 1970-2004 USGS Streamflow Record and Half Buildout Conservation Plan Assumptions.

MISF = Minimum Instream Flow
Source = Pacific Groundwater Group, Inc. (2007)

Irrigation Diversions

Irrigation diversions have been decreasing over the last decade as a result of conservation measures instituted by the Irrigation District members, less water demand and the use of temporary water right leases to support instream flows during critical low flow periods. Irrigation diversions during the winter and spring TM assessment periods are estimated as follows:

Mid-November through January. Irrigators withdraw a consistently small portion of water during this period to provide stock water and to keep their conveyance ditches wet for infiltration and vegetation control. According to recent records the typical withdrawal during this period is approximately 15 cfs. This volume is used herein to represent winter season irrigation diversions.

May through July. The spring snowmelt period occurs during the active irrigation withdrawal season. Although the combined withdrawals from the various irrigation districts and companies vary, the current diversion rates average approximately 60 cfs. This volume is used herein to represent spring snowmelt season irrigation diversions.

The synthetic flow exceedance probabilities at the Schoolhouse Bridge shown on Figure 1 incorporate flow reductions through irrigation diversions assuming half buildout of the conservation plan. These estimates are preliminary in nature and intended to provide a general overview of flow availability. Analysis of flow availability will be updated later in the project.

Losses to Groundwater Downstream of USGS Gage

Simonds and Sinclair (2002) measured the loss to groundwater as a function of surface water elevations and head loss through five study reaches in the mainstem Dungeness River (Table 3). Although the data were noted to be highly variable, certain reaches routinely lost or gained flow. Overall, the researchers noted a consistent trend of natural flow reductions between the USGS gauge at RM 11.8 and the Old Olympic Highway Bridge at RM 3.7 and then again between Woodcock Road at RM 2.9 and the Schoolhouse Bridge at RM 0.75, as a result of losses to groundwater. The magnitude of the loss was variable but it generally decreased as the main channel flow decreased (Simonds and Sinclair, 2002). A summary of measured seepage losses is presented in Table 3.

Table 3. Change in Dungeness River Mainstem Flow Rates due to Groundwater Flux in Five Study Reaches.

	4/11/00	10/4/00	4/12/01	Mean
Reach 5: SHB RM 0.7 - RM 2.9	-11.6	-6.6	-4.7	-7.6
Reach 4: RM 2.9 to RM 3.7	16	-5.1	9.3	6.7
Reach 3: RM 3.7-RM 5.5	-23.9	-1.1	-10.4	-11.8
RM 3.7 - RM 4.2*	-6.6	-0.3	-2.9	-3.3
Net Gain (RM 0.7 - RM 4.2)	**-2.2**	**-12.0**	**1.7**	**-4.2**
RM 4.2 - RM 5.5*	-17.3	-0.8	-7.5	-8.5
Reach 2: RM 5-5 to RM 8.1	9.2	0.6	2.8	4.2
Reach 1: RM 8.1 to RM 11.8	-15.1	-8.0	-9.1	-10.7
Net Gain (RM 4.2 - RM 11.8)	**-23.2**	**-8.2**	**-13.8**	**-15.1**
Total Gain (SHB - RM 11.8)	**-25.4**	**-20.2**	**-12.1**	**-21.6**

*Assumes that losses in Reach 3 are consistent over the reach.
Note: negative values indicate losing conditions.

Tributary Inflow

Three tributaries offer direct contributions to surface water flow in the Dungeness River mainstem downstream of any of the potential AR withdrawal points, including:

Bear Creek	RM 7.3
Hurd Creek	RM 2.7
Matriotti Creek	RM 1.9

Bear Creek occurs between the USGS station at RM 11.8 and the upper IFIM study site at RM 4.2. Bear Creek is a medium-sized stream entering the Dungeness River at RM 7.3. Its bankfull width (BFW) near the mouth is approximately 50 ft. and bankfull depth is 2.7 ft. (Clallam County Streamkeepers' unpublished database 2003). Stormwater flows, augmented by irrigation ditch water, are conveyed from Bear Creek to the Dungeness River during peak flow events. Spot checks of stream flow conditions at the mouth of Bear Creek during the low flow season ranged between 1.0 and 14.4 cfs and averaged 6.8 cfs since 2000 (Clallam County Streamkeepers' unpublished database 2003). A flat rate of 14 cfs was used to represent wet-weather flow conditions during the winter and spring assessment periods to establish reference conditions.

Hurd Creek is a short, low-gradient tributary entering the Dungeness River at RM 2.7. Little flow information is available for Hurd Creek, but it is assumed to be small and relatively inconsequential to winter and spring flow periods.

Matriotti Creek is the largest low-elevation tributary to the Dungeness River entering the River at RM 1.9. Stream flows have been recorded between 7 (1961) and 23 cfs (1980) at Ward Rd. (PSCRBT 1991). Ecology operated a stand-alone stream flow gauge on Matriotti Creek at the Olympic Game Farm from November 1999 to November 2000. The information is available in their River and Stream Flow Monitoring database as Ecology gage 18D060. Daily stream flows were recorded between the range of 10 and 50 cfs, but normally occurred around 15 cfs on an annual basis. Flows during mid-November through January averaged near 20 cfs and May through July averaged 14 cfs during the 1999-2000 water year.

The habitat assessment in this TM refers to river flows at the Schoolhouse Bridge (RM 0.75), as per the preliminary synthetic estimates shown in Figure 1. As noted in the section above, seepage losses between the upper IFIM site at RM 4.2 and the Schoolhouse Bridge at RM 0.75 (Table 3) nearly offset the tributary input. It appears tributary input might exceed seepage losses by approximately 10 cfs, regardless of the season. Given the small quantity of this flow and the scale of the analysis, we treat river discharge at RM 4.2 and 0.75 as indistinguishable. Whereas we realize river flows at RM 4.2 might be slightly lower than measured at the Schoolhouse Bridge, the synthetic data provide sufficient indication of typical seasonal flows for the purpose of this analysis. Task 3 of the grant will provide additional assessment of flow data to enhance the understanding of this relationship.

Fish Species of Interest

The following anadromous salmonid fish species were included in the original IFIM study (Hiss and Lichatowich, 1990) and in the Bureau of Reclamation side channel study (Daraio et al. 2003): Chinook, coho and pink salmon, steelhead trout and Dolly Varden (representing native char). The assumed presence of these species and other salmonid fishes in the lower Dungeness River system is shown in Figure 2.

Life History Stages and Timing in the lower Dungeness River

The presence and seasonal timing of the various life history stages including, upstream migration, spawning and incubation, fry emergence, juvenile rearing, outmigration for the fish species of interest is shown in Figure 3.

Sensitivity of Habitat to Changes in Flow

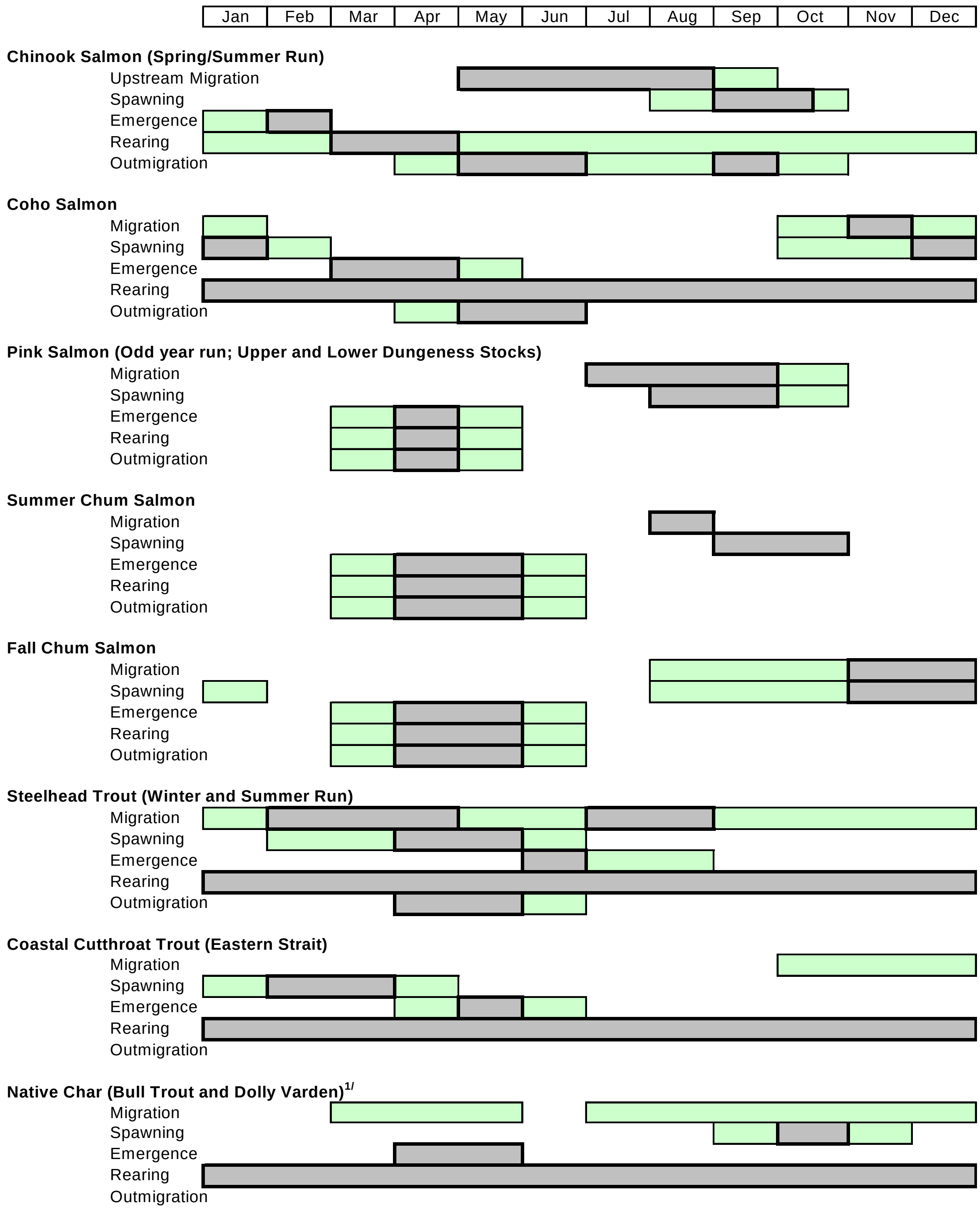
The Instream Flow Incremental Methodology (IFIM) was specifically designed to explore potential habitat changes as a result in incremental changes in stream flow and stage (Bovee 1982). IFIM study transects at a mainstem site representative of braided reach conditions in the lower river system are ideal for the purpose of exploring changes in habitat with seasonal AR withdrawals. The original IFIM study examined changes to spawning and rearing habitat for specific salmonid fish species as shown in Table 4. Similarly, the Bureau of Reclamation used species habitat criteria to indicate when flow conditions in side channels offered suitable habitat for use of various life stages of salmonid fishes (Daraio et al. 2003).

	Dungeness River									
		Side Channels						Tributaries		
Species/Stock	**Mainstem**	**Kinkade**	**Dawley**	**L.East Railroad Bridge**	**Stevens/Savage**	**Anderson**	**Gagnon**	**Bear**	**Hurd**	**Matriotti**
Chinook Salmon										
Dungeness Sp/Su	X	X	X	X	X	X	X			
Coho Salmon										
Dungeness	X	X	X	X	X	X	X	X	X	X
Chum Salmon										
Dungeness Su	X								X	X
Dungeness Fall	X			X				X		X
Pink Salmon (odd-yr. only)										
Upper Dungeness	X									
Lower Dungeness	X	X	X						X	X
Steelhead Trout										
Dungeness Su	X									
Dungeness Wi	X	X	X					X	X	X
Native Char (Bull trout/Dolly Varden)										
Dungeness/Gray Wolf	T									
Coastal Cutthrout Trout										
Eastern Strait	X	X	X		X	X				X

Source: (after Foster Wheeler, 2003; Rot 2003)
T) Transportation Corridor
X) Confirmed Presence

Sp - Spring
Su - Summer
Wi - Winter

Figure 2. Anadromous species presence in Action Area streams.



Sources: WDFW (1975), Sandercock (1991), Hiss (1993), USFWS (1994), Osborn and Ralph (1994), McHenry et al. (1996), Goin (1998), WDFW (1998), Haring (1999), Foster Wheeler (2003), Rot (2003), Ogg pers. comm. (2005).

1) Timing and status of char in the Dungeness watershed are unknown [WDFW (1998) and Haring (1999)] but recent telemetry data suggest upstream adult migrations are occurring in late-fall and spring (Ogg, pers.comm. 2005)

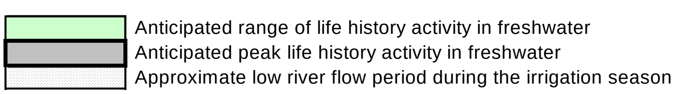


Figure 3. Periods of Life History Stage Use of Salmonid Fishes in the Dungeness River

Table 4. Species and Life Stages Evaluated in the Mainstem and Side Channel Habitat versus Flow Studies.

Species/Life History Stage	Mainstem [1/]	Side Channels [2/]
Chinook Salmon		
Adult	X	
Spawning	X	X
Juvenile Rearing	X	X
Coho Salmon		
Spawning	X	X
Juvenile Rearing	X	X
Pink Salmon		
Spawning	X	X
Steelhead Trout		
Adult	X	X
Spawning	X	X
Juvenile Rearing	X	X
Dolly Varden		
Juvenile Rearing	X	X

Source: 1) Hiss (1993); 2) Daraio et al. (2003)

Hiss (1993) prioritized the species and life history stages for recommending the seasonal instream flow levels based on periodicity of use, stock status and quality of the habitat utilization information. We established the following species priority for the two periods of interest when water is most likely available for AR, based on the work of Hiss (1993) and what is currently known about fish utilization timing and limiting factors in the lower river:

Mid-November through January

Spawning, Incubation, Emergence

- Coho

Juvenile Rearing

- Coho, Steelhead, Native Char

May through July

Spawning, Incubation, Emergence

- Steelhead

Juvenile Rearing

- Chinook, Coho, Steelhead, Native Char

Mainstem Habitat

IFIM Weighted Usable Area (WUA) for various increments of mainstem river flow between 10 and 750 cfs at RM 4.2 are included in Appendix A for the species and life stages of interest (Hiss 1993). Various WUA versus discharge curves for the species are shown in Figure 4.

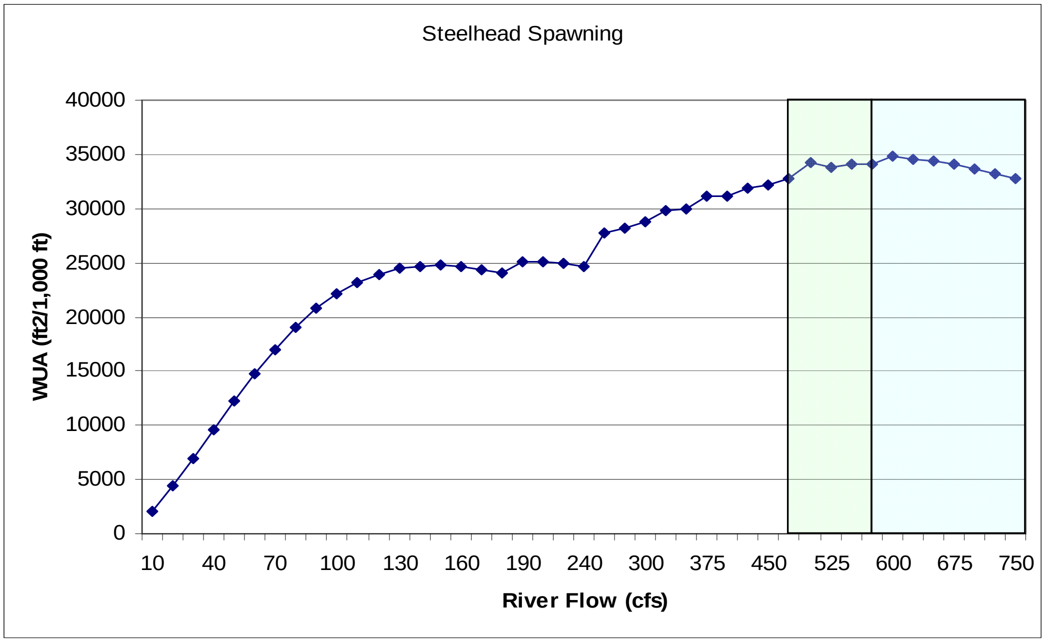


Figure 4a. Steelhead Spawning Weighted Usable Area (WUA) at Dungeness River IFIM Site (RM 4.2).

