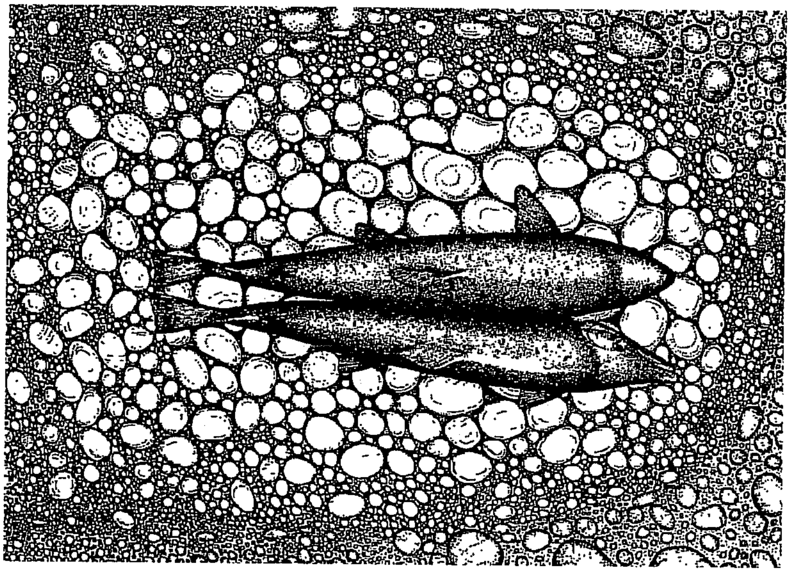
DWR-1140

RELATIONSHIPS BETWEEN FLOW FLUCTUATIONS AND REDD DEWATERING AND JUVENILE STRANDING FOR CHINOOK SALMON AND STEELHEAD IN THE SACRAMENTO RIVER BETWEEN KESWICK DAM AND BATTLE CREEK



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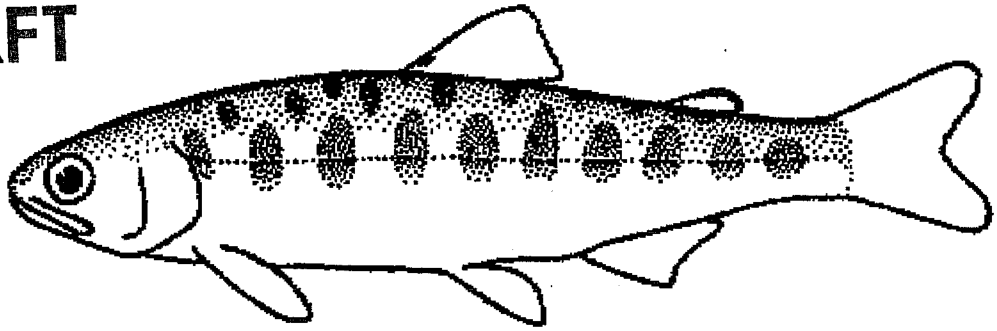

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CVPIA INSTREAM FLOW INVESTIGATIONS
SACRAMENTO RIVER BETWEEN KESWICK DAM TO BATTLE CREEK
CHINOOK SALMON AND STEELHEAD
REDD DEWATERING AND JUVENILE STRANDING

PREFACE

The following is the final report for the U. S. Fish and Wildlife Service's investigations on the effects of flow fluctuations on anadromous salmonid redd dewatering and juvenile stranding in the Sacramento River between Keswick Dam and Battle Creek. These investigations are part of the Central Valley Project Improvement Act (CVPIA) Instream Flow Investigations, a 7-year effort which began in February, 1995. Title 34, Section 3406(b)(1)(B) of the CVPIA, P.L. 102-575, requires the Secretary of the Interior to determine instream flow needs for anadromous fish for all Central Valley Project controlled streams and rivers, based on recommendations of the U. S. Fish and Wildlife Service after consultation with the California Department of Fish and Game (CDFG). The purpose of these investigations are to provide scientific information to the U. S. Fish and Wildlife Service Central Valley Project Improvement Act Program to assist in developing such recommendations for Central Valley rivers.

Written comments or questions about this report or these investigations should be submitted to:

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INTRODUCTION

In response to substantial declines in anadromous fish populations, the Central Valley Project Improvement Act requires the doubling of the natural production of anadromous fish stocks, including the four races of chinook salmon (fall, late-fall, winter, and spring runs), steelhead, and white and green sturgeon. For the Sacramento River, the Central Valley Project Improvement Act Anadromous Restoration Plan calls for October through April flows ranging from 3,250 to 5,500 cfs, with the recommended flow varying with the October 1 carryover storage in Shasta Reservoir (U. S. Fish and Wildlife Service 1995). In December 1994, the U. S. Fish and Wildlife Service prepared a study proposal to identify the instream flow requirements for anadromous fish in certain streams within the Central Valley of California, including the Sacramento River. The purpose of this report is to model the effects of flow fluctuations on chinook salmon and steelhead redd dewatering and juvenile entrapment stranding in the Sacramento River between Keswick Reservoir and Battle Creek.

A 2-dimensional hydraulic and habitat model (RIVER2D) was used for the redd dewatering portion of this modeling, instead of the Physical Habitat Simulation (PHABSIM[1]) component of the Instream Flow Incremental Methodology (IFIM). The 2-D model uses as inputs the bed topography and substrate of a site, total discharge at the upstream transect, and the water surface elevation at the downstream transect of the site, to predict the amount of habitat present in the site. The 2-D model avoids problems of transect placement, since the entire site can be modeled. The 2-D model also has the potential to model depths and velocities over a range of flows more accurately than PHABSIM because it takes into account upstream and downstream bed topography and bed roughness, and explicitly uses mechanistic processes (conservation of mass and momentum), rather than Manning's n and a velocity adjustment factor.

Other advantages of 2-D modeling are that it can explicitly handle complex habitats, including transverse flows, across-channel variation in water surface elevations, and flow contractions/expansions. The model scale is small enough to correspond to the scale of microhabitat use data with depths and velocities produced on a continuous basis, rather than in discrete cells. The 2-D model does a better job of representing patchy microhabitat features, such as gravel patches. The data can be collected with a stratified sampling scheme, with higher intensity sampling in areas with more complex or more quickly varying microhabitat features, and lower intensity sampling in areas with uniformly varying bed topography and uniform substrate. Bed topography and substrate mapping data can be collected at a very low flow, with the only data needed at high flow being water surface elevations at the upstream and downstream transects of the site and flow and edge velocities for validation purposes. In addition, alternative habitat suitability criteria, such as measures of habitat diversity, can be used.

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[1] PHABSIM is the collection of one dimensional hydraulic and habitat models which are used to predict the relationship between physical habitat availability and streamflow over a range of river discharges.

The results of this study are intended to support or revise the flow recommendations above.

METHODS

Study Site Selection

We have divided the Sacramento River study area into six stream segments (Figure 1), based on hydrology and other factors: Grimes to Colusa (Segment 1); Deer Creek to Red Bluff Diversion Dam (Segment 2); above Lake Red Bluff to Battle Creek (Segment 3); Battle Creek to Cow Creek (Segment 4); Cow Creek to ACID (Segment 5); and ACID to Keswick Dam (Segment 6). Segment one addresses green and white sturgeon, while the other segments address chinook salmon and steelhead.

CDFG conducted mesohabitat mapping of the Sacramento River between Keswick Dam and Battle Creek. CDFG used thirteen mesohabitat types: bar complex glides, bar complex pools, bar complex riffles, bar complex runs, flatwater glides, flatwater pools, flatwater riffles, flatwater runs, side channel glides, side channel pools, side channel riffles, side channel runs, and off-channel areas (Snider et al 1992). The mesohabitat units (MHUs) were designated with numbers, starting with MHU # 5 at Battle Creek to MHU # 143 just below Keswick Dam.