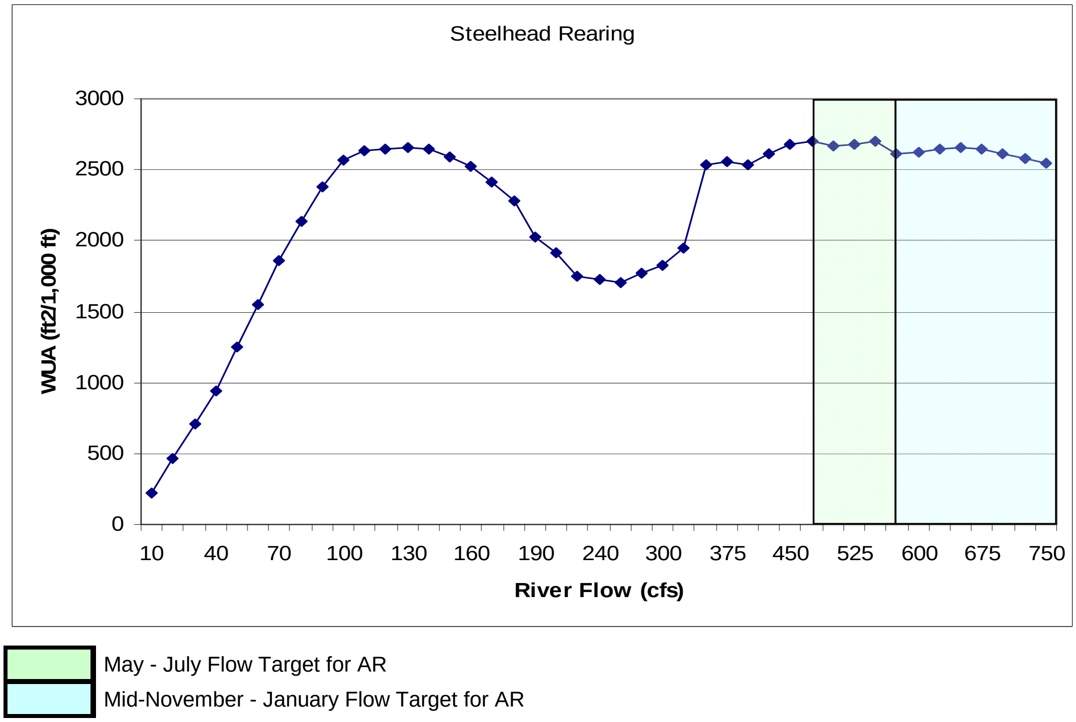


Figure 4b. Juvenile Steelhead Rearing Weighted Usable Area (WUA) at Dungeness River IFIM Site (RM 4.2).

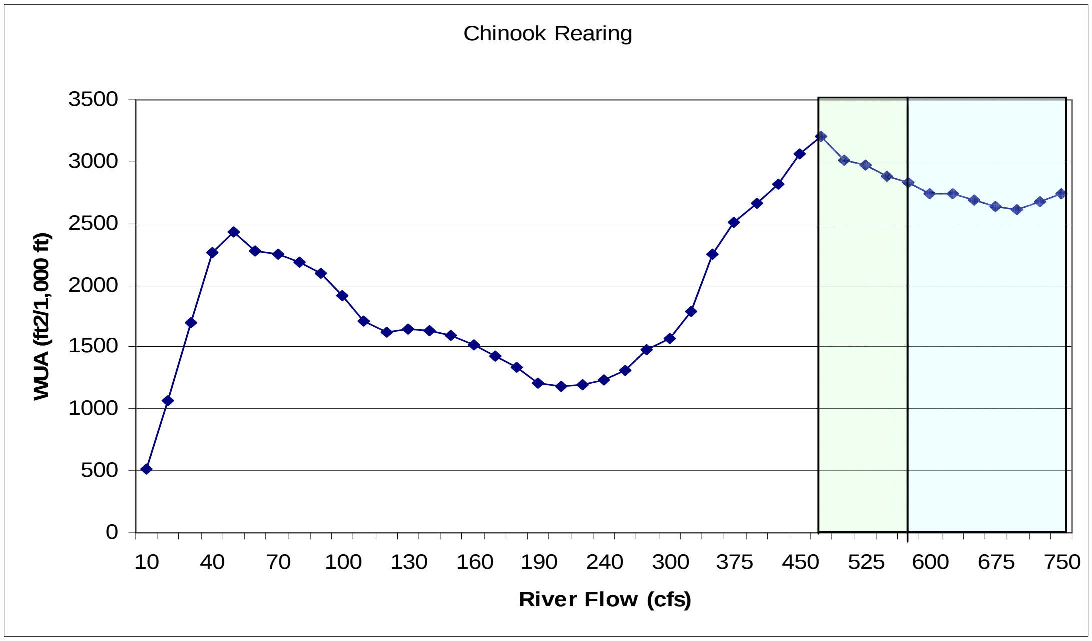


Figure 4c. Juvenile Chinook Rearing Weighted Usable Area (WUA) at Dungeness River IFIM Site (RM 4.2).

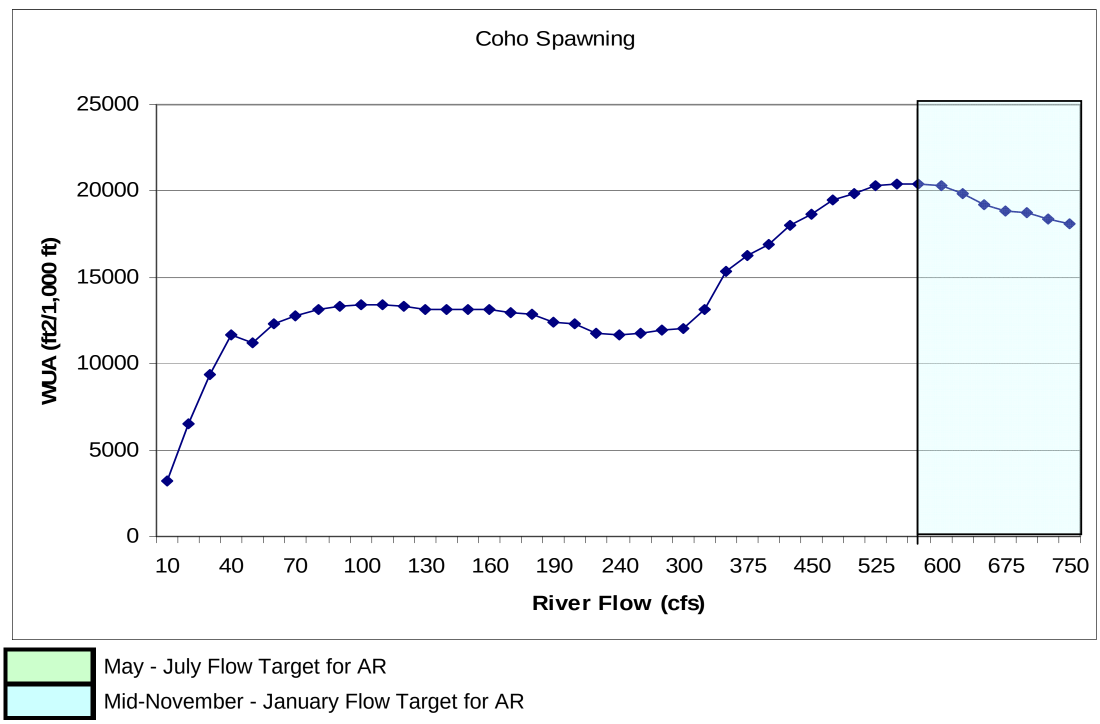


Figure 4d. Juvenile Coho Rearing Weighted Usable Area (WUA) at Dungeness River IFIM Site (RM 4.2).

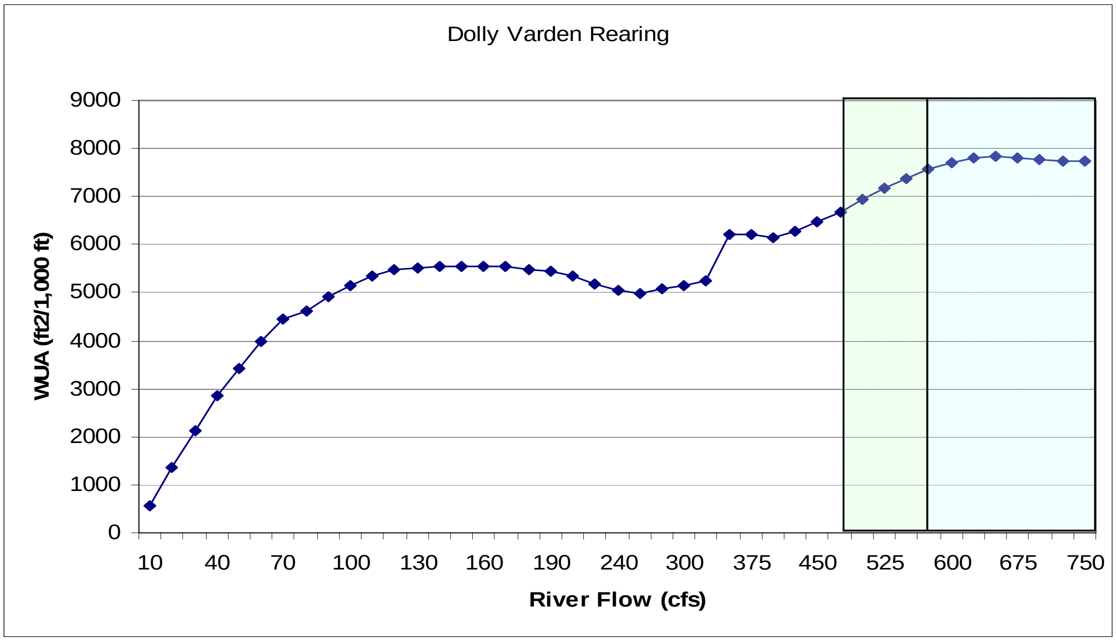


Figure 4e. Juvenile Native Char Rearing Weighted Usable Area (WUA) at Dungeness River IFIM Site (RM 4.2).

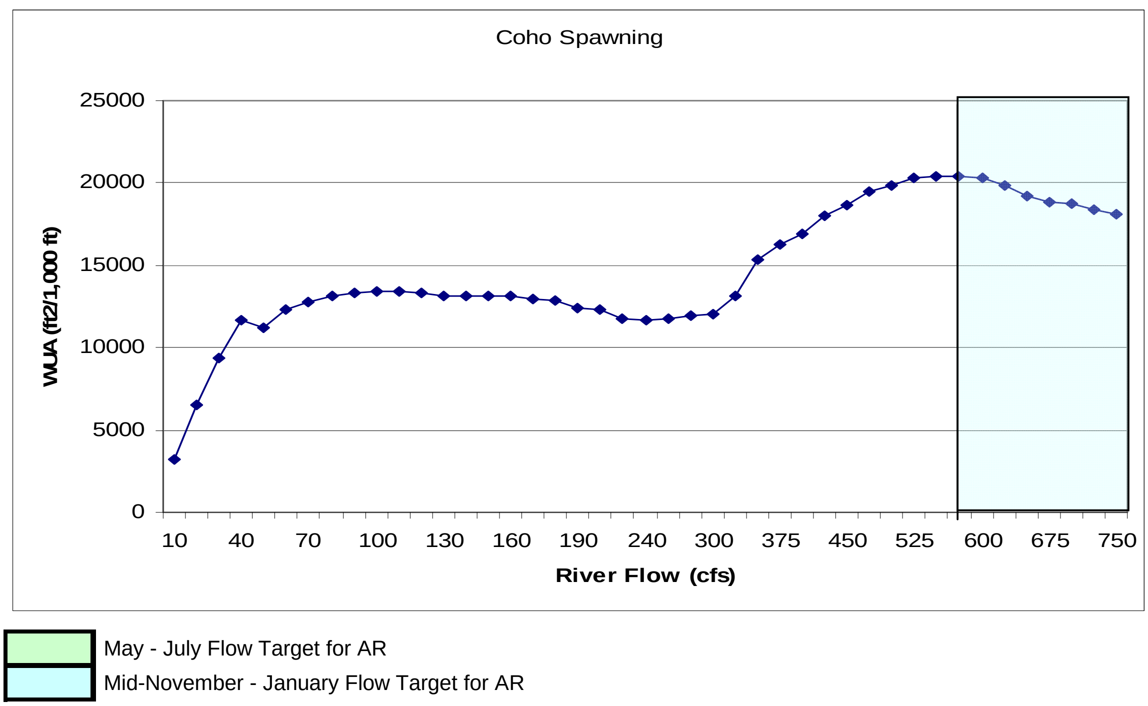


Figure 4f. Adult Coho Spawning Weighted Usable Area (WUA) at Dungeness River IFIM Site (RM 4.2).

The results of an analysis of instream flow presented for the two evaluation periods versus the weighted usable area (WUA) for the species and life stages in question at the IFIM site are presented in detail in Appendix A (Tables A-2 and illustrated in Figure A-1). Anticipated habitat impacts of AR target flow diversion between 2 and 50 cfs, based on the instream flow model, are a function of the shape of the WUA vs Q curve for various life stages of the species of interest (Figure 4a-f). AR diversions during the target flow periods provide variable changes for all life history stages, with respect to both increases and decreases in habitat levels. Indices of habitat area increase as a result of AR diversions along descending portions of the curves. Conversely, habitat is projected to decrease with mainstem flow reductions along ascending portions of the curves.

The overall habitat change as a result of AR diversions, across all mainstem flows between 475 and 750 cfs at RM 4.2, average between a 2.9 percent improvement and a 2.5 percent decrease in habitat indices for juvenile Chinook salmon and for juvenile native char, respectively (Tables 5a and 6a). Habitat changes for the balance of the species and life stages fall in between these levels.

The maximum projected instantaneous increases and decreases in habitat indices across the range of modeled mainstem river flows for each life stage are shown in Tables 6b, 6c and 7b, 7c. All life history stages show improvements in habitat with AR diversions at some point across the range of modeled flows. The largest increases occur with the greatest withdrawal rates of 30 and 50 cfs. The life stages benefiting the most include: (1) steelhead and Chinook rearing in spring, with 3 to 8 percent improvements in WUA, respectively, and (2) steelhead rearing and coho spawning with 3 to 6 percent habitat increases in winter.

The single largest average increase for any life stage is 2.9 percent for juvenile Chinook salmon in spring. This increase in WUA occurs with a 50 cfs withdrawal representing an improvement of 80 ft^2/1,000 lineal feet of stream (2.4 m^2/100m). Cumulatively, over the lower 11 miles of the mainstem Dungeness River, this increase is equivalent to approximately 0.11 acres of juvenile rearing habitat.

In winter, coho salmon spawning exhibit the highest average WUA gain with AR diversions across the modeled flow range from 575 to 750 cfs of 2.8 percent. This increase occurs with a 50 cfs withdrawal representing a WUA increase of 522 ft^2/1,000 lineal feet of stream (15.9

m^2/100m). Cumulatively, over the lower 11 miles of the mainstem Dungeness River, this increase is equivalent to approximately 0.70 acres of spawning habitat.

Similarly, all species show habitat decreases across the modeled flow range predominantly with AR diversions of 30 to 50 cfs. The largest instantaneous decreases occur in spring between 3 and 7 percent for steelhead spawning, Chinook rearing, and native char rearing, and between 2 and 5 percent for coho and native char rearing in winter, respectively.

The single largest average decrease for any life stage is 2.5 percent for native char in spring. This decrease occurs with a 50 cfs withdrawal representing a reduction in 193 ft^2/1,000 lineal feet of stream (5.9 m^2/100m). Cumulatively, over the lower 11 miles of the mainstem Dungeness River, this reduction is equivalent to approximately 0.25 acres of habitat.

Given the shape of the habitat versus flow curve, juvenile native char were also the most sensitive life stage to flow reductions in winter, with an average WUA loss across the modeled flow range from 575 to 750 cfs of 1.5 percent. This decrease occurs with a 50 cfs withdrawal representing a reduction in 115 ft^2/1,000 lineal feet of stream (3.5 m^2/100m). Cumulatively, over the lower 11 miles of the mainstem Dungeness River, this reduction is equivalent to approximately 0.15 acres of habitat.

Table 5a. Average percent change[1/] in habitat (WUA index) for various life stages with AR diversions during spring snowmelt period (May – July).

AR Diversion	Spawning	Rearing			
	Steelhead	Steelhead	Coho	Chinook	Dolly Varden
(cfs)	(%)	(%)	(%)	(%)	(%)
2	0.0	0.0	0.0	0.1	-0.1
5	0.0	0.1	0.0	0.2	-0.2
10	0.0	0.2	0.0	0.2	-0.5
15	0.1	0.3	0.0	0.8	-0.7
30	0.2	0.6	0.1	1.6	-1.5
50	0.3	0.8	0.2	2.9	-2.5

1) Positive numbers imply an improved and negative numbers imply a reduction in habitat indices.

Table 5b. Maximum instantaneous percent *increase* in habitat (WUA index) for various life stages with AR diversions during spring snowmelt period (May – July).

AR Diversion	Spawning	Rearing			
	Steelhead	Steelhead	Coho	Chinook	Dolly Varden
(cfs)	(%)	(%)	(%)	(%)	(%)
2	0.1	0.3	0.1	0.5	0.0
5	0.3	0.7	0.3	1.3	0.1
10	0.5	1.3	0.6	2.6	0.2
15	0.8	2.0	0.9	4.0	0.3
30	1.5	3.2	1.4	6.9	0.6
50	2.5	2.9	1.8	7.9	0.8

Table 5c. Maximum instantaneous percent *decrease* in habitat (WUA index) for various life stages with AR diversions during spring snowmelt period (May – July).

AR Diversion	Spawning	Rearing			
	Steelhead	Steelhead	Coho	Chinook	Dolly Varden
(cfs)	(%)	(%)	(%)	(%)	(%)
2	0.4	0.1	0.1	0.2	0.3
5	0.9	0.2	0.4	0.6	0.8
10	1.8	0.4	0.7	1.1	1.5
15	2.7	0.6	1.1	1.7	2.3
30	4.2	1.0	1.7	3.2	4.5
50	3.3	1.3	1.5	4.8	7.1

Table 6a. Average percent change[1/] in habitat (WUA index) for various life stages with AR diversions during winter rainfall period (mid-November – January).

AR Diversion	Spawning	Rearing		
	Coho	Steelhead	Coho	Dolly Varden
(cfs)	(%)	(%)	(%)	(%)
2	0.1	0.0	0.0	0.0
5	0.4	0.1	0.1	-0.1
10	0.7	0.2	0.1	-0.2
15	1.0	0.3	0.2	-0.3
30	2.0	0.7	0.3	-0.7
50	2.8	1.0	0.4	-1.5

1) Positive numbers imply an improved and negative numbers imply a reduction in habitat indices.

Table 6b. Maximum instantaneous percent *increase* in habitat (WUA index) for various life stages with AR diversions during winter rainfall period (mid-November – January).

AR Diversion	Spawning	Rearing		
	Coho	Steelhead	Coho	Dolly Varden
(cfs)	(%)	(%)	(%)	(%)
2	0.2	0.1	0.1	0.0
5	0.6	0.3	0.3	0.1
10	1.2	1.3	0.6	0.2
15	1.8	2.0	0.9	0.3
30	3.5	3.2	1.4	0.6
50	5.5	2.9	1.2	0.8

Table 6c. Maximum instantaneous percent *decrease* in habitat (WUA index) for various life stages with AR diversions during winter rainfall period (mid-November – January).

AR Diversion	Spawning	Rearing		
	Coho	Steelhead	Coho	Dolly Varden
(cfs)	(%)	(%)	(%)	(%)
2	0.0	0.1	0.0	0.1
5	0.0	0.2	0.4	0.5
10	0.1	0.4	0.7	1.1
15	0.1	0.6	1.1	1.6
30	0.3	1.0	1.7	3.2
50	0.8	1.3	1.4	5.0

Side Channel Habitat

Side channels of the mainstem Dungeness River offer substantial spawning and rearing habitat for salmonid fish species. Although a number of side channels exist along the lower river, their contribution to fish production depends upon the overall connection of surface water or groundwater sources to the mainstem river. The Bureau of Reclamation with assistance of the Jamestown S'Klallam Tribe, performed an extensive physical survey of side channel characteristics in relation to mainstem river flow volumes (Daraio et al. 2003). The researchers developed side channel stage/discharge relationships and determined the mainstem flow levels when surface side channels were connected to the mainstem as well as when flows in each side channel contributed preferred habitat conditions for fish species of interest (Appendix B).

Reclamations' study is useful for the purpose of incrementally assessing changes in mainstem flow as a result of AR diversions with potential changes in habitat conditions (discharge, width, depth, velocity) in the side channels. Rating curves and regression equations for habitat suitability of each life stage in each side channel based on the Bureau of Reclamation study are shown in Appendix B.

Individual Side Channel Assessment

Changes in habitat suitability for fish use in each side channel were evaluated with the incremental series of AR diversions from 2 to 50 cfs. The flow modifications and resulting habitat changes are summarized in Tables 7 and 8 and shown in detail in Appendix Tables B-2 and B-3 for both the spring and winter evaluation seasons.

Table 7. Maximum decrease (%) in physical habitat parameters across all surface water-connected side channels with series of AR diversions during spring evaluation period.

Habitat Parameter	2 cfs	5 cfs	10 cfs	15 cfs	30 cfs	50 cfs
Mainstem Discharge	0.4%	1%	2%	3%	6%	10%
Mainstem Depth	0.1%	0.3%	0.5%	0.8%	1.6%	2.6%
Side Channel Discharge	0.5%	1.2%	2.4%	3.5%	6.9%	11.0%
Velocity	0.3%	0.7%	1.4%	2.1%	4.1%	6.5%
Depth	0.2%	0.4%	0.9%	1.3%	2.5%	4.0%
Width	0.1%	0.3%	0.7%	1.0%	2.0%	3.2%

Table 8. Maximum decrease (%) in habitat parameters across all surface water-connected side channels with series of AR diversions during winter evaluation period.

Habitat Parameter	2 cfs	5 cfs	10 cfs	15 cfs	30 cfs	50 cfs
Mainstem Discharge	0.3%	1%	2%	2.5%	5%	8%
Mainstem Depth	0.1%	0.2%	0.4%	0.7%	1.3%	2.1%
Side Channel Discharge	0.4%	1.0%	2.0%	2.9%	5.7%	9.2%
Velocity	0.2%	0.6%	1.2%	1.7%	3.4%	5.5%
Depth	0.1%	0.4%	0.7%	1.1%	2.1%	3.4%
Width	0.1%	0.3%	0.6%	0.8%	1.6%	2.7%

The Bureau of Reclamation study used habitat preference criteria for various life history stages to describe the time periods when side channel flows offered available conditions for spawning or rearing habitat (Appendix Table B-1, after Daraio et al. 2003). The maximum estimated changes in physical habitat features with the largest AR diversion of 50 cfs, as shown in Table 9, are too small to identify potential changes in habitat suitability for fish use. This assessment suggests diversions of 2 to 50 cfs during high stream flows in the Dungeness River are commensurate with side channel discharge reductions between 0 and 19 cfs. Resulting depth, velocity and wetted width changes were generally less than 0.2 ft, 0.3 fps, and 1.2 feet, respectively. Such flow modifications are not sufficient to estimate changes in physical habitat features in side channel important for fish habitat.

Table 9. Maximum decrease in habitat attribute values in individual surface water-connected side channels in the Lower Dungeness River System with 50 cfs AR diversion rate (after Daraio et al. 2003).

	Habitat Parameter Values							
	Discharge (cfs)		Velocity (fps)		Max. Depth (ft)		Width (ft)	
Side Channel	Spring	Winter	Spring	Winter	Spring	Winter	Spring	Winter
Kinkade - East	8	7	0.2	0.1	0.1	0.1	0.2	0.2
Kinkade – Middle	3	3	0.3	0.2	0.1	0.1	0.8	0.7
Kinkade – West	13	11	0.1	0.1	0.1	0.1	0.4	0.3
Dawley	9	7	0.2	0.2	0.1	0.0	0.4	0.3
Lower E- RXR Bdg	9	8	0.2	0.2	0.1	0.1	0.2	0.2
Stevens/Savage	19	16	0.3	0.2	0.0	0.0	0.0	0.0
Anderson	4	3	0.1	0.1	0.2	0.1	1.2	1.0

Cumulative Side Channel Assessment

Mainstem river flows that offer a range of preferred habitat conditions in surface-water connected side channels for various species and life stages are shown for each side channel in Figure 5. An example of steelhead trout spawning and rearing for the spring snowmelt runoff season is depicted in this graph. Similar graphs for all life history stages in both of the season evaluation periods are provided in Appendix B. Using the priority life history stages identified for each of the spring and winter evaluation periods, we tallied the number of life history stages supported by side channels at various mainstem discharges as shown in Figures 6 and 7. The data from these figures show the probability for peak life stage usage in the side channels between mainstem river flows of 375 and 500 cfs and high usage between a broad range of 160 and 575 cfs in spring. Slightly lower optimal flow levels are suggested in winter, based on different species life histories. This concept is consistent with a seasonal shift to cooler water temperatures and a general fish preference for lower water velocities than during warmer periods of the year. According to Reclamation's study, peak side channel use by life stages is likely to occur in winter when the mainstem river is flowing between 160 and 260 cfs. Side channel flows offer relatively high levels of preferred habitat on a cumulative basis when the Dungeness River discharge is between 110 and 480 cfs.

The side channel assessment implies reductions in mainstem river flow during periods of runoff above 575 cfs in the spring and above 500 cfs in winter will support additional levels of preferred habitat for more life stages in the side channels than at higher river flows. The shape of these curves also implies the return of AR water to the channel network in the lower river will benefit side channel habitat at periods of the year when the mainstem river is running at 160 cfs of less.

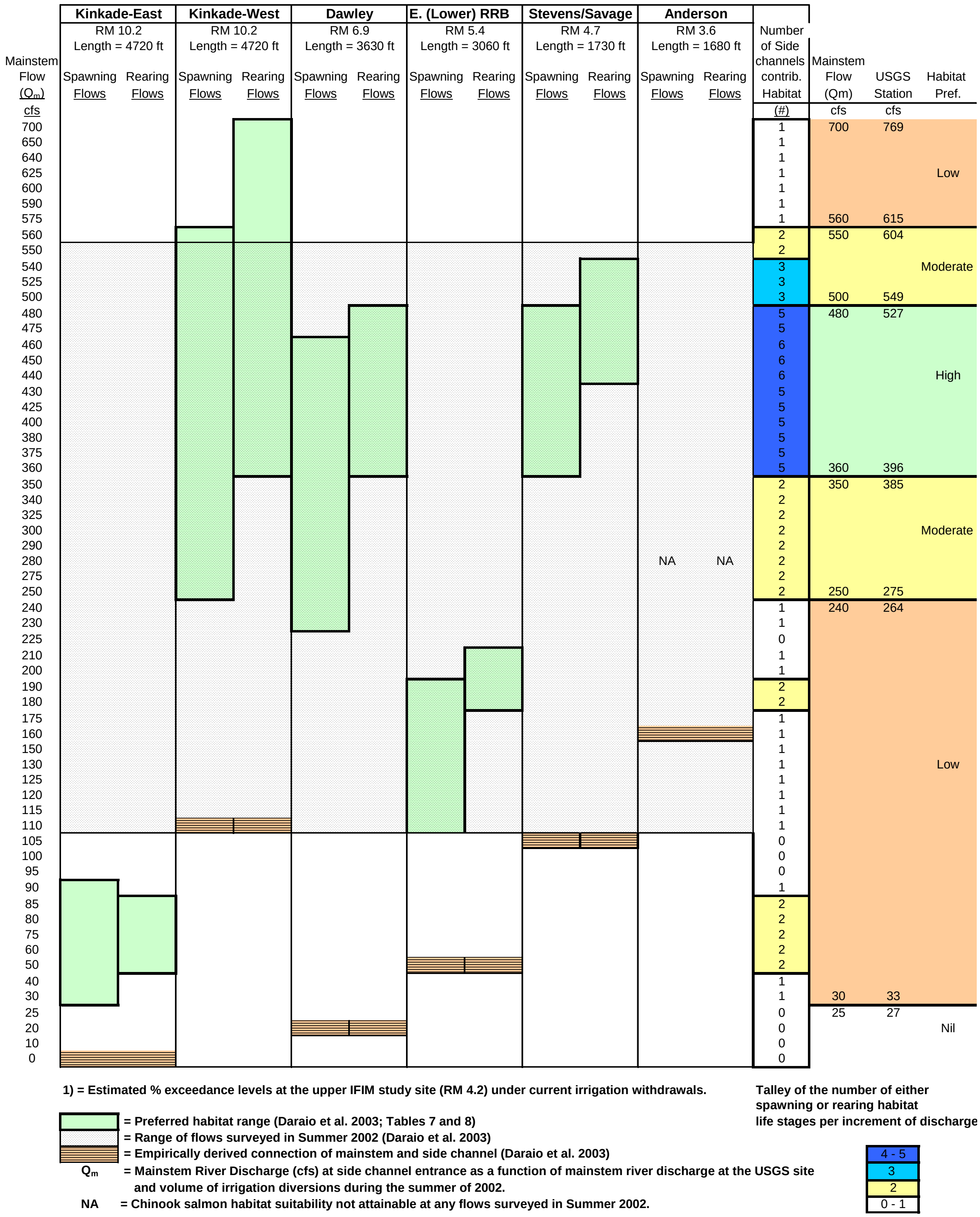


Figure 5. Assessment of mainstem Dungeness River flows for preferred steelhead trout spawning and rearing habitat conditions during the spring snowmelt runoff season in surface water-connected side channels
[after: Daraio et al. 2003].

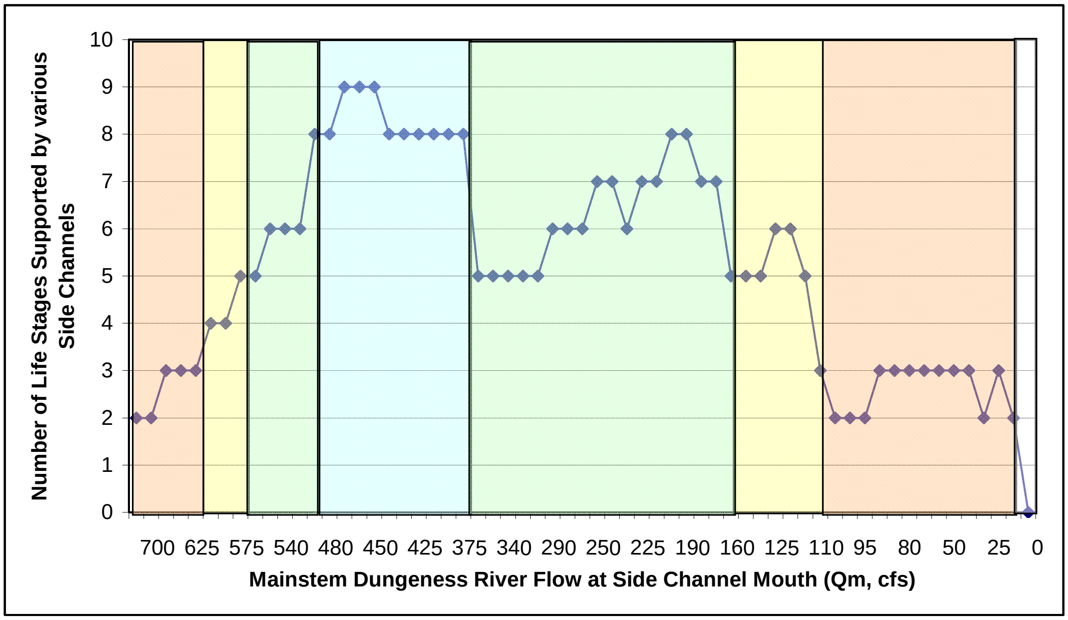


Figure 6. Side Channel Suitability for various spawning and rearing fish life history stages during the spring snowmelt runoff season in surface water-connected side channels in the lower Dungeness River system.

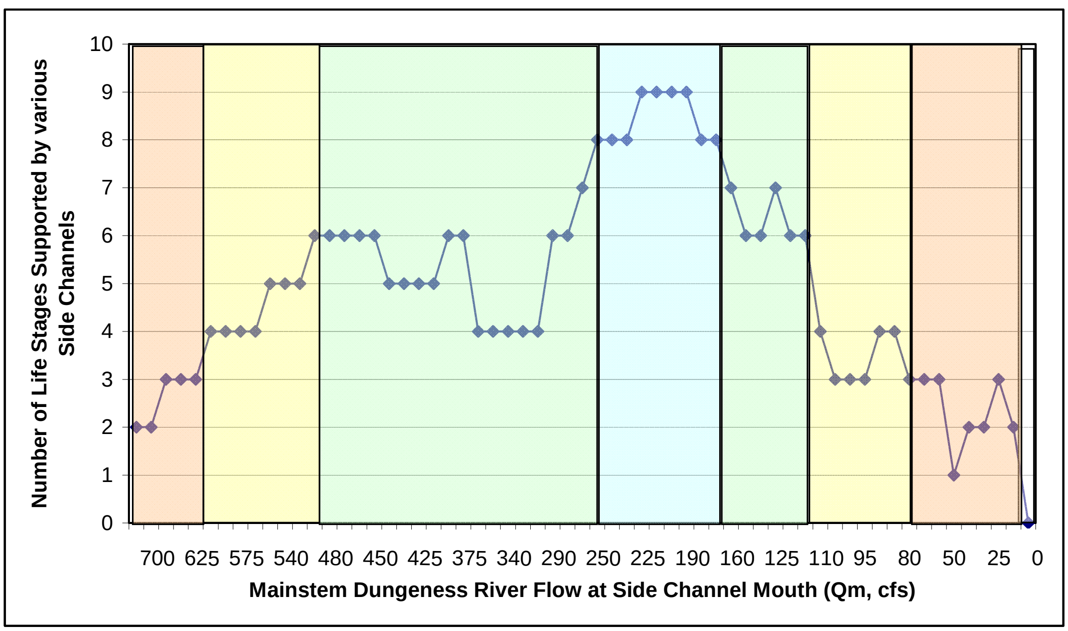


Figure 7. Side Channel Suitability for various spawning and rearing fish life history stages during the winter rainfall season in surface water-connected side channels in the lower Dungeness River system.