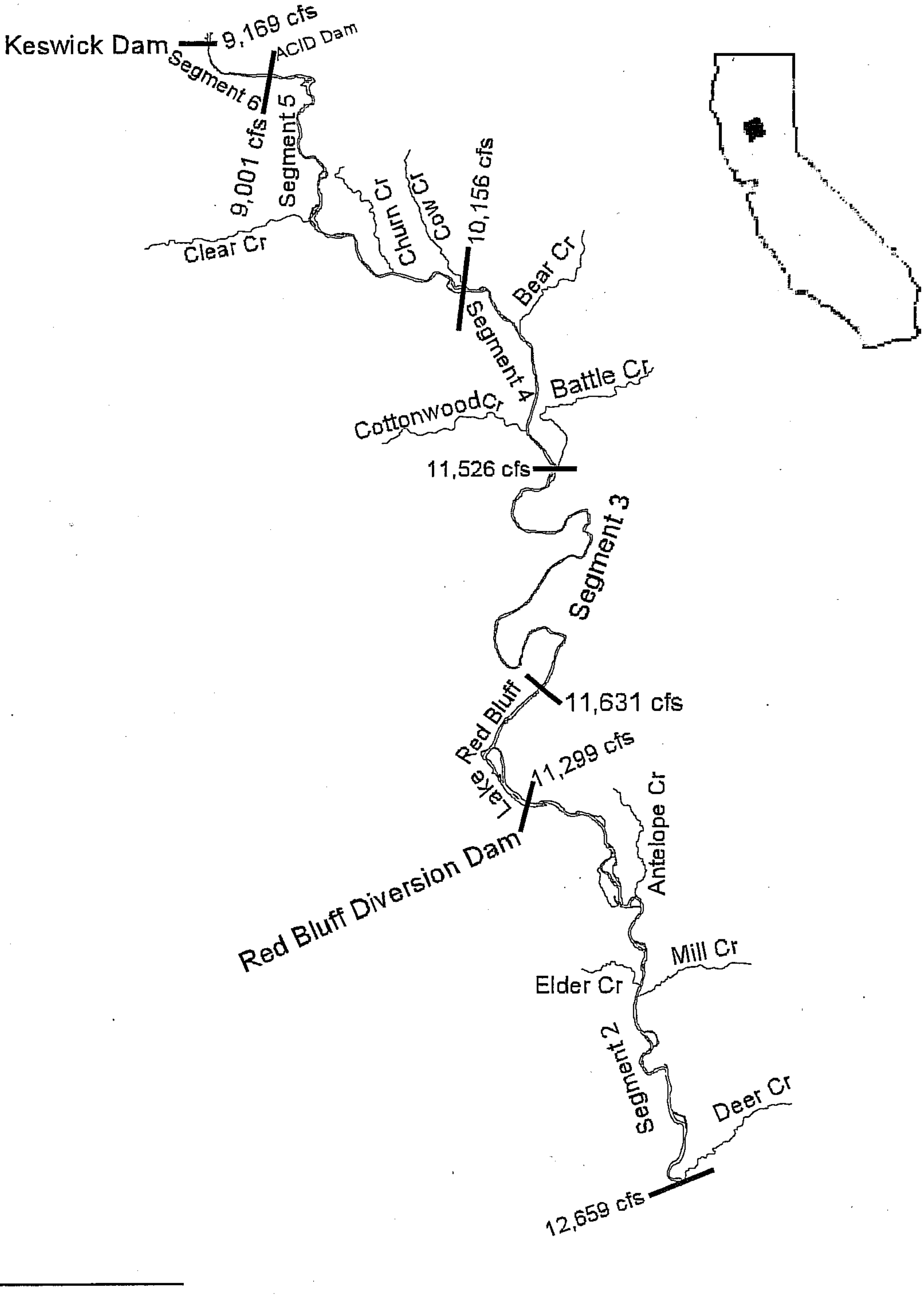
The redd dewatering analysis was conducted using data from our eight spawning sites (Lower Lake Redding, Upper Lake Redding, Salt Creek, Bridge Riffle, Posse Grounds, Above Hawes Hole, Powerline Riffle and Price Riffle). Information on these sites is given in U.S. Fish and Wildlife Service 1999.

We surveyed both banks of the Sacramento River from Keswick Dam to Battle Creek to identify locations where juvenile chinook salmon could become trapped in inundated areas isolated from the main river channel when Sacramento River flows drop. Our surveys were conducted at relatively low flows (less than 8,000 cfs). The criteria that we used to identify stranding areas were: 1) the area would not drain to the main river channel; 2) the area would strand at river flows ranging from 3,250 to 15,000 cfs; and 3) the area was not the mouth of a tributary. We found 107 locations which would potentially become isolated from the main channel at flows ranging from 3,250 to 15,000 cfs. Twenty-seven of these sites were identified in October 1998. The remaining sites were identified in December 1999 and January and April 2000. The location of these sites are identified in Appendix A.

Transect Placement (study site setup)

Details on transect placement for the spawning sites are given in U.S. Fish and Wildlife Service 1999. Details on site setup for our juvenile habitat modeling sites (used as discussed below for some of the stranding sites) are given in U.S. Fish and Wildlife Service 2005.

Figure 1
Sacramento River Stream Segments 2-6[2]



1 in = 7.2 mi

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[2] Flows are the average flows for the period October 1974 to September 1993 at the top of each segment.

Three main approaches were used to determine the stranding flows[3] for the 107 stranding sites: 1) for those stranding sites located in one of our juvenile habitat modeling sites, the 2-dimensional hydraulic model of the juvenile habitat site was used to determine the stranding flow for the stranding site; 2) for those stranding sites where the flow during our identification of the stranding site was at or slightly above or below the stranding flow for that site, we determined the stranding flow based on the flow on that date; and 3) for the remaining sites, we developed a stage-discharge relationship for the main river channel at the stranding site to determine the stranding flow. There were 10 stranding sites in our juvenile habitat modeling sites, 44 sites where the flow during our identification of the stranding site was at or slightly above or below the stranding flow for that site, and 53 sites for which we developed stage-discharge relationships. The first two categories of sites did not require any site setup or data collection, while the third category of site required the installation of a vertical benchmark (a lag bolt in a tree).

Hydraulic and Structural Data Collection

Areas were determined for all of the stranding sites. For smaller sites, we determined the area by measuring the length and two to six widths of the stranding site, using an electronic distance meter; the area is calculated by multiplying the length times the average width. The areas of larger sites were measured on aerial photos or output of the RIVER2D modeling of our juvenile habitat modeling sites using a planimeter, or for Site 45B, using digitized aerial photos in GIS.

Vertical benchmarks were established at each of the 53 stranding sites for which we developed flow-habitat relationships to serve as the reference elevations to which all elevations (streambed and water surface) were tied. Vertical benchmarks consisted of lag bolts driven into trees.

Data required for developing a stage discharge relationship are: 1) water surface elevations (WSELs, stages), measured to the nearest 0.01 foot at three flows using standard surveying techniques (differential leveling); and 2) the stage of zero flow (SZF). Water surface elevations were measured at all but one of the 53 stranding sites for which we developed flow-habitat relationships at the following three flow ranges: 4,700-8,000 cfs, 6,000-12,000 cfs and 11,800-15,100 cfs (Appendix B)[4]. For one site, WSELs were measured at four different flows, with two

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[3] We defined the stranding flow as the flow where the connection between the stranding area and main river channel has a maximum depth of 0.1 feet. We selected 0.1 feet because the minimum depth at which we found juvenile salmon during our juvenile HSI data collection was 0.2 feet. When flows drop to or below the stranding flow, juvenile salmon will be isolated from the main river channel.

[4] For the remaining site, we were only able to measure WSELs at two flows (10,181 and 14,986 cfs, since this site was located on a side channel which stopped flowing when the total river flow dropped below 9,300 cfs.

flows in the first flow range. We also measured the bed elevation of the stranding point (the lowest point at the connection between the stranding area and the main river channel) using differential leveling; the stage at the stranding flow was calculated by adding 0.1 feet to the bed elevation of the stranding point. After the stage discharge relationship was developed, it was used to determine what the flow is at the stranding flow stage. For most of the sites, the SZF was determined by making a traverse with a 600 kHz Broad-Band Acoustic Doppler Current Profiler (ADCP) across the main channel at the stranding point. For a few sites on side channels where the entire channel could be waded, the SZF was determined by measuring depths across the side channel with a wading rod. In both cases, the SZF was calculated as the difference between the WSEL on that date and the largest depth.