CONCLUSIONS

Given assumptions of compliance with recommended minimum instream flows and maintenance of flushing flows, the water available for surface water diversions for AR purposes would likely occur between 475 and 2,650 cfs during the spring period and between 575 and 2,650 cfs during winter as measured at the Ecology gaging station at RM 0.75. Incremental increases in diversions above 2,650 cfs during both periods may occur if the function of flushing flows to form habitat features is maintained. Anticipated habitat changes resulting from a series of AR diversions between 2 and 50 cfs during these flow periods, based on IFIM studies in the mainstem Dungeness River and Bureau of Reclamation studies in associated mainstem river side channels downstream of RM 11, are variable but small. Both benefits and impacts of the diversions are identified, based on the shape of the habitat versus flow relationships for the various life history stages of the species of interest.

As expected, the largest adverse and beneficial changes resulting from proposed diversions occur at the highest assessed levels of AR diversion; 30 and 50 cfs. The proposed withdrawals rates at all levels are less than 10 percent of the discharge in the mainstem Dungeness River. As such, they lie within the accuracy of USGS measurements for the Dungeness River system. Worst case flow changes of 7 to 9 percent at the highest withdrawal rates are commensurate with 2 to 3 percent changes in mainstem river stage or generally less than 1 inch in depth at a cross section with a thalweg of 3 feet or less than 0.3 inches at a 1-ft. thalweg.

The IFIM assessment suggests mainstem habitat levels for any life stage, on average, are not sensitive (< 1% decrease in WUA indices) to withdrawal rates of equal to or less than 15 cfs in spring and 30 cfs in winter (Tables 5a and 6a). Peak instantaneous adverse influences on WUA for any single life stage are on the order of 3 percent or less for withdrawal rates of 15 cfs in spring and 30 cfs in winter (Tables 5c and 6c). Improvements in WUA are generally more prevalent than reductions as a result of AR diversions during both the spring and winter evaluation periods with the exception of habitat for juvenile native char. Unlike other life stages, the shape of the habitat versus flow curve for native char continues to rise until approximately 650 cfs at RM 4.2 (Figure 4e).

The maximum estimated decreases in physical habitat attribute values in side channels of the Dungeness River with the largest AR diversion of 50 cfs are too small to identify potential changes in preferred fish habitat conditions. The side channel assessment suggests diversions of 2 to 50 cfs during high stream flows in the Dungeness River are not sufficient to predict changes in side channel features important for fish habitat. Cumulative availability of preferred physical habitat attributes across all of the measured surface water-connected side channels for priority life stages at various mainstem river flow levels (Figures 6 and 7), suggest reductions of high river flows in the spring and winter evaluation periods would enhance habitat conditions for salmonid fishes in Dungeness River side channels. These data reinforce the concept that AR diversions can occur at high river flow levels without significant adverse effects on priority species and life stages.

REFERENCES

Beecher, H. 1989. Habitat preference curves for Dungeness River IFIM study. Washington Department of Wildlife Letter Report dated January 30, 1989. 2 p. plus Tables.

Beecher, H. and B. Caldwell. 1997. Proposed Instream Flows for Dungeness Tributaries.

Bounty, J.A., T.J. Randle, L.A. Piety and R.A. Link. 2002. Physical processes, human impacts, and restoration issues of the lower Dungeness River, Clallam County, Washington. Report prepared for the Jamestown S'Klallam Tribe by the US Department of the Interior, Bureau of Reclamation. May 2002. 111p

Bovee, K.D. 1982. A guide to stream habitat analysis using the instream flow incremental methodology. Instream Flow Information paper No. 12. Western Energy and Land Use Team, U.S. Fish and Wildlife Service. Fort Collins, Colorado. FWS/OBS-82/26, 248 p.

Castro, J.M. and P.L. Jackson. 2001. Bankfull discharge recurrence intervals and regional hydraulic geometry relationships: Patterns in the Pacific Northwest, USA. Journal of the American Water Resources Association. 37 (5): 1249 – 1262.

Clallam County Streamkeepers. 2003. Unpublished Stream Flow Data, 1999 to 2001. Clallam County Department of Community Development.

Daraio, J.A., J.A. Bountry and T.J. Randle. 2003. Dungeness River instream flow side channel study. Report prepared for: State of Washington Department of Ecology and Clallam County by the U.S. Department of Interior, Technical Service Center, Bureau of Reclamation, Denver, CO. in cooperation with the Jamestown S'Klallam Tribe. 44p. plus Attachments. February 2003.

DQ. 1994. The Dungeness-Quilcene Water Resources Management Plan. Chapter 2, Characterization of the DQ Region and Its Water Resources. 44 p.

DQ. 1994. The Dungeness-Quilcene Water Resources Management Plan. Chapter 6, East Clallam County, Dungeness Watershed Recommendations. 49 p.

Dungeness River Management Team (DRMT) website: 2004. Chinook salmon spawning survey data downloaded through the fall of 2004 via http://www/olympus.net/community/ dungenessws. November 2004.

Dungeness River Restoration Work Group. 1997. Recommended Restorations Projects for the Dungeness River. (Contributors include: Jamestown S'Klallam Tribe, Washington Department of Fish and Wildlife, Clallam County, U.S. Fish and Wildlife Service, U.S. Forest Service, Natural Resources Conservation Service, Clallam Conservation District, Private Landowners). Final Report by the Dungeness River Restoration Work Group. Jamestown S'Klallam Tribe, Blyn, WA. 57 p. July 1, 1997.

Dunne, T. and L.B. Leopold. 1978. Water in environmental planning. W.H. Freeman and Company, San Francisco, CA.

Ecology. 2007. River & stream flow monitoring data. Dungeness River nr mouth. Station 18A050; www.ecy.wa.gov/apps/watersheds/flows/station.asp?wria=18.

England, J.F. Jr. 1999. Flood frequency, flow duration and trend analyses, Dungeness River geomorphology investigation, Dungeness River, Washington. Report prepared by the U.S. Department of Interior, Bureau of Reclamation, Technical Service Center, Denver, Colorado. 17 pp + figures.

Foster Wheeler Environmental Corporation. 2003. Final Environmental Impact Statement (FEIS). Dungeness River Agricultural Water Users Association Comprehensive Water Conservation Plan. Report prepared for State of Washington Department of Ecology. August, 2003

Haring, D. 1999. WRIA 18 Limiting Factors Report. Washington State Conservation Commission, Olympia, WA

Heard, W.R. 1991. "Life History of Pink Salmon *(Oncorhynchus gorbusch*a)." Pp. 121 to 230 *in* Groot, C. and L. Margolis. 1991. *Pacific Salmon Life Histories.* UBC Press, Vancouver, B.C.

Hirschi, R. and M. Reed. 1998. Salmon and Trout Life History Study in the Dungeness River. Report prepared for the Jamestown S'Klallam Tribe, Sequim, Washington.

Hiss, J.M. 1993a. Recommended instream flows for the lower Dungeness River. Report prepared for the Dungeness-Quilcene Regional Planning Group, U.S. Fish and Wildlife Service, Western Washington Fishery Resource Office, Olympia, WA 20 May 1993. 15 p.

Hiss, J.M. 1993b. Instream flow recommendations for the Dungeness-Quilcene Area Salmon and Steelhead streams. Report prepared by the U.S. Fish and Wildlife Service, Western Washington, Fishery Resource Office, Olympia, WA for the Dungeness-Quilcene Regional Planning Group. September 3, 1993. 34 p.

Hiss, J.M. and J. Lichatowich. 1990. The Dungeness River IFIM Study. Executive Summary prepared by the U.S. Fish and Wildlife Service and the Jamestown Klallam Tribe for the Dungeness River Management Team. September 15, 1990. 7 p.

Jamestown S'Klallam Tribe. 2003. Restoring the Dungeness; An overview of the Dungeness River Restoration Strategy; How a community works together to restore a river. Document prepared by the Jamestown S'Klallam tribe under a funding grant of the Pacific Coastal Salmon Recovery Program (NOAA). 2003. 118 p.

Jones, M.A., 1996. Delineation of Hydrogeologic Units in the Lower Dungeness River Basin, Clallam County, Washington. U.S. Geological Survey Water Resources

Investigations Report 95-4008. Tacoma, Washington.

Lestelle, L. 2004. Key Points in Understanding EDT Action Analysis for Dungeness Chinook. Memorandum dated June 26, 2004 from Larry Lestelle, Mobrand Biometrics, Inc. related to the EDT model run of June 23rd 2004. 12 p.

Lichatowich, J. 1992. Dungeness River Pink and Chinook Salmon Historical Abundance, Current Status, and Restoration. Prepared for Jamestown S'Klallam Tribe. Sequim, Washington.

Marlow, C., B. Freymond, R.W. Rogers, and G. Volkhardt. 2001. Dungeness River Chinook Salmon Rebuilding Project, Progress Report 1993-1998. Report #FPA 00-24 (draft), Washington Department of Fish and Wildlife, Fish Program, Science Division. Olympia, Washington.

McHenry M.L., J. Lichatowich and R. Kowalski-Hagaman. 1996. Status of Pacific Salmon and their habitats on the Olympic Peninsula, Washington. Chapter 5, Eastern Strait of Juan de Fuca. Report to the Lower Elwah Klallam Tribe, Department of Fisheries, Port Angeles, WA p 147 – 179.

McPhail, J.D. and J.S. Baxter. 1996. A Review of Bull Trout *(Salvelinus confluentu*s) Life-history and Habitat Use in Relation to Compensation and Improvement Opportunities. Fisheries Management Report No. 104, Province of British Columbia, Fisheries Branch.

Mobrand Biometrics Inc. (MBI) 2002. Dungeness River Chinook EDT Model 1-low marine survival. Ecosystem and Diagnostic and Treatment-Lite; draft model run of Dungeness River Chinook salmon April 2002.

Mobrand Biometrics Inc. (MBI). 2004. Dungeness River Chinook EDT Model 1-low marine survival. Ecosystem and Diagnostic and Treatment-Lite; model run of Dungeness River Chinook salmon September 2004.

Ogg, L. 2005. Personal communication. Telephone conversation with Larry Ogg, fisheries biologist for the Olympic National Park, National Park Service with R. Campbell, R2 Resource Consultants, Inc., January 10, 2005.

Orsborn, J.F. and S.C. Ralph. 1992. An Aquatic Resource Assessment of the Dungeness River Basin System—Problem Definition, Information Assessment and Study Design. Prepared for the Jamestown S'Klallam Tribe. Sequim, Washington.

Orsborn, J.F. and S.C. Ralph. 1994. An aquatic resource assessment of the Dungeness River system – Phase II. Physical channel analysis, hydrology, and hydraulics and Phase III. Fisheries habitat survey: Report prepared for the Jamestown S'Klallam Tribe, Sequim, WA and the Quilcene Ranger Station, Olympic National Forest, Quilcene, WA.

Puget Sound Cooperative River Basin Team (PSCRBT). 1991. Dungeness River Area Watershed. Report prepared by the Puget Sound Cooperative River Basin Team, representing USDA Soil Conservation Service, USDA Forest Service, Washington State Department of Fisheries, Washington State Department of Ecology, US Environmental Protection Agency for the Dungeness River Area Watershed Management Committee at the request of Clallam County. 132 pp + app.

Rot, B. 2003. The evolving Dungeness River: juvenile salmon and their use of side channel habitat. Jamestown S'Klallam Tribe for US EPA, Region 10. 35 p.

Salo, E.O. 1991. "Life History of Chum Salmon *(Oncorhynchus ket*a)." Pp. 233-309 393 *in* Groot, C. and L. Margolis. 1991. *Pacific Salmon Life Histories.* UBC Press, Vancouver, B.C.

Simonds, F.W., and K. Sinclair. 2002. Surface Water Ground Water Interactions along the Lower Dungeness River and Vertical Hydraulic Conductivity of Streambed Sediments, Clallam County, Washington, September 1999-July 2001. Prepared by for the US Geological Society as USGS Water Resources Investigations Report 02-4161.

US Bureau of Reclamation. 2002. Physical processes, human impacts and restoration issues of the lower Dungeness River, Clallam County, Washington. Report prepared the Jamestown S'Klallam Tribe by the U.S. Department of the Interior, Bureau of Reclamation, May 2002

USDA Forest Service. 1995. Dungeness Area Watershed Analysis, including Gray Wolf River and MacDonald, Siebert and Johnson Creek. Report prepared for USDA Forest Service, Olympic National Park, by the Dungeness Area Watershed Analysis Cooperative Team. September, 1995.

US Fish and Wildlife Service. 1991. Fish habitat analysis for the Dungeness River using the instream flow incremental methodology. US Fish and Wildlife Service, Western Washington Fishery Resource Office, Olympia, WA July 1991.

US Fish and Wildlife Service. 1993. Recommended instream flows for the lower Dungeness River. US Fish and Wildlife Service, Western Washington Fishery Resource Office, Olympia, WA May 1993. 12 p.

US Fish and Wildlife Service. 1993. Instream flow recommendations for Dungeness-Quilcene Area salmon and steelhead streams.. US Fish and Wildlife Service, Western Washington Fishery Resource Office, Olympia, WA September 1993. 34 p.

USGS 1994. A Plan of Study for the Ground-and Surface-Water Resources, the Dungeness-Quilcene Water Resource Pilot Planning Project, Project Report.

USGS 2002. Surface Water Ground Water Interactions along the Lower Dungeness River and Vertical Hydraulic Conductivity of Streambed Sediments, Clallam County, Washington, September 1999-July 2001. Prepared by F.W. Simonds and K. Sinclair for the USGS. US Geological Society Water Resources Investigations Report 02-4161.

Wampler, P.L. and J.M. Hiss. 1991. Fish habitat analysis for the Dungeness River using the Instream Flow Incremental Methodology. US Fish and Wildlife Service, Western Washington Fishery Resource Office, Olympia, WA.

Washington State Conservation Commission. 2000. WRIA 18 Limiting Factors Report. Cited as Haring 1999.

Washington Department of Fisheries, Washington Department of Wildlife, and Western Washington Treaty Indian Tribes. 1994. 1992 Washington State Salmon and Steelhead Stock Inventory (SASSI). WDF, Information and Education Division. Olympia, Washington.

Washington Department of Fish and Wildlife and Western Washington Treaty Indian Tribes. 1998. Washington State Salmonid Stock Inventory: Bull trout/Dolly Varden. Washington Department of Fish and Wildlife. Olympia, Washington.

Washington Department of Fish and Wildlife and Western Washington Treaty Indian Tribes. 2000. Washington State Salmonid Stock Inventory: Coastal Cutthroat Trout. Washington Department of Fish and Wildlife. Olympia, Washington.

APPENDICES

Appendix A - Mainstem IFIM and WUA Data

Appendix B – Side Channel Assessment Data

Task 4 Dungeness River Aquifer Recharge Habitat Technical Memorandum

APPENDIX A
Mainstem Data

Table A-1. Weighted Usable Area (WUA) versus River Flow at RM 4.2 for Various Species and Life History Stages.

WUA vs Q curves at RM 4.2

IFIM	Chinook Salmon		Coho Salmon		Pink Salmon		Steelhead Trout		Dolly Varden	
Flow (cfs)	Juvenile WUA[1/]	Spawning WUA[1/]	Juvenile WUA[1/]	Spawning WUA[1/]	Juvenile WUA[1/]	Spawning WUA[1/]	Juvenile WUA[1/]	Spawning WUA[1/]	Juvenile WUA[1/]	Spawning WUA[1/]
10	511	321	7902	3248	-	2882	222	1994	580	-
20	1069	1581	8816	6527	-	7383	461	4448	1351	-
30	1705	3540	8973	9365	-	11259	707	6996	2134	-
40	2266	5873	8882	11639	-	14105	943	9644	2851	-
50	2437	8417	8734	11204	-	16889	1246	12289	3437	-
60	2277	10680	8535	12271	-	19043	1553	14720	3970	-
70	2255	12731	8269	12754	-	20660	1864	17022	4458	-
80	2183	14605	7998	13124	-	21546	2136	19073	4620	-
90	2097	16177	7729	13340	-	22057	2384	20809	4902	-
100	1923	17503	7469	13408	-	22366	2567	22149	5147	-
110	1714	18449	7231	13409	-	22436	2631	23142	5341	-
120	1622	19130	7023	13329	-	22303	2650	23891	5467	-
130	1644	19676	6846	13180	-	21986	2658	24446	5528	-
140	1635	19996	6693	13130	-	22007	2648	24717	5551	-
150	1591	20114	6544	13157	-	22699	2586	24781	5555	-
160	1521	21237	6390	13105	-	22693	2519	24650	5556	-
170	1431	22043	6256	12985	-	22606	2413	24426	5533	-
180	1335	22683	6140	12848	-	22536	2285	24129	5487	-
190	1204	23192	4966	12376	-	22647	2029	25070	5437	-
200	1178	23535	4878	12300	-	22426	1914	25071	5340	-
220	1191	23732	4941	11731	-	22346	1751	24934	5169	-
240	1241	23519	7282	11649	-	22587	1723	24649	5036	-
260	1308	23188	10483	11745	-	22545	1701	27709	4997	-
280	1482	22704	12647	11906	-	24030	1772	28131	5070	-
300	1573	22430	13896	12030	-	24788	1825	28855	5134	-
330	1785	21948	16514	13130	-	26258	1944	29841	5246	-
350	2255	22659	19314	15311	-	28027	2534	30008	6213	-
375	2506	22381	19602	16226	-	29293	2562	31074	6204	-
400	2666	21531	19588	16936	-	30318	2539	31074	6146	-
425	2818	21583	19277	18058	-	31707	2617	31879	6292	-
450	3060	21903	19038	18702	-	32553	2683	32215	6480	-
475	3209	22377	18413	19502	-	33395	2704	32714	6675	-
500	3008	24222	18661	19811	-	34534	2665	34216	6939	-
525	2974	24742	18685	20284	-	35205	2674	33837	7185	-
550	2880	25024	18607	20421	-	35542	2700	34166	7365	-
575	2828	26098	18952	20449	-	35963	2615	34117	7567	-
600	2735	25921	18686	20300	-	35779	2624	34780	7691	-
625	2742	25670	18729	19822	-	35939	2649	34572	7798	-
650	2691	25270	18636	19244	-	35680	2657	34430	7829	-
675	2639	25127	18527	18819	-	35417	2644	34023	7816	-
700	2609	24954	18540	18712	-	34861	2618	33593	7774	-
725	2683	24469	18373	18415	-	34420	2582	33222	7753	-
750	2741	24112	18413	18092	-	34038	2547	32820	7750	-

1) Habitat Indice of Weighted Usable Area; reported as ft^2/1,000 ft of stream length.

Table A-2. Summary statistics for changes in WUA with series of AR diversions during spring and winter evaluation periods.

Spring Evaluation Period (May - July)

IFIM Flow (cfs)	Chinook Salmon Juvenile Rearing													
		WUA w/ Diversion												
		2 cfs		5 cfs		10 cfs		15 cfs		30 cfs		50 cfs		
	WUA[1/]	WUA	%	WUA	%	WUA	%	WUA	%	WUA	%	WUA	%	
475	2609	2609	0.5%	2609	1.3%	2609	2.6%	2609	4.0%	2609	6.9%	2609	7.9%	Min
750	3193	3209	-0.2%	3209	-0.6%	3169	-1.1%	3169	-1.7%	3209	-3.2%	3209	-4.8%	Max
614	2795	2799	0.1%	2786	0.2%	2785	0.5%	2790	0.8%	2807	1.6%	2827	2.9%	Mean
615	2738	2739	0.1%	2738	0.4%	2738	0.7%	2739	1.1%	2748	2.2%	2785	3.5%	Median

IFIM Flow (cfs)	Coho Salmon Juvenile Rearing													
		WUA w/ Diversion												
		2 cfs		5 cfs		10 cfs		15 cfs		30 cfs		50 cfs		
	WUA[1/]	WUA	%	WUA	%	WUA	%	WUA	%	WUA	%	WUA	%	
475	18373	18373	0.1%	18373	0.3%	18373	0.6%	18373	0.0	18406	1.4%	18413	1.2%	Min
750	18952	18952	-0.1%	18952	-0.4%	18952	-0.7%	18952	0.0	18952	-1.7%	18952	-1.5%	Max
614	18622	18626	0.0%	18623	0.0%	18631	0.0%	18636	0.0	18645	0.1%	18660	0.2%	Mean
615	18641	18640	0.0%	18644	0.0%	18648	0.1%	18654	0.1%	18658	0.2%	18665	0.6%	Median

IFIM Flow (cfs)	Steelhead Trout Juvenile Rearing													
		WUA w/ Diversion												
		2 cfs		5 cfs		10 cfs		15 cfs		30 cfs		50 cfs		
	WUA[1/]	WUA	%	WUA	%	WUA	%	WUA	%	WUA	%	WUA	%	
475	2547	2557	0.3%	2554	0.7%	2561	1.3%	2568	2.0%	2589	3.2%	2615	2.9%	Min
750	2701	2704	-0.1%	2704	-0.2%	2700	-0.4%	2700	-0.6%	2704	-1.0%	2704	-1.3%	Max
614	2640	2642	0.0%	2640	0.1%	2642	0.2%	2644	0.3%	2649	0.6%	2655	0.8%	Mean
615	2645	2646	0.0%	2644	0.1%	2644	0.2%	2649	0.3%	2650	0.5%	2653	0.8%	Median

IFIM Flow (cfs)	Native Char Juvenile Rearing													
		WUA w/ Diversion												
		2 cfs		5 cfs		10 cfs		15 cfs		30 cfs		50 cfs		
	WUA[1/]	WUA	%	WUA	%	WUA	%	WUA	%	WUA	%	WUA	%	
475	6675	6675	0.0%	6675	0.1%	6728	0.2%	6728	0.3%	6675	0.6%	6675	0.8%	Min
750	7829	7829	-0.3%	7829	-0.8%	7829	-1.5%	7829	-2.3%	7829	-4.5%	7829	-7.1%	Max
614	7541	7530	-0.1%	7564	-0.2%	7565	-0.5%	7552	-0.7%	7513	-1.5%	7479	-2.5%	Mean
615	7748	7725	-0.1%	7751	-0.3%	7751	-0.5%	7734	-0.7%	7679	-1.5%	7624	-2.4%	Median

IFIM Flow (cfs)	Steelhead Trout Adult Spawning													
		WUA w/ Diversion												
		2 cfs		5 cfs		10 cfs		15 cfs		30 cfs		50 cfs		
	WUA[1/]	WUA	%	WUA	%	WUA	%	WUA	%	WUA	%	WUA	%	
475	32714	32714	0.1%	32714	0.3%	32981	0.5%	33014	0.0	32714	1.5%	32714	2.5%	Min
750	34780	34780	-0.4%	34780	-0.9%	34780	-1.8%	34780	0.0	34780	-4.2%	34780	-3.3%	Max
614	33982	33991	0.0%	33989	0.0%	34033	0.0%	34051	0.0	34068	0.2%	34118	0.3%	Mean
615	34102	34095	0.0%	34104	0.1%	34104	0.2%	34117	0.0	34122	0.6%	34139	0.1%	Median

1) Weighted Usable Area without AR Diversion

Winter Evaluation Period (mid-November - January)

	Coho Salmon														
	Juvenile Rearing														
IFIM		WUA w/ Diversion													
Flow		2 cfs		5 cfs		10 cfs		15 cfs		30 cfs		50 cfs			
(cfs)	WUA[1/]	WUA	%	WUA	%	WUA	%	WUA	%	WUA	%	WUA	%		
575	18373	18373	0.1%	18373	0.3%	18373	0.6%	18373	0.9%	18406	1.4%	18527	1.2%	Min	
750	18952	18952	0.0%	18952	-0.4%	18952	-0.7%	18952	-1.1%	18952	-1.7%	18952	-1.4%	Max	
661	18602	18609	0.0%	18609	0.1%	18626	0.1%	18634	0.2%	18653	0.3%	18678	0.4%	Mean	
662	18586	18601	0.0%	18592	0.1%	18629	0.2%	18645	0.2%	18673	0.4%	18676	0.7%	Median	

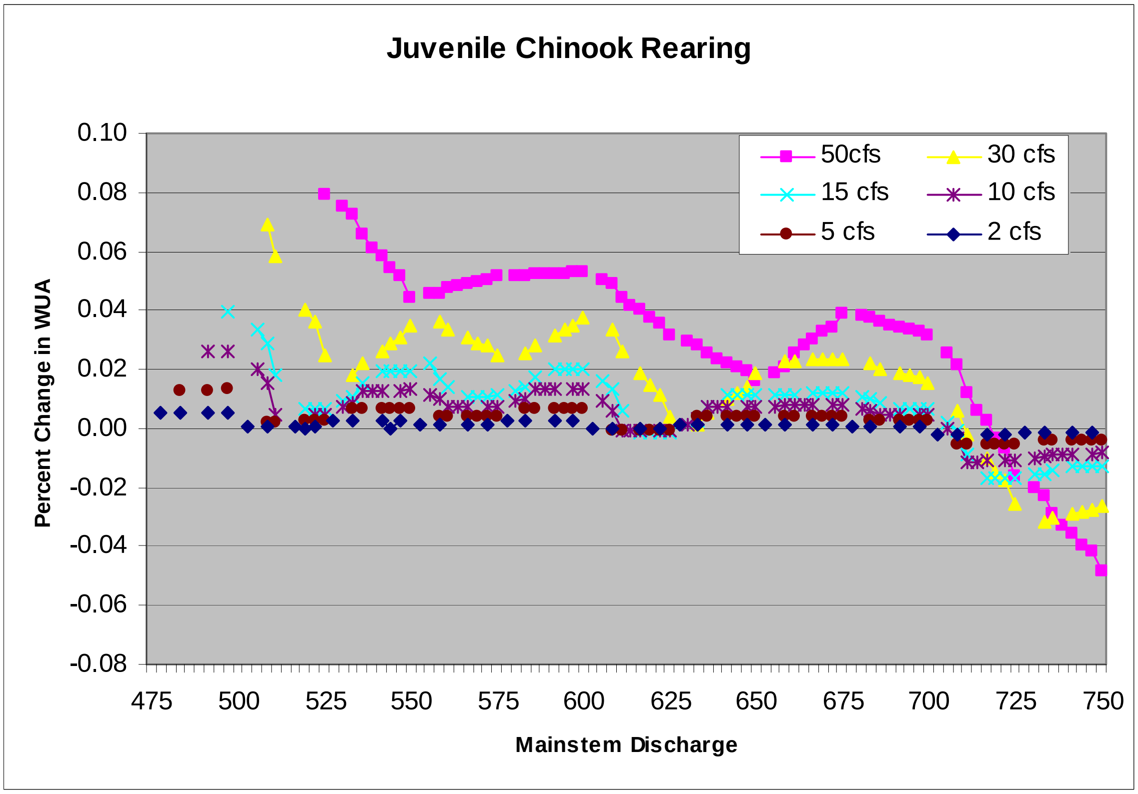
	Steelhead Trout													
	Juvenile Rearing													
IFIM		WUA w/ Diversion												
Flow		2 cfs		5 cfs		10 cfs		15 cfs		30 cfs		50 cfs		
(cfs)	WUA[1/]	WUA	%	WUA	%	WUA	%	WUA	%	WUA	%	WUA	%	
575	2547	2557	0.1%	2554	0.7%	2561	1.3%	2568	2.0%	2589	3.2%	2615	2.9%	Min
750	2657	2657	-0.1%	2657	-0.2%	2657	-0.4%	2666	-0.6%	2700	-1.0%	2700	-1.3%	Max
661	2622	2624	0.0%	2623	0.1%	2627	0.2%	2629	0.3%	2638	0.7%	2648	1.0%	Mean
662	2627	2626	0.0%	2629	0.1%	2631	0.2%	2633	0.3%	2639	0.9%	2648	1.2%	Median

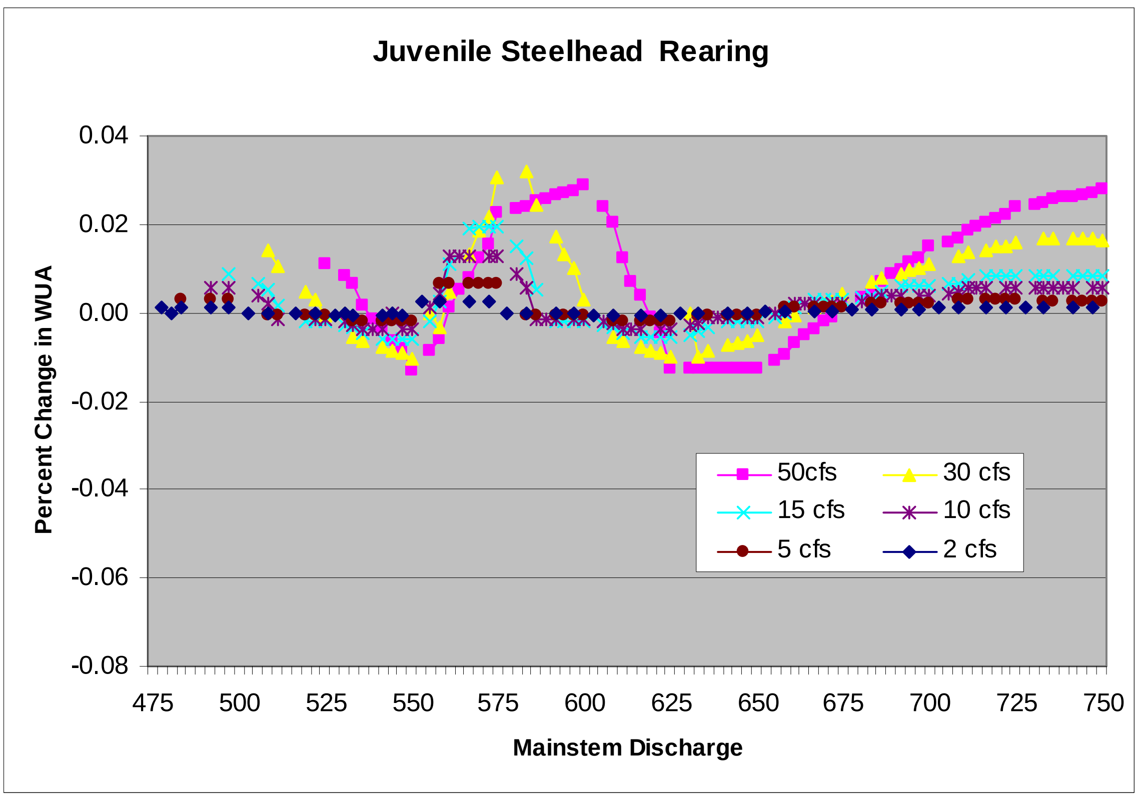
	Native Char													
	Juvenile Rearing													
IFIM		WUA w/ Diversion												
Flow		2 cfs		5 cfs		10 cfs		15 cfs		30 cfs		50 cfs		
(cfs)	WUA[1/]	WUA	%	WUA	%	WUA	%	WUA	%	WUA	%	WUA	%	
575	7567	7567	0.0%	7527	0.1%	7486	0.2%	7446	0.3%	7329	0.6%	7185	0.8%	Min
750	7829	7829	-0.1%	7829	-0.5%	7829	-1.1%	7829	-1.6%	7829	-3.2%	7829	-5.0%	Max
661	7757	7756	0.0%	7753	-0.1%	7743	-0.2%	7735	-0.3%	7706	-0.7%	7645	-1.5%	Mean
662	7769	7770	0.0%	7766	0.0%	7769	0.0%	7768	0.0%	7766	-0.1%	7747	-1.0%	Median

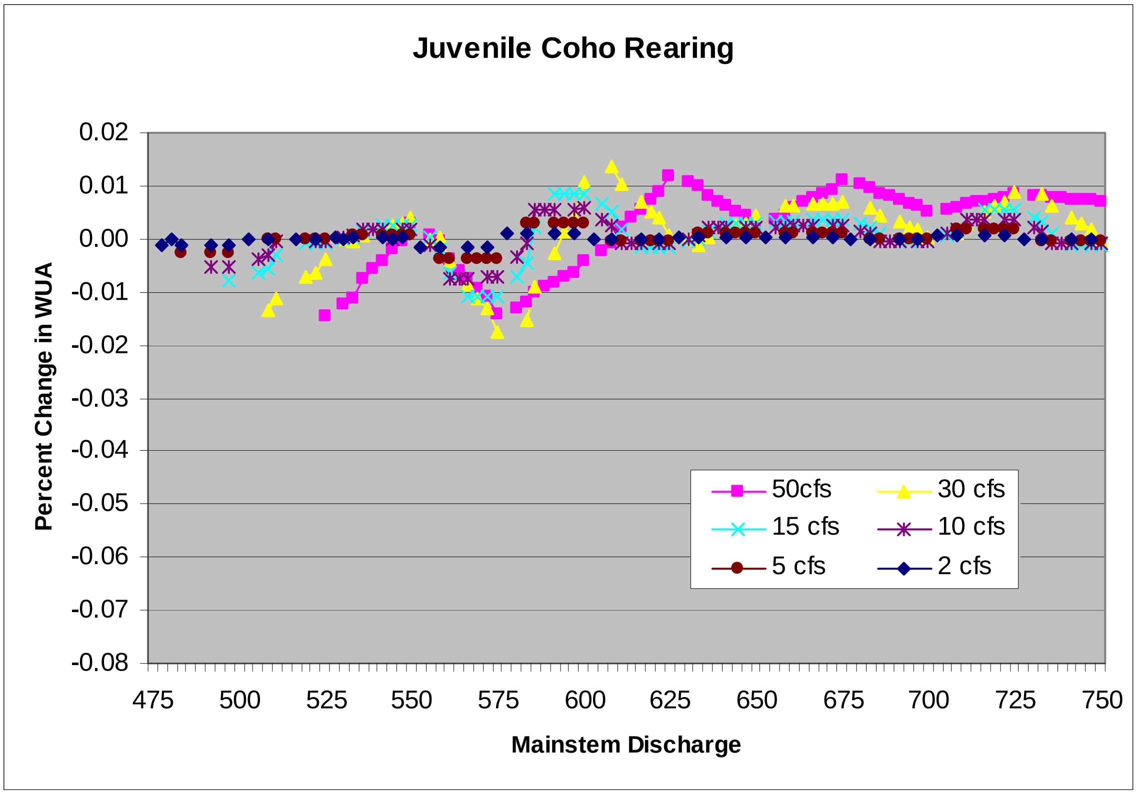
	Coho Salmon													
	Adult Spawning													
IFIM		WUA w/ Diversion												
Flow		2 cfs		5 cfs		10 cfs		15 cfs		30 cfs		50 cfs		
(cfs)	WUA[1/]	WUA	%	WUA	%	WUA	%	WUA	%	WUA	%	WUA	%	
575	18092	18182	0.2%	18157	0.6%	18221	1.2%	18286	1.8%	18474	0.0	18712	5.5%	Min
750	20449	20449	0.0%	20449	0.0%	20449	-0.1%	20449	-0.1%	20449	0.0	20449	-0.8%	Max
661	19247	19280	0.1%	19281	0.3%	19372	0.7%	19425	1.0%	19580	0.0	19792	2.9%	Mean
662	19049	19108	0.1%	19074	0.4%	19219	0.7%	19302	1.0%	19591	0.0	20051	2.8%	Median