Flows for most sites were determined from gage data. There were 12 of the 53 stranding sites that were located on split channels. For 4 of these sites, we used flow/flow regressions between the split channel flow and the total Sacramento River discharge developed for the juvenile rearing habitat modeling sites. For the remaining 8 sites located on split channels, flows were measured when the WSELs were collected, to enable the development of flow/flow regressions between the split channel flow and the total Sacramento River discharge. For sites where the entire channel was wadable, flows were measured by making depth and velocity measurements by wading with a wading rod equipped with a Marsh-McBirney^R model 2000 or a Price AA velocity meter. For deeper sites, depth and velocity measurements in portions of the channel with depths greater than 3 feet were made with the ADCP, while depth and velocity measurements in shallower areas were made by wading with a wading rod equipped with a Marsh-McBirney^R model 2000 or a Price AA velocity meter. The ADCP settings used are shown in Table 1. Starting at the water's edge, water depths and velocities were made at measured intervals using the wading rod and Marsh-McBirney^R model 2000 or Price AA velocity meter until the water became sufficiently deep to operate the ADCP (approximately 3 feet). The distance intervals of each depth and velocity measurement from the water's edge were measured using a hand held laser range finder. At the location of the last depth and velocity measurement made while wading, a buoy was placed to serve as a starting point for the ADCP. The boat was then positioned so that the ADCP started operation at the buoy, and water depth and velocity data were collected across the channel to the location near the opposite bank where water depths of approximately 3 feet were reached. A buoy was placed at the location where ADCP operation ceased and the procedure used for measuring depths and velocities in shallow water was repeated until the far bank water's edge was reached. Additional details on the ADCP operation are given in Gard and Ballard (2003).

Data collection started in October 1998 and was completed in August 2001.

Table 1
CFG Files[5] Used for ADCP Data

CFG File	Mode	Depth Cell Size (ft)	Depth Cell Number	Max Bottom Track Depth (ft)	Pings	WT[6]	First Depth Cell (ft)	Blanking Dist. (ft)
MD8A	8	0.66	15	26	4	5	1.61	0.33
MD4C	4	0.33	30	26	4	5	1.51	0.33
MD4E	4	0.66	30	26	4	5	1.84	0.33
MD4H	4	0.66	100	52	4	5	1.84	0.33
D45D	8	0.66	30	26	4	5	1.94	0.66

Our eight spawning sites were originally modeled with PHABSIM (U.S. Fish and Wildlife Service 1999). Seven of these sites were subsequently modeled with RIVER2D for our juvenile habitat modeling (U.S. Fish and Wildlife Service 2005). We measured the horizontal location of the head and tail pins of the transects at the remaining spawning site, Bridge Riffle, with a total station, so that we could model this site with RIVER2D, using all of the points on these transects to determine the bed topography and substrate of this site. We collected 383 data points on the Bridge Riffle site transects, corresponding to a density of 3.9 points/100 m^2.

Hydraulic Model Construction and Calibration

ASCII files of each ADCP traverse for flow or SZF measurements were produced using the Playback feature of the Transect program[7]. Each ASCII file was then imported into the Riverine Habitat Simulation (RHABSIM)[8] Version 2.0 to produce the bed elevations, the component of the average water column velocities perpendicular to the transect, and stations (relative to the

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[5] The first four characters of the ADCP traverses designates which CDG file (containing the ADCP settings) was used for the traverses.

[6] WT is the water track transmit length.

[7] The Transect program is the software used to receive, record and process data from the ADCP.

[8] RHABSIM is a commercially-produced software (Payne and Associates 1998) that incorporates the modeling procedures used in PHABSIM.

start of the ADCP traverse). RHABSIM was then used to output a second ASCII file containing this data. For the SZF measurements, the second ASCII file was input into a QuattroPro spreadsheet where the maximum depth was subtracted from the measured WSEL to compute the SZF (Appendix B).

For the ADCP traverses made for flow measurements, the second ASCII file was input into a QuattroPro spreadsheet and combined with the velocity, depth, and station data collected in shallow water. We defined a statistic (R) to provide a quality control check of the velocity measured by the ADCP at a given station n, where $R = Vel_n/(Vel_{n-1} + Vel_{n+1})/2$ at station n[9]. R was calculated for each velocity where Vel_n, Vel_{n-1} and Vel_{n+1} were all greater than 1 ft/s for each ADCP data set. Based on data collected using a Price AA velocity meter on the Lower American River, the acceptable range of R was set at 0.5-1.6. All verticals with R values less than 0.5 or greater than 1.6 were deleted from each ADCP data set[10]. Discharges were calculated for each ADCP traverse, including the data collected in shallow water.

Flow/flow regressions were performed for sites which did not include the entire Sacramento River flow (Stranding Sites 14, 66, 87-90 and 97), using the flows measured in the site, and the corresponding total flows determined from gage readings[11] (Table 2). For Stranding Sites 87-90 and 97, the regressions were developed from three sets of flows, with the entire river discharge around 6,000 cfs, 9,000-10,000 cfs and 15,000 cfs. For Stranding Site 66, the regressions were only developed from two sets of flows, at 10,181 and 14,986 cfs, since the side channel on which this site was located stopped flowing when the total river flow dropped below 9,300 cfs. For Stranding Site 14, the regressions were also only developed from two sets of flows, at 6,152 and 8,826 cfs, made by wading the channel, since the channel could not be waded at flows above 9,000 cfs, and the channel was too shallow for accurate ADCP measurements. The site flows used in the regression were either the average of the ADCP traverses at the site or the flows measured with a wading rod and Price AA or Marsh-McBirney meter on the site. Calibration flows for Stranding Sites 14, 66, 87-90 and 97 (Table 4) were computed from the total discharge in Table 2 and the appropriate regression equation in Table 3.

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[9] n - 1 refers to the station immediately before station n and n + 1 refers to the station immediately after station n.

[10] We also deleted velocities where Vel_n was less than 1.00 ft/s and Vel_{n-1} and Vel_{n+1} were greater than 2.00 ft/s, and where Vel_n had one sign (negative or positive) and Vel_{n-1} and Vel_{n+1} had the opposite sign (when the absolute value of all three velocities were greater than 1.00 ft/s); these criteria were also based on the Lower American River dataset (Gard and Ballard 2003).

[11] As shown in Table 2, the flow calculated at Bend Bridge from upstream and tributary gage readings often differed from the gage reading at Bend Bridge by less than 5% and never differed by more than 10%. Flows could be calculated using either USBR or USGS flows measured at Keswick Dam; the flows selected for use were those which had the smaller Bend error.

Table 2
Sacramento River Flows at Stranding Study Sites[12] (cfs)

Date	Stranding Study Site Number: 1-8	9-22 & 27-32	23-26, 33-34, 39-52, 55-56	35-38, 53-54, 57, 59-70	58, 71-79C, 83-90	80-81, 91, 96-97	92-94	82, 95	Bend error	Keswick Flow Used
10/13/98	6580								7.64%	USGS
10/14/98		6152	6361						9.19%	USGS
5/25/99	10045	9813	9753						2.53%	USBR
8/5/99	12032	11822	11762						0.02%	USBR
12/9/99		7683	7683	7898					0.74%	USBR
12/10/99			7554						1.53%	USBR
1/12/00		4710	4710	4936					5.51%	USGS
3/17/00		11700	11700	12009					9.66%	USGS
4/25/00				8994					2.48%	USGS
4/26/00				8700	8926	9428			2.74%	USGS
4/27/00			8608		9035		9606		3.17%	USGS
7/10/00		14990							0.43%	USGS
7/11/00		14987	14927	14986					0.32%	USGS
7/12/00					14988	15409			0.43%	USGS
7/13/00							15071		0.79%	USGS
3/13/01			6150						5.55%	USGS
3/14/01				6086	6244				4.52%	USGS
3/15/01					5977	6454	6511		4.36%	USGS
7/9/01					14580				2.32%	USGS
8/20/01					10181				2.23%	USGS
8/22/01						9239			2.33%	USGS

See U.S. Fish and Wildlife Service 1999 and U.S. and Fish and Wildlife Service 2005, respectively, for details on the hydraulic model construction and calibration on the spawning site PHABSIM transects and our juvenile habitat modeling RIVER2D sites.

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[12] These flows are the same as the stranding study site flows for those stranding sites that include all of the Sacramento River flow.

Table 3
Flow/Flow Regression Equations

Stranding Study Site	Regression Equation[13]	R^2-value
Site 14	Site 14 Q = -377 + 0.1365 x Q	1[14]
Site 66	Site 66 Q = -542 + 0.0583 x Q	1[14]
Sites 87-90	Sites 87-90 Q = -1976 + 0.3566 x Q	0.9655
Site 97	Site 97 Q = -1424 + 0.5696 x Q	0.99999

Table 4
Calibration Flows for Stranding Study Sites 14, 66, 87-90 and 97 (cfs)

Date	Site 14	Site 66	Sites 87-90	Site 97
10/14/98	463			
5/25/99	963			
8/5/99	1237			
7/11/00		331		
7/12/00			3368	7148
3/14/01			201	
3/15/01			155	2252
8/20/01		51	1654	
8/22/01				3839

All stage-discharge data were compiled and checked before entry into PHABSIM data decks for the 53 stranding sites for which we developed flow-habitat relationships. A total of two to four sets of WSELs at widely spaced flows were used. Calibration flows in the data decks were the flows calculated from gage readings or the flows calculated from gage readings and the regression equations in Table 3. A separate deck was constructed for each set of study sites with the same calibration flows.

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[13] Q is the total river flow, Site 14 Q is the flow in Stranding Site 14, etc.

[14] Since only two flows were used in these regressions, the R^2-values, by definition, were one.

The first step in the calibration procedure was to determine the best approach for WSEL simulation. Initially, the *IFG4* hydraulic model (Milhous *et al.*, 1989) was run on each deck to compare predicted and measured WSELs. This model produces a stage-discharge relationship using a log-log linear rating curve calculated from at least three sets of measurements taken at different flows. *IFG4* is considered to have worked well if the following criteria are met: 1) the beta value (a measure of the change in channel roughness with changes in streamflow) is between 2.0 and 4.5; 2) the mean error in calculated versus given discharges is less than 10%; 3) there is no more than a 25% difference for any calculated versus given discharge; and 4) there is no more than a 0.1 foot difference between measured and simulated WSELs[15]. For a majority of the sites, *IFG4* met the above criteria for *IFG4* (Appendix B).

For those transects/flow ranges modeled with *IFG4*, the mean error and calculated-given discharge criteria were met in all cases, and the measured-simulated WSEL difference criterion for *IFG4* was met in all cases except for stranding sites 15, 16, 30, 39, 46 and 77. We still used *IFG4* for these sites because: 1) the difference between measured and simulated WSELs for all sites was less than 0.19 foot[16]; 2) in all cases the stranding flow was not greater than the highest calibration flow; and 3) the calibration plots indicated that there was a linear log-log relationship over the range of calibration flows.

For stranding sites 57, 87, 88A and 90, the initial *IFG4* calibration indicated that there was a significantly non-linear log-log relationship between stage and flow over the range of calibration flows. In these cases, we used a modification of *IFG4* where we only used two calibration flows. The calibration flows selected were those which bracketed the stranding flow. While this technique is not accepted for developing stage-discharge relationships, we concluded that it was sufficiently accurate for interpolating a stranding flow in between two calibration flows. Since only two flows are used in this method, the mean error and calculated versus given discharge criteria of *IFG4* do not apply and the difference between measured and predicted WSELs will always be zero.

As shown in Appendix B, the beta coefficient values were less than 2.0 for stranding sites 15, 57, 72, 74, 81 and 88A. We concluded that this phenomenon were caused by channel characteristics which form hydraulic controls at some flows but not at others (compound controls), thus affecting upstream water elevations. Specifically, at lower flows the channel at these sites controlled the water surface elevations, while at higher flows the water surface elevations were controlled by downstream hydraulic controls. Accordingly, the performance of *IFG4* for these sites was considered adequate despite the beta coefficient criterion not being met.

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[15] The first three criteria are from U.S. Fish and Wildlife Service 1994, while the fourth criterion is our own.

[16] For much of the Sacramento River, the WSEL going across the river will differ by more than 0.2 feet.

As shown in Appendix B, the beta coefficient values were greater than 4.5 for stranding sites 11, 13, 37/38, 69/70, 87, 88 and 97. We concluded that this phenomenon was caused by the presence of a downstream hydraulic control, such that the actual SZFs of these sites were greater than those in Appendix B. We determined that the correct SZF would have had a minimal effect on the estimated stranding flows for these sites - for example, a SZF which produced a beta coefficient of 4.5 for stranding site 38 would have only increased the stranding flow from 13,771 cfs to 13,775 cfs. As a result, we concluded that the SZFs in Appendix B were sufficiently accurate for the purposes of estimating stranding flows.

There were three other sites (stranding sites 36, 66 and 75) for which we developed stage-discharge relationships using methods other than *IFG4*. Sites 36 and 75 were located in bar complexes where there was a significant variation in WSEL across the entire river; *IFG4* can not be used in this case since a basic assumption of *IFG4* is that the WSEL does not vary across the channel. For site 36, we developed a stage-discharge relationship using a regression of log(WSEL) versus log(flow), with the three measured WSELs at 4,936, 6,086 and 12,009 cfs. There was a significantly non-log-linear relationship between stage and flow for site 75 over the range of measured WSELs; since the stranding flow for this site ended up being less than 3,250 cfs, we used the two lower measured WSELs to estimate the stranding flow. We used a regression equation of the form log(WSEL - A) = B + C x log(flow) for site 75, where we determined A in the field by subtracting the maximum depth in the main channel from the WSEL measured at the stranding location[17]; B and C were derived from the regression. For site 66, we developed stage-discharge relationships using a regression of log(WSEL-SZF) versus log(flow), but only using two flows (14,986 cfs and 10,181 cfs). As discussed above, we only measured WSELs at two flows for site 66. The regression equations for these sites are given in Table 5.

Table 5
Stage-Discharge Regression Equations

Stranding Study Site	Regression Equation[18]	R^2-value
Site 36	log (WSEL) = 1.913 + 0.01979 x log (Q)	0.9997
Site 66	log (WSEL - 96.0) = -0.506 + 0.376 x log (Site 66 Q)	1[19]
Site 75	log (WSEL - 80.8) = 0.7670+ 0.0755 x log (Q)	1[19]

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[17] A is similar to a SZF, but is not strictly speaking a SZF since the WSEL at the location with the maximum depth was significantly lower than the WSEL at the stranding location.

[18] Q is the total river flow, Site 66 Q is the flow in Stranding Site 66, etc.

[19] Since only two flows were used in these regressions, the R^2-values, by definition, were one.

The stranding flows for the 107 stranding sites are given in Appendix A. Sites 1-8, located upstream of ACID, had different stranding flows depending on whether the ACID dam was in or out. The stage-discharge relationships for 13 of the stranding sites resulted in a stranding flow of less than 3,250 cfs; these sites were thus dropped from consideration, since we are identifying areas that strand at flows between 3,250 and 15,000 cfs. Another two sites were dropped from consideration because they stranded at flows significantly greater than 15,000 cfs.

For the Bridge Riffle site, the PHABSIM transect data was used in QuattroPro to create the input files (bed and substrate) for the 2-D modeling program. An artificial extension one channel-width-long was added upstream of the top of the site to enable the flow to be distributed by the model when it reached the study area, thus minimizing boundary conditions influencing the flow distribution at the upstream transect and within the study site. The bed files contain the horizontal location (northing and easting), bed elevation and initial bed roughness value for each point, while the substrate files contain the horizontal location, bed elevation and substrate code for each point. The initial bed roughness value for each point was determined from the substrate codes for that point and the corresponding bed roughness values in Table 6. The bed roughness values in Table 6 were computed as five times the average particle size. The bed and substrate files were exported from QuattroPro as ASCII files.

A utility program, R2D_BED (Steffler 2001b), was used to define the study area boundary and to refine the raw topographical data TIN (triangulated irregular network) by defining breaklines[20] following longitudinal features such as thalwegs, tops of bars and bottoms of banks. Breaklines were also added along lines of constant elevation. The bed topography of Bridge Riffle site is shown in Figure 2.