1) Weighted Usable Area without AR Diversion

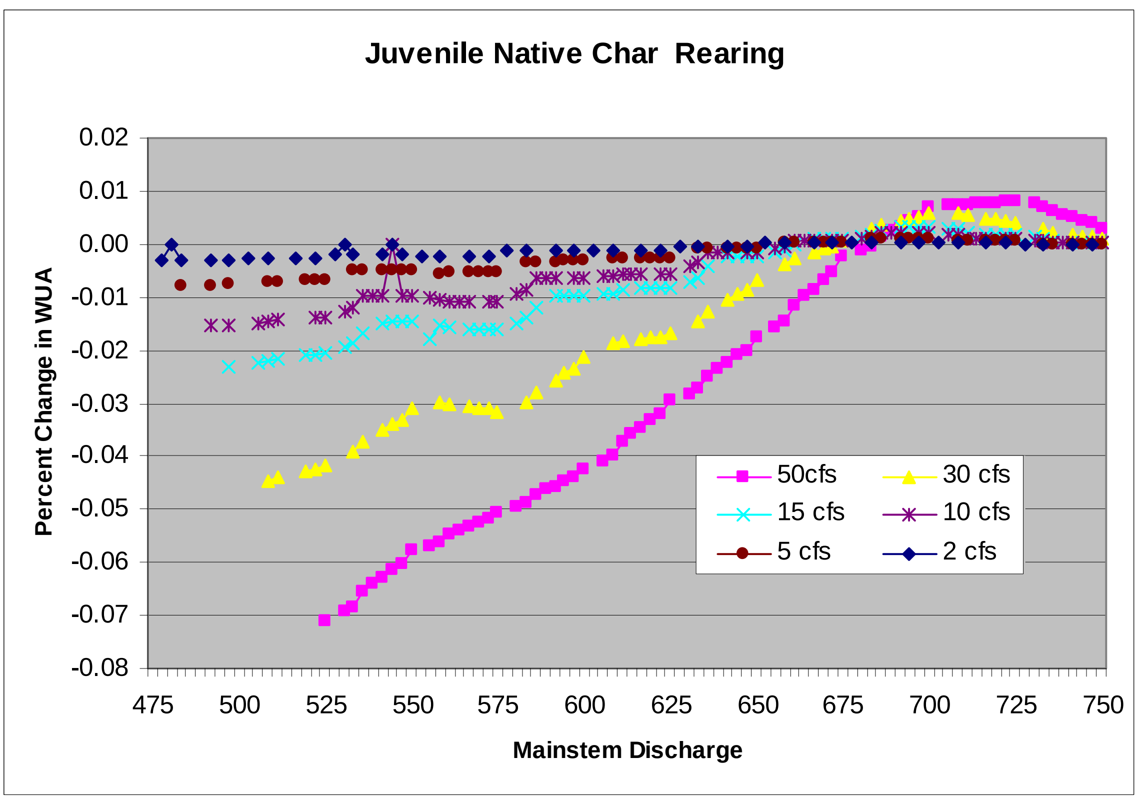
Figure A-1. Percent change in WUA vs. Dungeness River Flow at RM 4.2 with series of AR Diversions for Various Species and Life History Stages.


Juvenile Chinook Rearing
50cfs
30 cfs
15 cfs
10 cfs
5 cfs
2 cfs
Percent Change in WUA
0.10
0.08
0.06
0.04
0.02
0.00
-0.02
-0.04
-0.06
-0.08
475
500
525
550
575
600
625
650
675
700
725
750
Mainstem Discharge

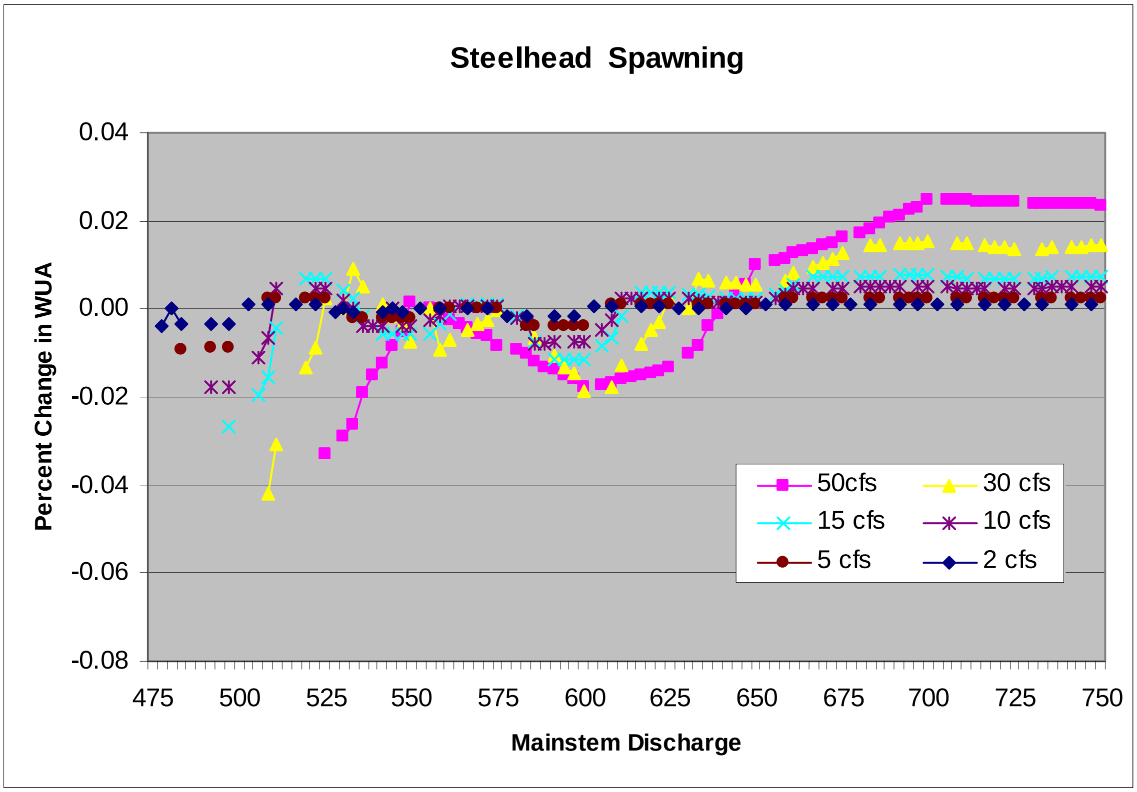

Juvenile Steelhead Rearing
50cfs
30 cfs
15 cfs
10 cfs
5 cfs
2 cfs
Percent Change in WUA
0.04
0.02
0.00
-0.02
-0.04
-0.06
-0.08
475
500
525
550
575
600
625
650
675
700
725
750
Mainstem Discharge

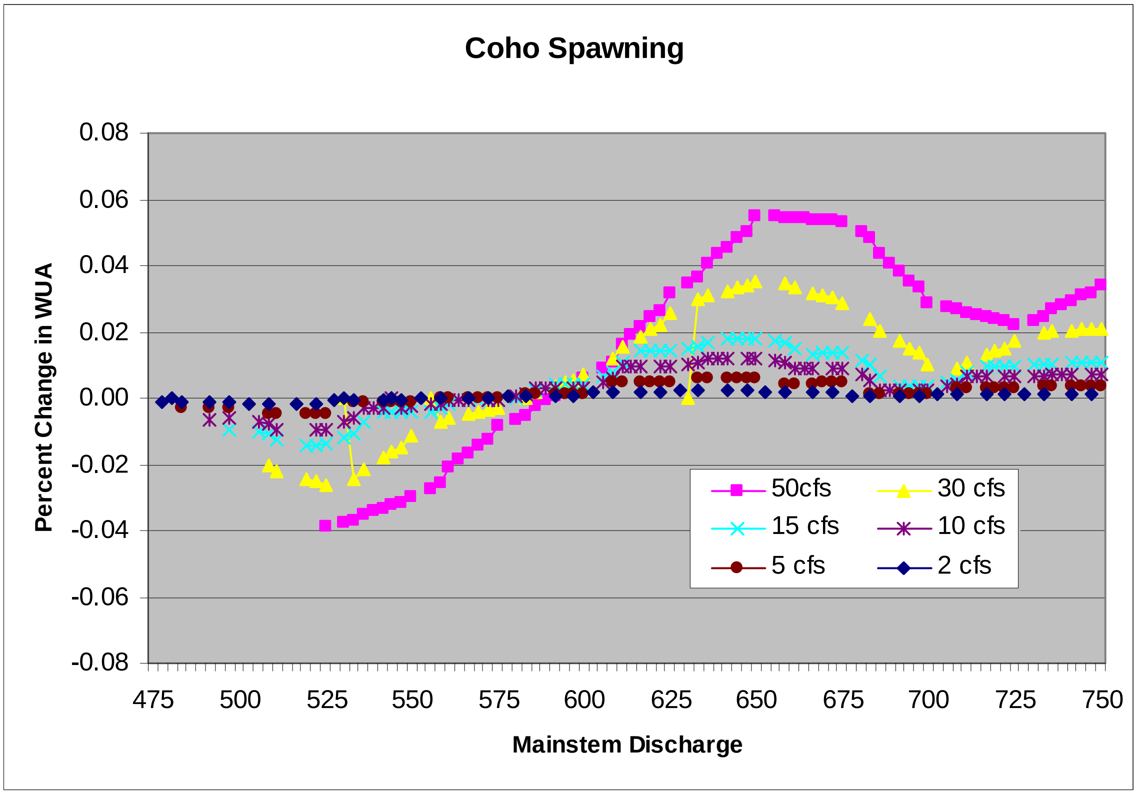


Juvenile Coho Rearing
Percent Change in WUA
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
475
500
525
550
575
600
625
650
675
700
725
750
Mainstem Discharge
50cfs
30 cfs
15 cfs
10 cfs
5 cfs
2 cfs



Juvenile Native Char Rearing
Percent Change in WUA
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
475
500
525
550
575
600
625
650
675
700
725
750
Mainstem Discharge
50cfs
30 cfs
15 cfs
10 cfs
5 cfs
2 cfs


Steelhead Spawning
0.04
0.02
0.00
-0.02
-0.04
-0.06
-0.08
Percent Change in WUA
475
500
525
550
575
600
625
650
675
700
725
750
Mainstem Discharge
50cfs
30 cfs
15 cfs
10 cfs
5 cfs
2 cfs


Coho Spawning
0.08
0.06
0.04
0.02
0.00
-0.02
-0.04
-0.06
-0.08
Percent Change in WUA
475
500
525
550
575
600
625
650
675
700
725
750
Mainstem Discharge
50cfs
30 cfs
15 cfs
10 cfs
5 cfs
2 cfs

APPENDIX B
Side Channel Data

Table B-1. Species/life stage habitat preference criteria and range of flows in surface water-connected side channels offering habitat conditions (Daraio et al. 2003).

Table 8. Range of flow required in surface water connected side channels to maintain specified habitat conditions, and the range of flows required in the main channel to maintain the specified flow in the side channels.

Species	IFIM, Depth Preference Range (ft)	IFIM, Velocity Preference Range (ft/s)	Anderson Required Discharge (cfs)	Stevens/Savage Required Discharge (cfs)		Right (east) RRB lower Required Discharge (cfs)		Dawley Required Discharge (cfs)		Kinkade East Required Discharge (cfs)		Kinkade Middle required discharge (cfs)	Kinkade West Required Discharge (cfs)	
			Side Channel	Side Channel	Main Channel	Side Channel	Main Channel	Side Channel	Main Channel	Side Channel	Main Channel	Side Channel	Side Channel	Main Channel
Steelhead														
Spawning	≥ 1.0	1.9-2.5	NA*	65-95	360-480	35-57	110-190	40-68	230-460	20-55	30-90	NA	25-54	250-560
Juvenile	≥ 2.0	2.2-2.6	NA	85-110	440-540	55-60	180-210	55-72	360-480	35-50	50-85	NA	35-75	360-700
Adult	≥ 1.7	1.5-1.8	NA	45-65	290-360	37-40	110-125	27-40	120-230	15-25	20-35	NA	11-25	150-280
Dolly Varden														
Juvenile	≥ 1.75	0.8-3.0	NA	18-120	160-590	35-75	110-280	25-90	115-640	0-70	0-240	NA	3-80	120-700
Coho														
Spawning	0.95-3.4	0.75-2.0	NA	17-70	150-375	≤ 37	≤ 110	15-45	80-280	≤ 20	≤ 30	NA	4-25	120-250
Juvenile	0.5-2.25	≤ 0.4	NA	≤ 8	≤ 120	NA		≤ 3	≤ 20	NA		NA	≤ 2	≤ 115
Chinook														
Spawning	1.2-3.4	1.75-3.0	NA	60-120	340-590	30-75	105-280	35-90	180-640	30-70	40-240	NA	20-25	240-290
Juvenile	1.5-2.25	1.55-1.8	NA	NA		25-30	95-105	30-42	160-240	≤ 35	≤ 50	NA	NA	
Adult	≥ 6.5	≤ 3.8	NA	NA		NA		NA		NA		NA	NA	
Pink														
Spawning	1.0-2.7	1.3-2.3	NA	35-80	240-430	20-55	80-180	20-60	100-380	≤ 40	≤ 60	NA	5-15	120-130

* NA = Habitat Parameters NOT ATTAINABLE

Table B-2. Side channel rating curves and habitat regression equations and the assessment of habitat parameter changes under various AR Diversions during the Spring (May – July) evaluation period (after Daraio et al. 2003).