An additional utility program, R2D_MESH (Steffler 2001a), was used to define the inflow and outflow boundaries and create the finite element computational mesh for the River2D model. R2D_MESH uses the final bed files as an input. The first stage in creating the computational mesh was to define mesh breaklines[21] which coincided with the final bed file breaklines. Additional mesh breaklines were then added between the initial mesh breaklines, and additional nodes were added as needed to improve the fit between the mesh and the final bed file and to improve the quality of the mesh, as measured by the Quality Index (QI) value. The QI is a

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[20] Breaklines are a feature of the R2D_Bed program which force the TIN of the bed nodes to linearly interpolate bed elevation and bed roughness values between the nodes on each breakline and force the TIN to fall on the breaklines (Steffler 2001b).

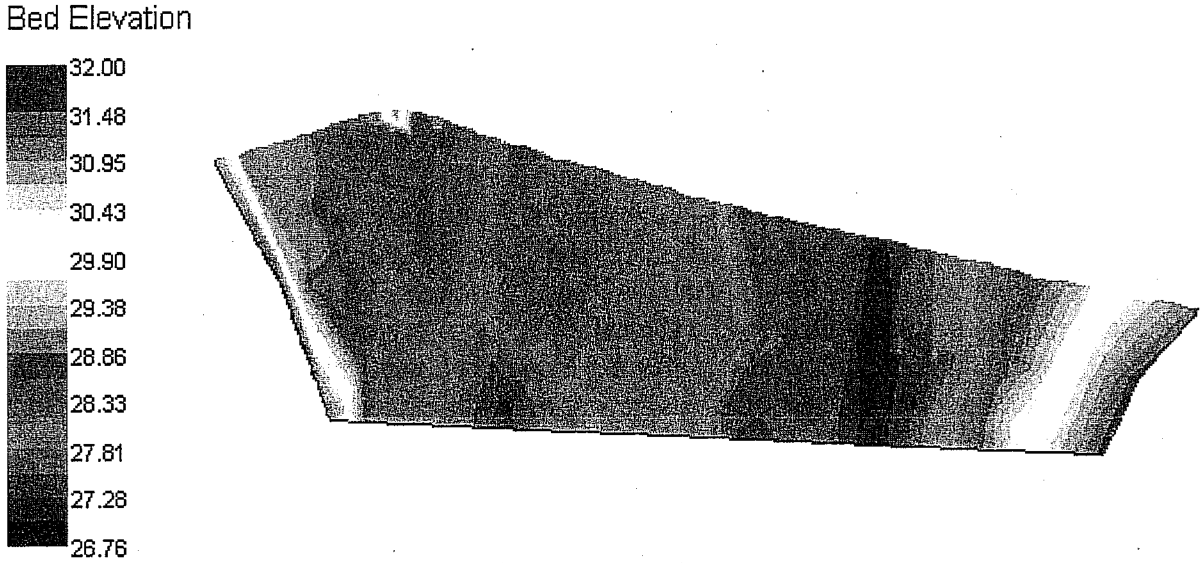
[21] Mesh breaklines are a feature of the R2D_MESH program which force edges of the computation mesh elements to fall on the mesh breaklines and force the TIN of the computational mesh to linearly interpolate the bed elevation and bed roughness values of mesh nodes between the nodes at the end of each breakline segment (Steffler 2001a). A better fit between the bed and mesh TINs is achieved by having the mesh and bed breaklines coincide.

Table 6
Initial Bed Roughness Values

Substrate Code	Type	Particle Size (inches)	Bed Roughness (m)
0.1	Sand/Silt	< 0.1	0.05
1	Small Gravel	0.1 - 1	0.1
1.2	Medium Gravel	1 - 2	0.2
1.3	Medium/Large Gravel	1 - 3	0.25
2.3	Large Gravel	2 - 3	0.3
2.4	Gravel/Cobble	2 - 4	0.4
3.4	Small Cobble	3 - 4	0.45
3.5	Small Cobble	3 - 5	0.5
4.6	Medium Cobble	4 - 6	0.65
6.8	Large Cobble	6 - 8	0.9
8	Large Cobble	8 - 10	1.25
9	Boulder/Bedrock	> 12	0.05
10	Large Cobble	10-12	1.4

measure of how much the least equilateral mesh element deviates from an equilateral triangle. An ideal mesh (all equilateral triangles) would have a QI of 1.0. A QI value of at least 0.2 is considered acceptable (Steffler 2001a). The mesh for the Bridge Riffle site, with 4819 nodes, had a QI value of 0.30. The percentage of the original bed nodes for which the mesh differed by less than 0.1 foot (0.03 m) from the elevation of the original bed nodes was 87% for the Bridge Riffle site. In most cases, the areas of the mesh where there was greater than a 0.1 foot (0.03 m) difference between the mesh and final bed file were in steep areas; in these areas, the mesh would be within 0.1 foot (0.03 m) vertically of the bed file within 1 foot (0.3 m) horizontally of the bed file location. Given that we had a 1-foot (0.3 m) horizontal level of accuracy, such areas would have an adequate fit of the mesh to the bed file. The final step with the R2D_MESH software was to generate the computational (cdg) file.

Figure 2
Bed Topography of Bridge Riffle Study Site



Units of Bed Elevation are meters.

The cdg file was opened in the RIVER2D software, where the computational bed topography mesh was used together with the WSEL at the bottom of the site, the flow entering the site, and the bed roughnesses of the computational mesh elements to compute the depths, velocities and WSELs throughout the site. The basis for the current form of RIVER2D is given in Ghanem *et al* (1995). The computational mesh was run in RIVER2D to steady state at a mid-range flow (15,149 cfs) for which WSELs were measured, and the WSELs predicted by RIVER2D at the upstream end of the site were compared to the WSELs measured at both upstream transects. The bed roughnesses of the computational mesh elements were then modified by multiplying them by a constant bed roughness multiplier (BR Mult) until the WSELs predicted by RIVER2D at the upstream transect locations matched the WSELs measured at both upstream transects. The values of all other River2D hydraulic parameters were left at their default values (upwinding coefficient = 0.5, minimum groundwater depth = 0.05 m, groundwater transmissivity = 0.1, groundwater storativity = 1, and eddy viscosity parameters epsilon 1 = 0.01, epsilon2 = 0.5 and epsilon3 = 0.1).

A stable solution will generally have a solution change (Sol Δ) of less than 0.00001 and a net flow (Net Q) of less than 1% (Steffler and Blackburn 2001). In addition, solutions for low gradient streams should usually have a maximum Froude Number (Max F) of less than one[22]. Finally, the WSEL predicted by the 2-D model should be within 0.10 foot (0.031 m) of the

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[22] This criteria is based on the assumption that flow in low gradient streams is usually subcritical, where the Froude number is less than one (Peter Steffler, personal communication).

WSEL measured at the upstream transects[23]. The calibrated cdg file for Bridge Riffle site, with a BR Mult of 0.3, had a Sol Δ of 2 x 10^{-7}, a net Q of 0.2%, and a Max F of 1.00. To get the Bridge Riffle site to calibrate, we needed to lower the downstream WSEL by 0.1 foot; the downstream WSELs for the simulation flows were also lowered by 0.1 foot. This allowed us to calibrate the model while still having the WSEL at the downstream transect within 0.1 foot of the measured WSEL. The Bridge Riffle site calibrated cdg file had WSELs that differed by more than 0.1 foot (0.031 m) from the measured WSELs for transects 2 and 3 main channel[24] (Table 7). For transect 2, the predicted WSELs near the water's edge, where the WSELs were measured, were within 0.1 foot (0.031 m) of the measured WSELs. For much of the Sacramento River, the WSEL going across the river will differ by more than 0.1 foot (0.031 m), with up to a 3-foot (0.91 m) measured difference in WSEL between the two banks in some areas, such as the Posse Grounds site. Accordingly, we conclude that the calibration for these transects was acceptable. For transect 3 main channel, the simulated WSEL on the left bank only differed by 0.18 foot (0.054 m) from the measured WSEL, and this was only at a small area right at the water's edge. Given the above discussion, we conclude that the WSEL calibration of Bridge Riffle site was acceptable.

Table 7
2-D WSEL Calibration Statistics

	Difference (measured versus predicted WSELs, ft)[25]		
Transect	Average	Standard Deviation	Maximum
1	0.10	---	0.10
2	0.03	0.28	0.49
2 LB	0.07	0.01	0.08
3 SC	0.07	0.002	0.08
3 MC	0.30	0.15	0.49
3 MC LB	0.09	0.04	0.18

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[23] We have selected this standard because it is a standard used for PHABSIM (U. S. Fish and Wildlife Service 2000).

[24] Bridge Riffle transect 3 had both a side channel (SC) and a main channel (MC).

[25] All WSEL measurements were made on the left bank (LB).

Velocity validation is the final step in the preparation of the hydraulic models for use in habitat simulation. Velocities predicted by RIVER2D were compared with measured velocities to determine the accuracy of the model's predictions of mean water column velocities. The measured velocities used were the velocities measured on the three transects. See Appendix C for velocity validation statistics. Although there was a strong correlation between predicted and measured velocities, there were significant differences between individual measured and predicted velocities. In general, the simulated and measured velocities profiles at the three transects (Appendix C[26]) were relatively similar in shape. Differences in magnitude in most cases are likely due to: (1) operator error during data collection, i.e., the probe was not facing precisely into the direction of current; (2) range of natural velocity variation at each point over time resulting in some measured data points at the low or high end of the velocity range averaged in the model simulations; (3) aspects of the bed topography of the site that were not captured in our data collection; (4) the effect of the velocity distribution at the upstream boundary of the site[27]; and (5) the measured velocities being the component of the velocity in the downstream direction, while the velocities predicted by the 2-D model were the absolute magnitude of the velocity[28]. As shown in the figures in Appendix C, we attribute most of the differences between measured and predicted velocities to noise in the measured velocity measurements; specifically, for the transects, the simulated velocities typically fell within the range of the measured velocities of the two to three ADCP traverses made on each transect. The 2-D model integrates effects from the surrounding elements at each point. Thus, point measurements of velocity can differ from simulated values simply due to the local area integration that takes place. As a result, the area integration effect noted above will produce somewhat smoother lateral velocity profiles than the observations.

The flow and downstream WSEL in the calibrated Bridge Riffle site cdg file were changed to simulate the hydrodynamics of the sites at the simulation flows (3,250 cfs to 5,500 cfs by 250 cfs increments, 5,500 cfs to 8,000 cfs by 500 cfs increments, 8,000 cfs to 15,000 cfs by 1,000 cfs increments, and 15,000 cfs to 31,000 cfs by 2,000 cfs increments). The cdg file for each flow contained the WSEL predicted by PHABSIM at the downstream transect at that flow minus 0.1

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[26] Velocities were plotted versus northing since the transects were orientated primarily north-south.

[27] River2D distributes velocities across the upstream boundary in proportion to depth, so that the fastest velocities are at the thalweg. In contrast, the bed topography of a site may be such that the fastest measured velocities may be located in a different part of the channel. Since we did not measure the bed topography above a site, this may result in River2D improperly distributing the flow across the top of the site. As discussed above, we added artificial upstream extensions to the sites to try to address this issue.

[28] For areas with transverse flow, this would result in the 2-D model appearing to overpredict velocities even if it was actually accurately predicting the velocities.

foot. Each discharge was run in RIVER2D to steady state. Again, a stable solution will generally have a Sol Δ of less than 0.00001 and a Net Q of less than 1%. In addition, solutions will usually have a Max F of less than one. The production cdg files all had a Sol Δ of less than 0.00001 and a Net Q of less than 1% (Table 8). The maximum Froude Number was greater than 1 for 16 simulated flows (Table 8); however, we considered these production runs to be acceptable since the Froude Number was only greater than 1 at a few nodes, with the vast majority of the area within the site having Froude Numbers less than 1. Also, these nodes were located either at water's edge or where water depth was extremely shallow, typically approaching zero and would be expected to have an insignificant effect on the model results.

Habitat Suitability Criteria (HSC) Development

We assumed that there would be reduced survival of eggs or pre-emergent fry, and thus spawning habitat would be lost, if the tailspill was exposed or if velocities dropped to the point where there was insufficient intragravel flow through the redd. While we did not make measurements on tailspill depths for Sacramento River redds, we did take these measurements for 851 fall-run chinook salmon and 106 steelhead/rainbow trout redds on the Yuba River. There was a significant positive correlation between the depth of the redds and the difference between the redd depth and tailspill depth for both fall-run chinook salmon ($R^2 = 0.74$, $p = 2 \times 10^{-251}$)and steelhead/rainbow trout ($R^2 = 0.04$, $p = 0.03$) redds (Figures 3 and 4). When only redds with depths less than 2 feet[29] were considered, the correlations for fall-run chinook salmon ($n = 664$, $R^2 = 0.31$, $p = 1 \times 10^{-55}$)and steelhead/rainbow trout ($n = 26$, $R^2 = 0.39$, $p = 0.0005$) were still significant. However, since we needed to pick a single value of the difference between the tailspill and redd depths for the redd dewatering analysis, we selected the average difference for fall-run chinook salmon (0.5 foot) and steelhead/rainbow trout (0.2 foot) redds with redd depths less than 2 feet. If the tailspill is 0.5 foot higher than the depth at the head of the pit (the depth used to compute spawning habitat), chinook salmon spawning habitat would be lost if the spawning depth fell below 0.5 foot. Similarly, if the tailspill is 0.2 foot higher than the depth at the head of the pit (the depth used to compute spawning habitat), steelhead spawning habitat would be lost if the spawning depth fell below 0.2 foot. We assumed that there would be insufficient intragravel flow through the redd if the spawning velocity was less than the lowest velocity at which we found a fall-run, late-fall-run or winter-run chinook salmon redd in the Sacramento River, or the lowest velocity of a steelhead redd in the Lower American River (the source of the steelhead spawning HSC used for the Sacramento River). The lowest velocities we found in measurements of Sacramento River fall-run, late-fall-run and winter-run chinook salmon were, respectively, 0.32 ft/s, 0.32 ft/s and 0.87 ft/s (U.S. Fish and Wildlife Service 2003). The lowest velocity of a steelhead redd in the Lower American River was 0.73 ft/s (U.S. Fish and Wildlife Service 1996a). The redd dewatering criteria used are given in Table 9.

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[29] Two feet was selected because the drop in stage associated with a change in flow for the Sacramento River sites is typically less than two feet.

Table 8
Bridge Riffle Site Simulation Statistics

Flow (cfs)	**Net Q**	**Sol Δ**	**Max F**
3250	0.3%	.000004	1.34
3500	0.3%	.000008	1.35
3750	0.3%	.000007	1.36
4000	0.2%	.000004	1.38
4250	0.1%	.000005	1.41
4500	0.1%	.000005	1.46
4750	0.02%	<.000001	1.46
5000	0.04%	.000003	1.45
5250	0.1%	.000008	1.43
5500	0.1%	.000002	1.33
6000	0.01%	.000003	1.05
6500	0.04%	.000006	1.00
7000	0.2%	.000005	1.55
7500	0.2%	.000004	1.00
8000	0.3%	.000003	1.00
9000	0.7%	<.000001	1.00
10000	0.01%	<.000001	1.00
11000	0.1%	<.000001	1.03
12000	0.1%	<.000001	1.00
13000	0.1%	<.000001	1.00
14000	0.6%	.000003	1.00
15000	0.2%	<.000001	1.00
17000	0.4%	<.000001	1.00
19000	0.6%	<.000001	1.00
21000	0.8%	.000006	1.00
23000	0.5%	.000003	1.00
25000	0.04%	<.000001	1.38
27000	0.1%	<.000001	1.06
29000	0.05%	<.000001	1.00
31000	0.1%	<.000001	4.34