Side Channel Flow Assessment (Spring)

Side Channel	Rating Curve Constant (b)[1]	Regression Equation	Relative Change in Parameter							Habitat Parameter under various AR Diverions														
			2	5	10	15	30	50	cfs	Background		2 cfs		5 cfs		10 cfs		15 cfs		30 cfs		50 cfs		
			477	480	485	490	505	525	cfs	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	
			0.4%	1.0%	2.1%	3.1%	5.9%	9.5%	%															
Kinkade - East																								
Discharge	0.5526	Qs = 4. 088(Qm) 0.5562	0.2%	0.6%	1.1%	1.7%	3.3%	5.4%		147	56	147	56	146	56	145	55	144	55	142	54	139	53	cfs
Velocity	0.4166	y = 0.5072x 0.4166	0.2%	0.4%	0.9%	1.3%	2.5%	4.1%		4.2	2.8	4.2	2.8	4.2	2.8	4.2	2.8	4.1	2.8	4.1	2.7	4.0	2.7	fps
Depth	0.2836	y = 0.7932x 0. 2836	0.1%	0.3%	0.6%	0.9%	1.7%	2.8%		3.3	2.5	3.3	2.5	3.3	2.5	3.3	2.5	3.3	2.5	3.2	2.5	3.2	2.4	ft
Width	0.0626	y = 22. 622x 0.0626	0.0%	0.1%	0.1%	0.2%	0.4%	0.6%		32	26	32	26	32	26	32	26	32	26	32	26	32	26	ft
Kinkade - Middle																								
Discharge	0.3847	Q s = 7. 1617(Q m -110) 0. 3847	0.2%	0.4%	0.8%	1.2%	2.3%	3.8%		91	20	91	20	91	20	90	20	90	20	89	20	88	19	cfs
Velocity	0.4718	y = 0.7651x 0.4718	0.2%	0.5%	1.0%	1.5%	2.8%	4.6%		6.4	2.6	6.4	2.6	6.4	2.6	6.3	2.6	6.3	2.6	6.2	2.5	6.1	2.5	fps
Depth	0.4195	y = 0.243x 0.4195	0.2%	0.4%	0.9%	1.3%	2.5%	4.1%		1.6	1.0	1.6	1.0	1.6	1.0	1.6	1.0	1.6	1.0	1.6	1.0	1.5	1.0	ft
Width	0.0904	y = 16. 836x 0.0904	0.0%	0.1%	0.2%	0.3%	0.6%	0.9%		91	21	91	21	91	21	91	21	91	21	90	21	90	21	ft
Kinkade - West																								
Discharge	0.7743	Q s = 0. 4522(Q m -110) 0.7743	0.3%	0.8%	1.6%	2.4%	4.6%	7.5%		175	66	174	66	174	65	172	65	171	64	167	63	162	61	cfs
Velocity	0.3257	y = 0.6842x 0.3257	0.1%	0.3%	0.7%	1.0%	2.0%	3.2%		3.9	2.7	3.9	2.7	3.9	2.7	3.9	2.7	3.9	2.7	3.8	2.6	3.8	2.6	fps
Depth	0.2199	y = 1.6602x 0.2199	0.1%	0.2%	0.5%	0.7%	1.3%	2.2%		5.2	4.2	5.2	4.2	5.2	4.2	5.2	4.2	5.2	4.2	5.1	4.1	5.1	4.1	ft
Width	0.0762	y = 27. 766x 0.0752	0.0%	0.1%	0.2%	0.2%	0.5%	0.8%		47	31	46	31	46	31	46	31	46	31	46	31	46	31	ft
Dawley																								
Discharge	0.7691	Q s = 0. 6603(Q m -20) 0. 7691	0.3%	0.8%	1.6%	2.4%	4.6%	7.4%		117	28	117	28	116	28	115	28	114	27	112	27	108	26	cfs
Velocity	0.5521	y = 0.2423x 0.5521	0.2%	0.6%	1.1%	1.7%	3.3%	5.4%		3.4	1.5	3.4	1.5	3.4	1.5	3.4	1.5	3.3	1.5	3.3	1.5	3.2	1.4	fps
Depth	0.2241	y = 0.8723x 0.2241	0.1%	0.2%	0.5%	0.7%	1.4%	2.2%		2.5	1.7	2.5	1.7	2.5	1.7	2.5	1.7	2.5	1.7	2.5	1.7	2.4	1.7	ft
Width	0.1247	y = 16. 252x 0.1247	0.1%	0.1%	0.3%	0.4%	0.8%	1.2%		29	22	29	22	29	22	29	22	29	22	29	22	29	22	ft
Lower East RRB																								
Discharge	0.7539	Q s = 1. 3149(Q m -50) 0. 7539	0.3%	0.8%	1.6%	2.3%	4.5%	7.3%		130	85	130	84	129	84	128	83	127	83	124	81	121	78	cfs
Velocity	0.5449	y = 0.2803x 0.5449	0.2%	0.6%	1.1%	1.7%	3.3%	5.3%		4.1	1.7	4.1	1.7	4.1	1.7	4.1	1.7	4.0	1.7	4.0	1.6	3.9	1.6	fps
Depth	0.3095	y = 0. 5868x 0.3095	0.1%	0.3%	0.6%	1.0%	1.9%	3.1%		2.7	1.7	2.7	1.7	2.7	1.7	2.7	1.7	2.7	1.7	2.6	1.7	2.6	1.6	ft
Width	0.0823	y = 19. 19x 0.0823	0.0%	0.1%	0.2%	0.3%	0.5%	0.8%		30	22	30	22	30	22	30	22	30	22	30	22	30	22	ft
Stevens/Savage																								
Discharge	1.0130	Q s = 0.2364(Q m -105) 1.013	0.4%	1.1%	2.1%	3.1%	6.0%	9.6%		194	11	193	11	192	11	190	11	188	11	182	10	175	10	cfs
Velocity	0.6768	y = 0.1122x 0.6768	0.3%	0.7%	1.4%	2.1%	4.1%	6.5%		4.0	0.6	4.0	0.6	4.0	0.6	3.9	0.6	3.9	0.6	3.8	0.6	3.7	0.6	fps
Depth	0.1392	y = 1. 5561x 0.1392	0.1%	0.1%	0.3%	0.4%	0.8%	1.4%		3.3	2.2	3.3	2.2	3.3	2.2	3.3	2.2	3.3	2.2	3.3	2.2	3.3	2.2	ft
Width	0.0172	y = 25. 324x0.0172	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%		29	26	29	26	29	26	29	26	29	26	29	26	29	26	ft
Anderson																								
Discharge	1.1600	Q s = 0. 0145(Q m -155) 1.16	0.5%	1.2%	2.4%	3.5%	6.9%	11.0%		37	5	37	5	37	5	36	5	36	5	34	5	33	4	cfs
Velocity	0.2570	y = 1.6911x 0.257	0.1%	0.3%	0.5%	0.8%	1.6%	2.5%		4.0	2.4	4.0	2.4	4.0	2.4	4.0	2.4	4.0	2.4	3.9	2.4	3.9	2.3	fps
Depth	0.4119	y = 0.2876x 0. 4119	0.2%	0.4%	0.9%	1.3%	2.5%	4.0%		4.4	2.2	4.4	2.2	4.4	2.2	4.4	2.2	4.3	2.2	4.3	2.1	4.2	2.1	ft
Width	0.3257	y = 4.3698x 0.3257	0.1%	0.3%	0.7%	1.0%	2.0%	3.2%		38	22	38	22	38	22	38	22	38	22	37	22	37	21	ft

1) Side channel rating curve data from the USBR side channel report (Daraio et al. 2003)
Background based on the minimum and maximum parameter values across the flow range for the season

Main Channel (USGS)							
Depth	0.2600	0.1%	0.3%	0.5%	0.8%	1.6%	2.6%
Kinkade Q	0.8023	0.3%	0.8%	1.7%	2.5%	4.8%	7.7%

Table B-3. Side channel rating curves and habitat regression equations and the assessment of habitat parameter changes under various AR Diversions during the winter (mid-November–January) evaluation period (after Daraio et al. 2003).

Side Channel Flow Assessment (Winter)

Side Channel	Rating Curve Constant (b)[1]	Regression Equation	Relative Change in Parameter						
			2	5	10	15	30	50	cfs
			577	580	585	590	605	625	cfs
			0.3%	0.9%	1.7%	2.5%	5.0%	8.0%	%
			(%)	(%)	(%)	(%)	(%)	(%)	
Kinkade - East									
Discharge	0.5526	Qs = 4. 088(Qm) 0.5562	0.2%	0.5%	0.9%	1.4%	2.8%	4.5%	
Velocity	0.4166	y = 0.5072x 0.4166	0.1%	0.4%	0.7%	1.1%	2.1%	3.4%	
Depth	0.2836	y = 0.7932x 0. 2836	0.1%	0.2%	0.5%	0.7%	1.4%	2.3%	
Width	0.0626	y = 22. 622x 0.0626	0.0%	0.1%	0.1%	0.2%	0.3%	0.5%	
Kinkade - Middle									
Discharge	0.3847	Q s = 7. 1617(Q m -110) 0. 3847	0.1%	0.3%	0.7%	1.0%	1.9%	3.2%	
Velocity	0.4718	y = 0.7651x 0.4718	0.2%	0.4%	0.8%	1.2%	2.4%	3.9%	
Depth	0.4195	y = 0.243x 0.4195	0.1%	0.4%	0.7%	1.1%	2.1%	3.4%	
Width	0.0904	y = 16. 836x 0.0904	0.0%	0.1%	0.2%	0.2%	0.5%	0.8%	
Kinkade - West									
Discharge	0.7743	Q s = 0. 4522(Q m -110) 0.7743	0.3%	0.7%	1.3%	2.0%	3.9%	6.3%	
Velocity	0.3257	y = 0.6842x 0.3257	0.1%	0.3%	0.6%	0.8%	1.6%	2.7%	
Depth	0.2199	y = 1.6602x 0.2199	0.1%	0.2%	0.4%	0.6%	1.1%	1.8%	
Width	0.0762	y = 27. 766x 0.0752	0.0%	0.1%	0.1%	0.2%	0.4%	0.6%	
Dawley									
Discharge	0.7691	Q s = 0. 6603(Q m -20) 0. 7691	0.3%	0.7%	1.3%	2.0%	3.8%	6.2%	
Velocity	0.5521	y = 0.2423x 0.5521	0.2%	0.5%	0.9%	1.4%	2.8%	4.5%	
Depth	0.2241	y = 0.8723x 0.2241	0.1%	0.2%	0.4%	0.6%	1.1%	1.9%	
Width	0.1247	y = 16. 252x 0.1247	0.0%	0.1%	0.2%	0.3%	0.6%	1.0%	
Lower East RRB									
Discharge	0.7539	Q s = 1. 3149(Q m -50) 0. 7539	0.3%	0.7%	1.3%	1.9%	3.8%	6.1%	
Velocity	0.5449	y = 0.2803x 0.5449	0.2%	0.5%	0.9%	1.4%	2.7%	4.4%	
Depth	0.3095	y = 0. 5868x 0.3095	0.1%	0.3%	0.5%	0.8%	1.6%	2.5%	
Width	0.0823	y = 19. 19x 0.0823	0.0%	0.1%	0.1%	0.2%	0.4%	0.7%	
Stevens/Savage									
Discharge	1.0130	Q s = 0.2364(Q m -105) 1.013	0.4%	0.9%	1.7%	2.6%	5.0%	8.1%	
Velocity	0.6768	y = 0.1122x 0.6768	0.2%	0.6%	1.2%	1.7%	3.4%	5.5%	
Depth	0.1392	y = 1. 5561x 0.1392	0.0%	0.1%	0.2%	0.4%	0.7%	1.2%	
Width	0.0172	y = 25. 324x0.0172	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	
Anderson									
Discharge	1.1600	Q s = 0. 0145(Q m -155) 1.16	0.4%	1.0%	2.0%	2.9%	5.7%	9.2%	
Velocity	0.2570	y = 1.6911x 0.257	0.1%	0.2%	0.4%	0.7%	1.3%	2.1%	
Depth	0.4119	y = 0.2876x 0. 4119	0.1%	0.4%	0.7%	1.1%	2.1%	3.4%	
Width	0.3257	y = 4.3698x 0.3257	0.1%	0.3%	0.6%	0.8%	1.6%	2.7%	

Side Channel	Habitat Parameter under various AR Diverions														
	Background		2 cfs		5 cfs		10 cfs		15 cfs		30 cfs		50 cfs		
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	
Kinkade - East															
Discharge	147	56	147	56	146	56	146	55	145	55	143	54	140	53	cfs
Velocity	4.2	2.8	4.2	2.8	4.2	2.8	4.2	2.8	4.2	2.8	4.1	2.7	4.1	2.7	fps
Depth	3.3	2.5	3.3	2.5	3.3	2.5	3.3	2.5	3.3	2.5	3.3	2.5	3.2	2.4	ft
Width	32	26	32	26	32	26	32	26	32	26	32	26	32	26	ft
Kinkade - Middle															
Discharge	91	20	91	20	91	20	90	20	90	20	89	20	88	19	cfs
Velocity	6.4	2.6	6.4	2.6	6.4	2.6	6.3	2.6	6.3	2.6	6.2	2.5	6.2	2.5	fps
Depth	1.6	1.0	1.6	1.0	1.6	1.0	1.6	1.0	1.6	1.0	1.6	1.0	1.5	1.0	ft
Width	91	21	91	21	91	21	91	21	91	21	91	21	90	21	ft
Kinkade - West															
Discharge	175	66	175	66	174	66	173	65	172	65	168	63	164	62	cfs
Velocity	3.9	2.7	3.9	2.7	3.9	2.7	3.9	2.7	3.9	2.7	3.8	2.7	3.8	2.6	fps
Depth	5.2	4.2	5.2	4.2	5.2	4.2	5.2	4.2	5.2	4.2	5.1	4.2	5.1	4.1	ft
Width	47	31	46	31	46	31	46	31	46	31	46	31	46	31	ft
Dawley															
Discharge	117	28	117	28	116	28	115	28	115	27	113	27	110	26	cfs
Velocity	3.4	1.5	3.4	1.5	3.4	1.5	3.4	1.5	3.4	1.5	3.3	1.5	3.2	1.4	fps
Depth	2.5	1.7	2.5	1.7	2.5	1.7	2.5	1.7	2.5	1.7	2.5	1.7	2.5	1.7	ft
Width	29	22	29	22	29	22	29	22	29	22	29	22	29	22	ft
Lower East RRB															
Discharge	130	85	130	84	129	84	129	83	128	83	125	81	122	79	cfs
Velocity	4.1	1.7	4.1	1.7	4.1	1.7	4.1	1.7	4.0	1.7	4.0	1.7	3.9	1.6	fps
Depth	2.7	1.7	2.7	1.7	2.7	1.7	2.7	1.7	2.7	1.7	2.7	1.7	2.6	1.7	ft
Width	30	22	30	22	30	22	30	22	30	22	30	22	30	22	ft
Stevens/Savage															
Discharge	194	11	193	11	192	11	191	11	189	11	184	10	178	10	cfs
Velocity	4.0	0.6	4.0	0.6	4.0	0.6	4.0	0.6	3.9	0.6	3.9	0.6	3.8	0.6	fps
Depth	3.3	2.2	3.3	2.2	3.3	2.2	3.3	2.2	3.3	2.2	3.3	2.2	3.3	2.2	ft
Width	29	26	29	26	29	26	29	26	29	26	29	26	29	26	ft
Anderson															
Discharge	37	5	37	5	37	5	36	5	36	5	35	5	34	5	cfs
Velocity	4.0	2.4	4.0	2.4	4.0	2.4	4.0	2.4	4.0	2.4	3.9	2.4	3.9	2.3	fps
Depth	4.4	2.2	4.4	2.2	4.4	2.2	4.4	2.2	4.4	2.2	4.3	2.2	4.3	2.1	ft
Width	38	22	38	22	38	22	38	22	38	22	37	22	37	21	ft

1) Side channel rating curve data from the USBR side channel report (Daraio et al. 2003)
Background based on the minimum and maximum parameter values across the flow range for the season

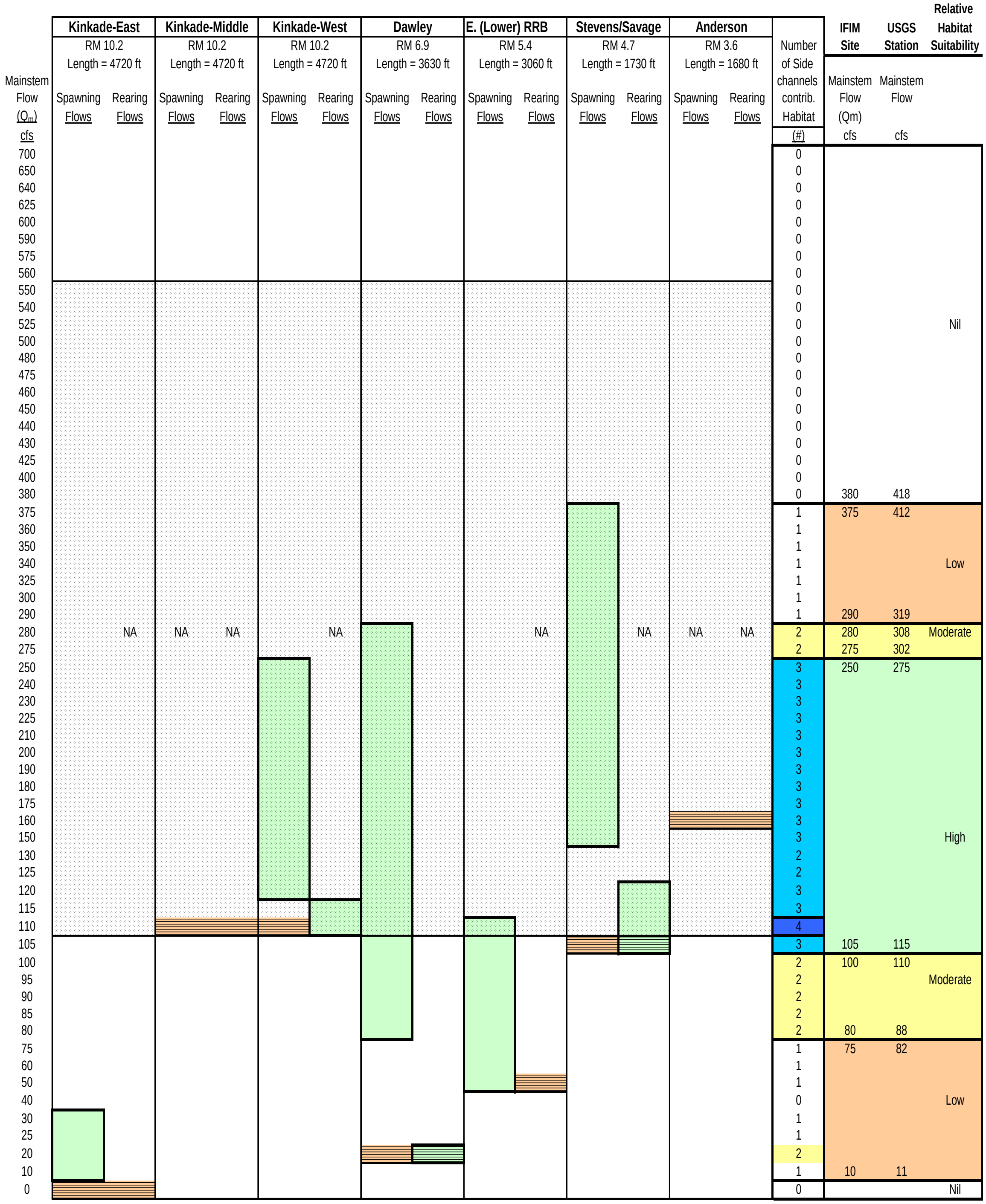
Main Channel (USGS)							
Depth	0.2600	0.1%	0.2%	0.4%	0.7%	1.3%	2.1%
Kinkade Q	0.8023	0.3%	0.7%	1.4%	2.0%	4.0%	6.5%

Figures B-1 to B-4.