Figure 3
Tailspill and Redd Depths for Yuba River Fall-run Chinook Salmon Redds

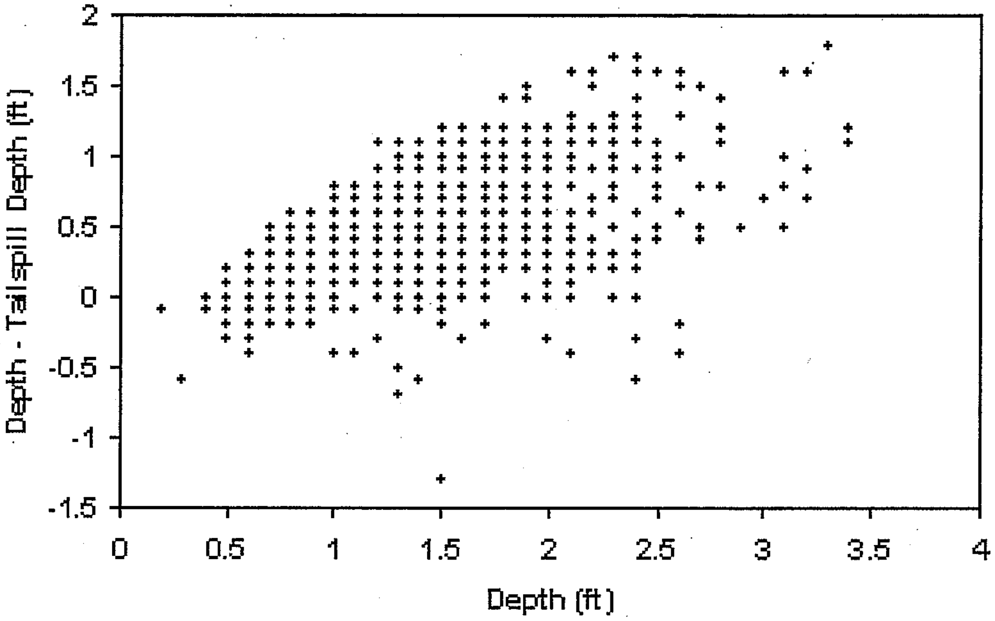

Figure 4
Tailspill and Redd Depths for Yuba River Steelhead/Rainbow Trout Redds

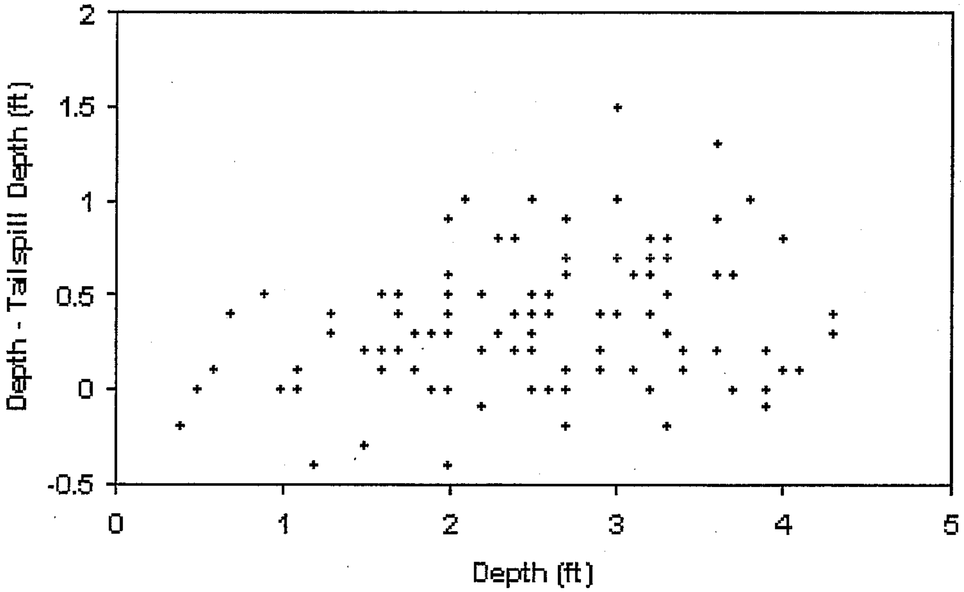

Table 9
Redd Dewatering HSC

Water Velocity (ft/s)	SI Value	Water Depth (ft)	SI Value	Channel Index Value	SI Value
		Fall-run Chinook Salmon			
0.00	0.00	0.00	0.00	0.00	0.00
0.31	0.00	0.50	0.00	1.00	1.00
0.32	1.00	0.52	1.00	100.0	1.00
100.0	1.00	100.0	1.00		
		Late-fall-run Chinook Salmon			
0.00	0.00	0.00	0.00	0.00	0.00
0.31	0.00	0.50	0.00	1.00	1.00
0.32	1.00	0.52	1.00	100.0	1.00
100.0	1.00	100.0	1.00		
		Winter-run Chinook Salmon			
0.00	0.00	0.00	0.00	0.00	0.00
0.86	0.00	0.50	0.00	1.00	1.00
0.87	1.00	0.52	1.00	100.0	1.00
100.0	1.00	100.0	1.00		
		Steelhead			
0.00	0.00	0.00	0.00	0.00	0.00
0.72	0.00	0.20	0.00	1.00	1.00
0.73	1.00	0.23	1.00	100.0	1.00
100.0	1.00	100.0	1.00		

Habitat Simulation

We classified the stranding sites as either off-channel-areas or in-channel-areas (Appendix A). In our 1996 snorkel surveys of juvenile chinook salmon (U.S. Fish and Wildlife Service 1996b), we found an average of 6.3 fish/1000 ft^2 in off-channel-areas, and an average of 30.2 fish/1000 ft^2 in in-channel-areas. We multiplied the areas of each stranding site by the appropriate fish density to determine the average number of fish in each stranding site. These were summed by range of stranding flows to determine the total number of juvenile salmon stranded in the Sacramento River between Keswick Dam and Battle Creek for different drops in flow (Appendix D). For example, if the Sacramento River flow drops from 3,750 to 3,250 cfs, 11,227 fish will be stranded[30]. In contrast, if the Sacramento River flow drops from 15,000 to 4,000 cfs with the ACID dam boards in, 12,044 fish will be stranded. There are minor differences in the number of fish stranded with the ACID dam boards out versus in due to the different stranding flows for stranding sites 1 to 8 when the ACID dam boards are out versus in.

We conducted an effective spawning analysis with River2D to determine the percentage loss of fall-run, late-fall-run and winter-run chinook salmon and steelhead spawning habitat in the Sacramento River between Keswick Dam and Battle Creek associated with drops in flow. An effective spawning analysis examines on a node by node basis the depths and velocities at lower flows, and sets the weighted useable area represented by each node at a given flow to zero if the depth or velocity at a lower flow are less than the parameters in Table 9; if the depth and velocity at the lower flow are both greater than the parameters in Table 9, the weighted useable area represented by a given node is not changed. By adding up the resulting weighted useable areas represented by all the nodes, the effective spawning analysis computes how much weighted useable area remains after the flow drops. The percentage loss in spawning habitat is then computed as:

(original spawning habitat - remaining spawning habitat)/original spawning habitat

We conducted the effective spawning habitat analysis by producing an output file containing the spawning combined habitat suitability from River2D with the spawning flow file for a given site. This file was then used as a channel index file for the River2D files for the dewatering flows for that site, along with the HSC in Table 9, to compute the remaining spawning habitat.

A byproduct of the effective spawning analysis were new flow-habitat relationships for fall-run, late-fall-run and winter-run chinook salmon and steelhead spawning for the eight spawning sites (Appendix F) and the three segments between Keswick Dam and Battle Creek (Appendix G) computed using River2D.

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[30] 11,227 fish is the total number of juvenile fish for the stranding sites (sites 36, 45B, 51, 51A, 61A and 71) that strand between 3,750 and 3,250 cfs. In the context of this report, juvenile fish refer to any young-of-the-year salmon, generally in the size range of 35 to 100 mm.

RESULTS

The effects of flow drops on juvenile salmon entrapment stranding are shown in Figures 5 and 6 and Appendix D. The results indicate that, as expected, greater drops in flow are associated with increased numbers of stranded juvenile salmon, but that substantial juvenile stranding could be avoided by keeping flows above 3,750 cfs. These results could be used to determine the amount of take of juvenile salmon associated with a given drop in releases of flow from Keswick Dam. The effects of flow drops on redd dewatering are shown in Figures 7 to 14 and Appendix E. Similar to juvenile stranding, the results of the redd dewatering analysis indicate that, as expected, greater drops in flow result in a greater percentage of salmon and steelhead redds being dewatered. These results also suggest that the percentage of redds dewatered associated with a given drop of flow is less with the ACID Dam in, versus the ACID Dam out, reflecting the deeper water conditions above the ACID Dam when the dam is in versus when the dam is out. These results could be used to determine the amount of take of chinook salmon and steelhead eggs and pre-emergent fry associated with a given drop in releases of flow from Keswick Dam.