Assessment of mainstem Dungeness River flows for preferred anadromous fish spawning and rearing habitat conditions in surface water-connected side channels after Daraio et al. (2003).

Coho Salmon Summary

Figure B-1. Assessment of mainstem Dungeness River flows for suitable coho salmon spawning and rearing habitat conditions in surface water-connected side channels after Daraio et al. (2003).



1) = Estimated % exceedance levels at the upper IFIM study site (RM 4.2) under average baseline (1999-2002) irrigation withdrawals.

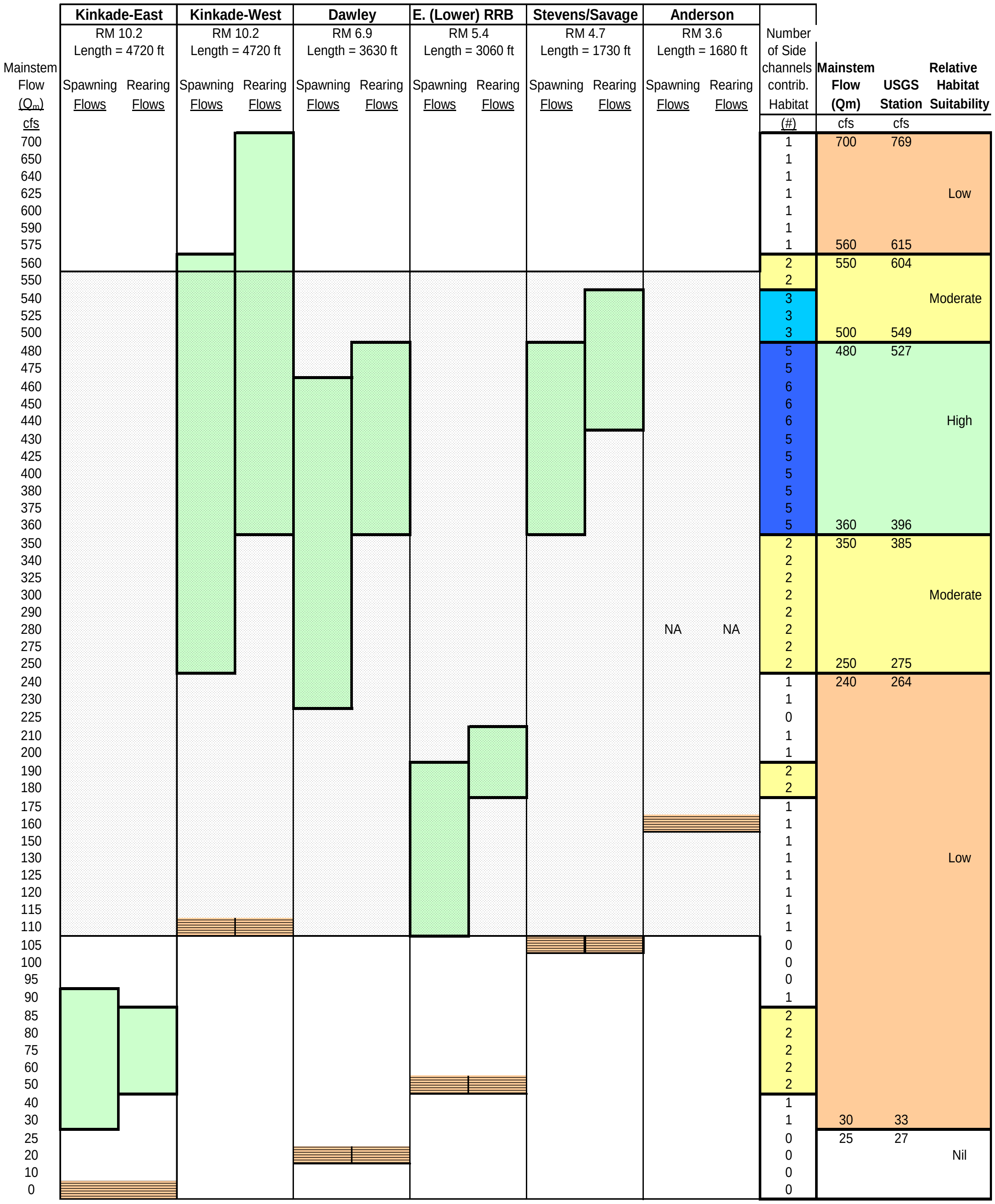
Number of side channels contributing either spawning or rearing habitat

(green box)	= Suitable habitat range (Daraio et al. 2003; Tables 7 and 8)
(stippled box)	= Range of flows surveyed in Summer 2002, within the suitable habitat range (Daraio et al. 2003)
(hatched box)	= Empirically derived connection of mainstem and side channel (Daraio et al. 2003; Table 4)
Q_m	= Mainstem River Discharge (cfs) at side channel entrance as a function of mainstem river discharge at the USGS site and volume of irrigation diversions during the summer of 2002.
NA	= Chinook salmon habitat suitability not attainable at any flows surveyed in Summer 2002.

Number of side channels
4 - 5
3
2
0 - 1

Steelhead Trout Summary

Figure B-2. Assessment of mainstem Dungeness River flows for preferred steelhead trout spawning and rearing habitat conditions in surface water-connected side channels after Daraio et al. (2003).



1) = Estimated % exceedance levels at the upper IFIM study site (RM 4.2) under current irrigation withdrawals.

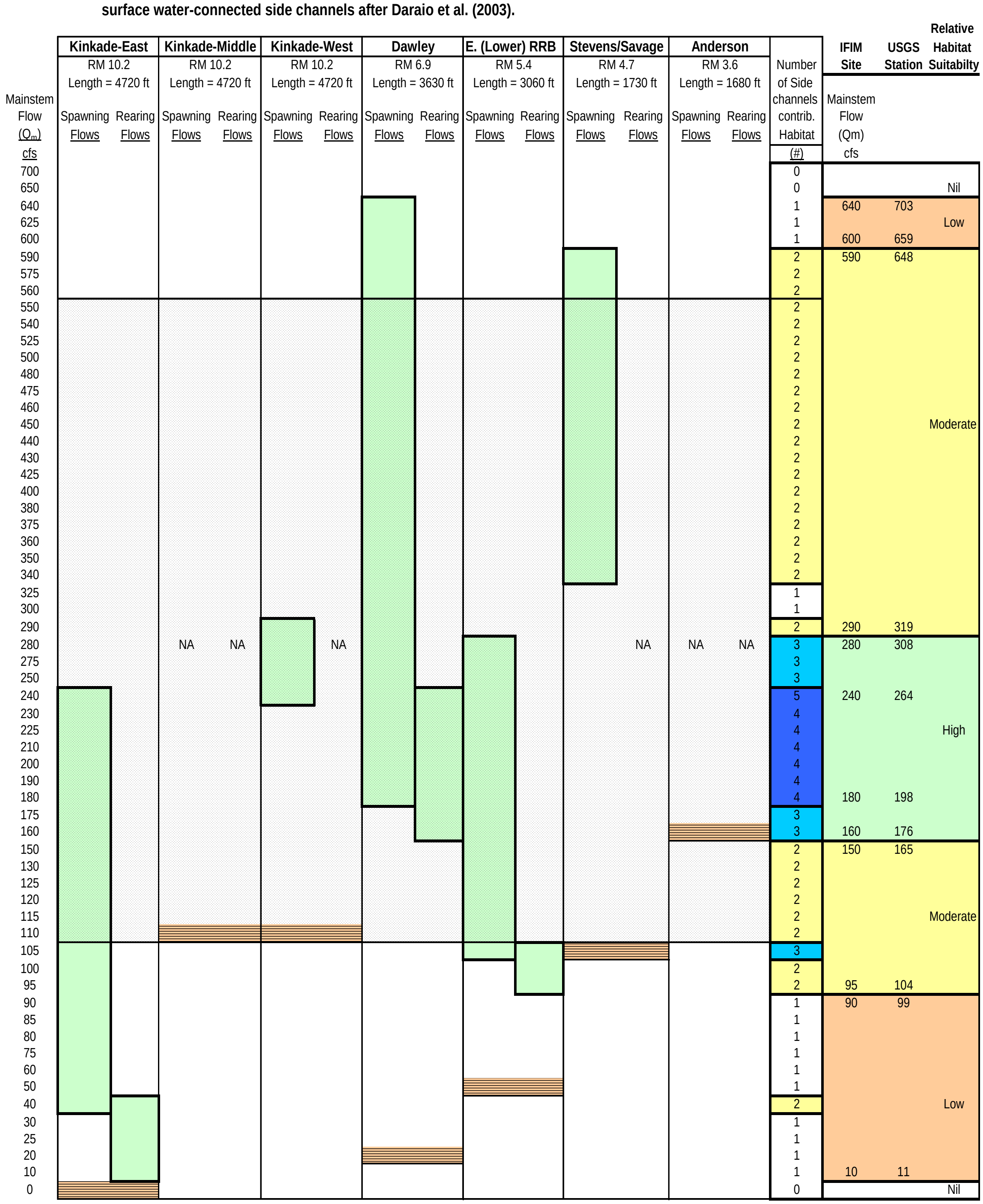
Talley of the number of either spawning or rearing habitat life stages per increment of discharge.

- = Preferred habitat range (Daraio et al. 2003; Tables 7 and 8)
- = Range of flows surveyed in Summer 2002 (Daraio et al. 2003)
- = Empirically derived connection of mainstem and side channel (Daraio et al. 2003)
- Q_m = Mainstem River Discharge (cfs) at side channel entrance as a function of mainstem river discharge at the USGS site and volume of irrigation diversions during the summer of 2002.
- NA = Chinook salmon habitat suitability not attainable at any flows surveyed in Summer 2002.

4 - 6
3
2
0 - 1

Chinook Salmon Summary

Figure B-3. Assessment of mainstem Dungeness River flows for preferred Chinook salmon spawning and rearing habitat conditions in surface water-connected side channels after Daraio et al. (2003).



1) = Estimated % exceedance levels at the upper IFIM study site (RM 4.2) under average baseline (1999-2002) irrigation withdrawals.

Number of side channels contributing either spawning or rearing habitat

= Suitable habitat range (Daraio et al. 2003; Tables 7 and 8)

= Range of flows surveyed in Summer 2002, within the suitable habitat range (Daraio et al. 2003)

= Empirically derived connection of mainstem and side channel (Daraio et al. 2003; Table 4)

Q_m = Mainstem River Discharge (cfs) at side channel entrance as a function of mainstem river discharge at the USGS site and volume of irrigation diversions during the summer of 2002.

NA = Chinook salmon habitat suitability not attainable at any flows surveyed in Summer 2002.

4 - 5

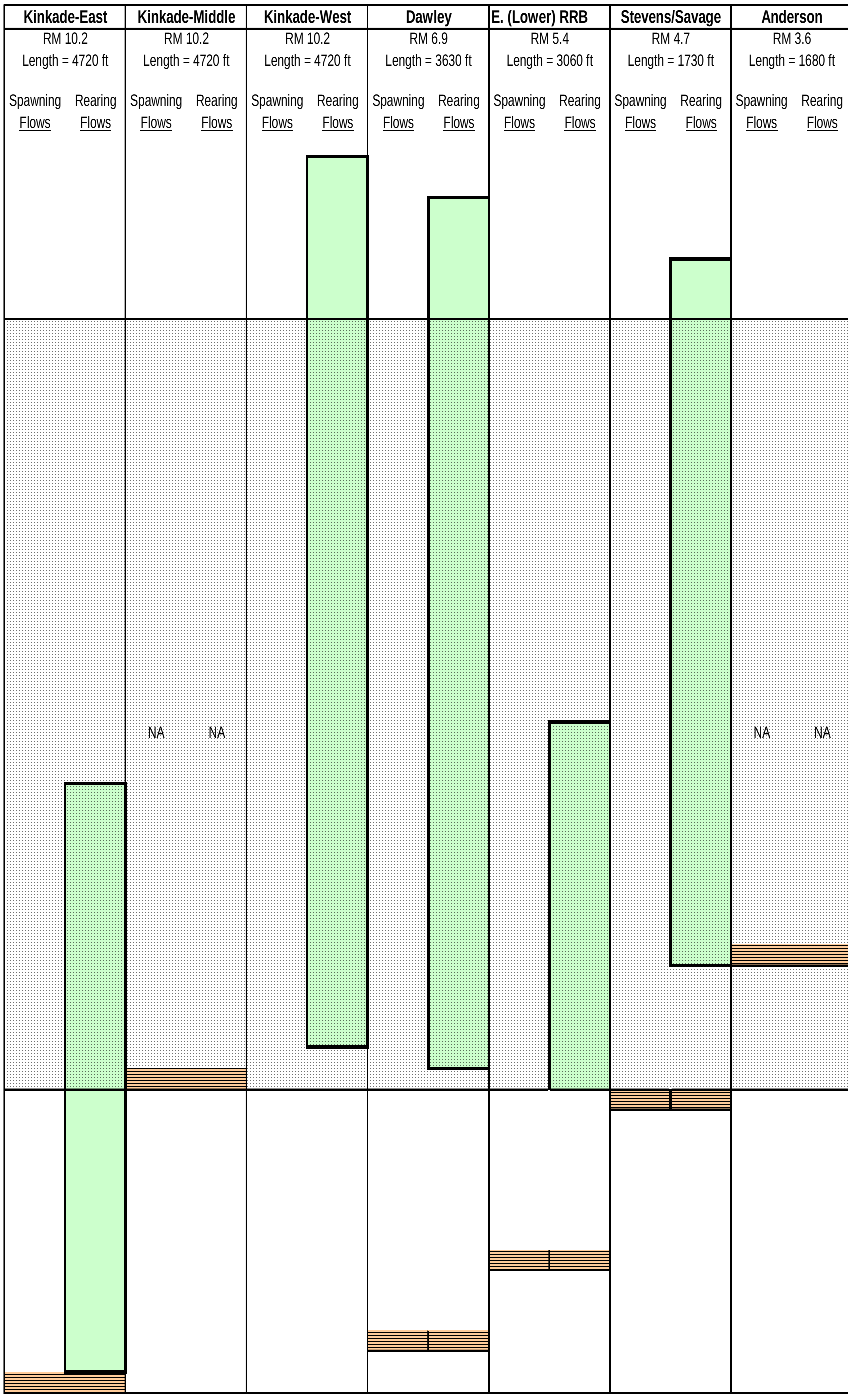
3

2

0 - 1

Native Char Summary

Figure B-4. Assessment of mainstem Dungeness River flows for preferred Dolly Varden rearing habitat conditions in surface water-connected side channels after Daraio et al. (2003).



Mainstem Flow (Q_m) cfs	Number of Side channels contrib. Habitat (#)	IFIM Site Mainstem Flow (Qm) cfs	USGS Station cfs	Relative Habitat Suitability
700	1			
650	1	650	714	Low
640	2	640	703	
625	2			
600	2			
590	3			
575	3			
560	3			
550	3			
540	3			Moderate
525	3			
500	3			
480	3			
475	3			
460	3			
450	3			
440	3			
430	3			
425	3			
400	3			
380	3			
375	3			
360	3			
350	3			
340	3			
325	3			
300	3			
290	3	290	319	
280	4	280	308	
275	4			
250	4			
240	5			
230	5			
225	5			
210	5			
200	5			High
190	5			
180	5			
175	5			
160	5			
150	4			
130	4			
125	4			
120	4	120	132	
115	3	115	126	Moderate
110	2	110	121	
105	1	105	115	
100	1			
95	1			
90	1			
85	1			
80	1			
75	1			Low
60	1			
50	1			
40	1			
30	1			
25	1			
20	1			
10	1	10	11	
0	0	0	0	Nil

1) = Estimated % exceedance levels at the upper IFIM study site (RM 4.2) under average baseline (1999-2002) irrigation withdrawals.

Number of side channels contributing either spawning or rearing habitat

= Suitable habitat range (Daraio et al. 2003; Tables 7 and 8)

= Range of flows surveyed in Summer 2002, within the suitable habitat range (Daraio et al. 2003)

= Empirically derived connection of mainstem and side channel (Daraio et al. 2003; Table 4)

Q_m = Mainstem River Discharge (cfs) at side channel entrance as a function of mainstem river discharge at the USGS site and volume of irrigation diversions during the summer of 2002.

NA = Chinook salmon habitat suitability not attainable at any flows surveyed in Summer 2002.

4 - 5

3

2

0 - 1