Flow-habitat relationships for fall-run, late-fall-run and winter-run chinook salmon and steelhead spawning, calculated using River2D, are given in Appendices F and G. We recommend that these results be used, rather than the results in U.S. Fish and Wildlife Service 2003, because of the improved prediction of flow-habitat relationships with River2D, versus PHABSIM.

Figure 5
Stranding of Juvenile Chinook Salmon with ACID Dam out

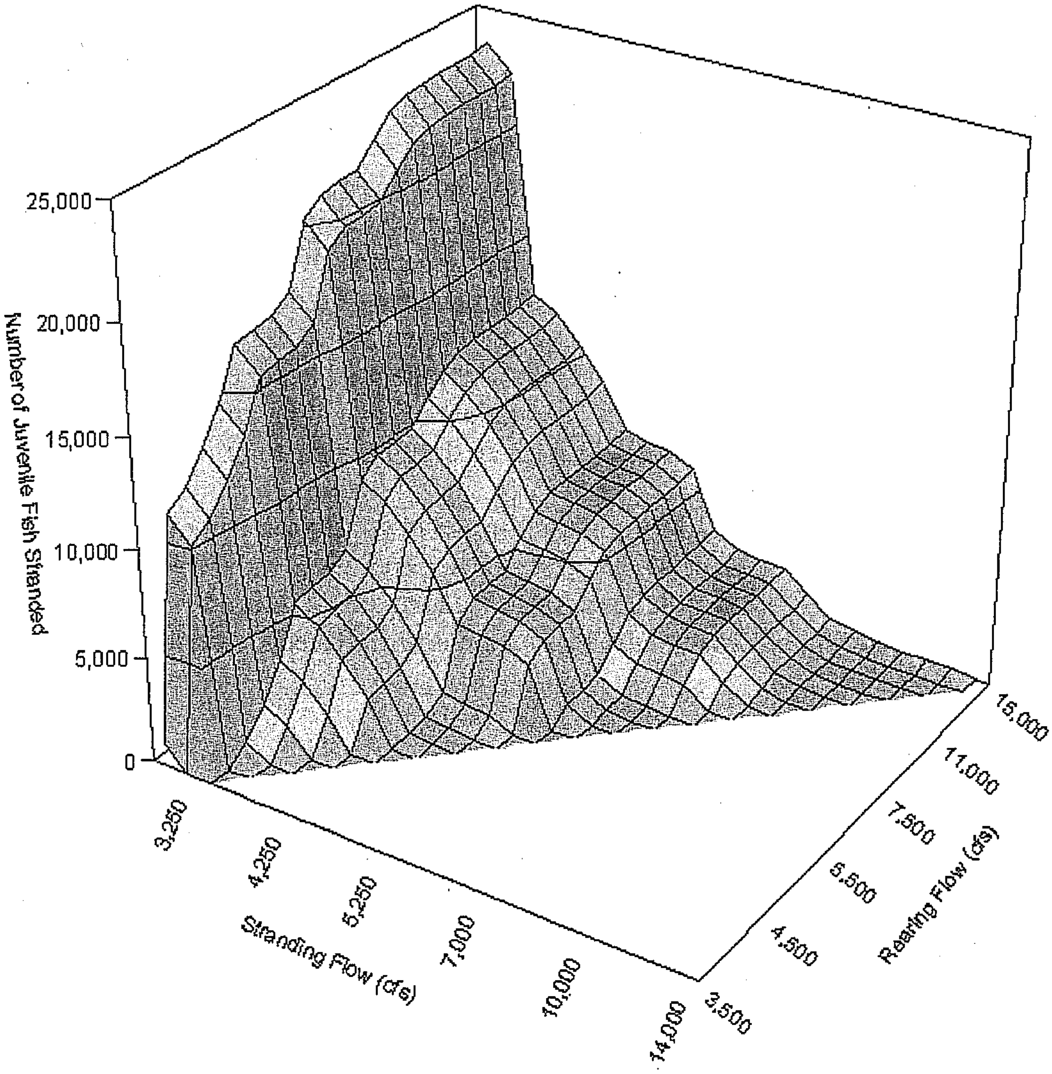


Figure 6
Stranding of Juvenile Chinook Salmon with ACID Dam in

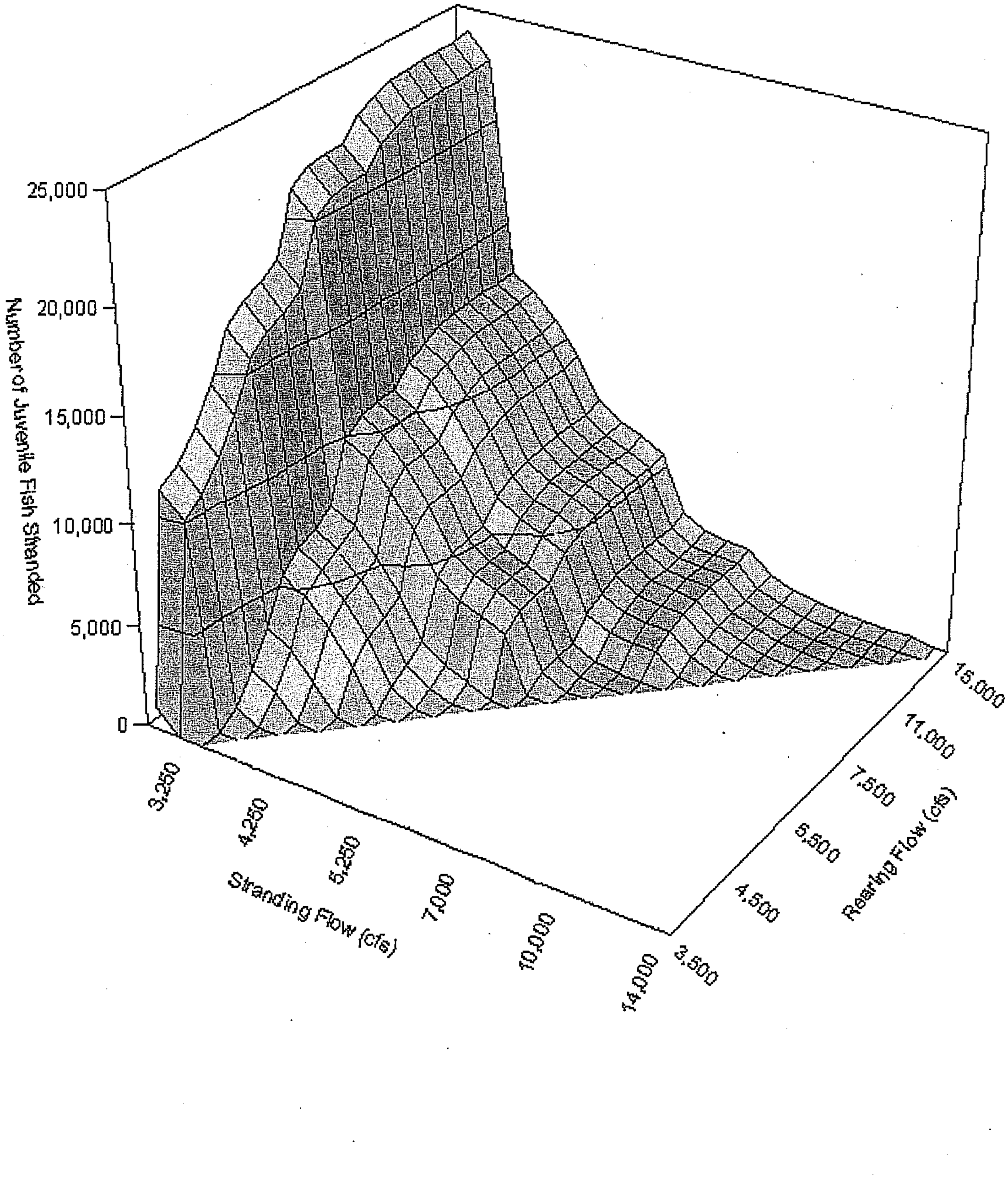


Figure 7
Dewatering of Fall-run Chinook Salmon Redds with ACID Dam out

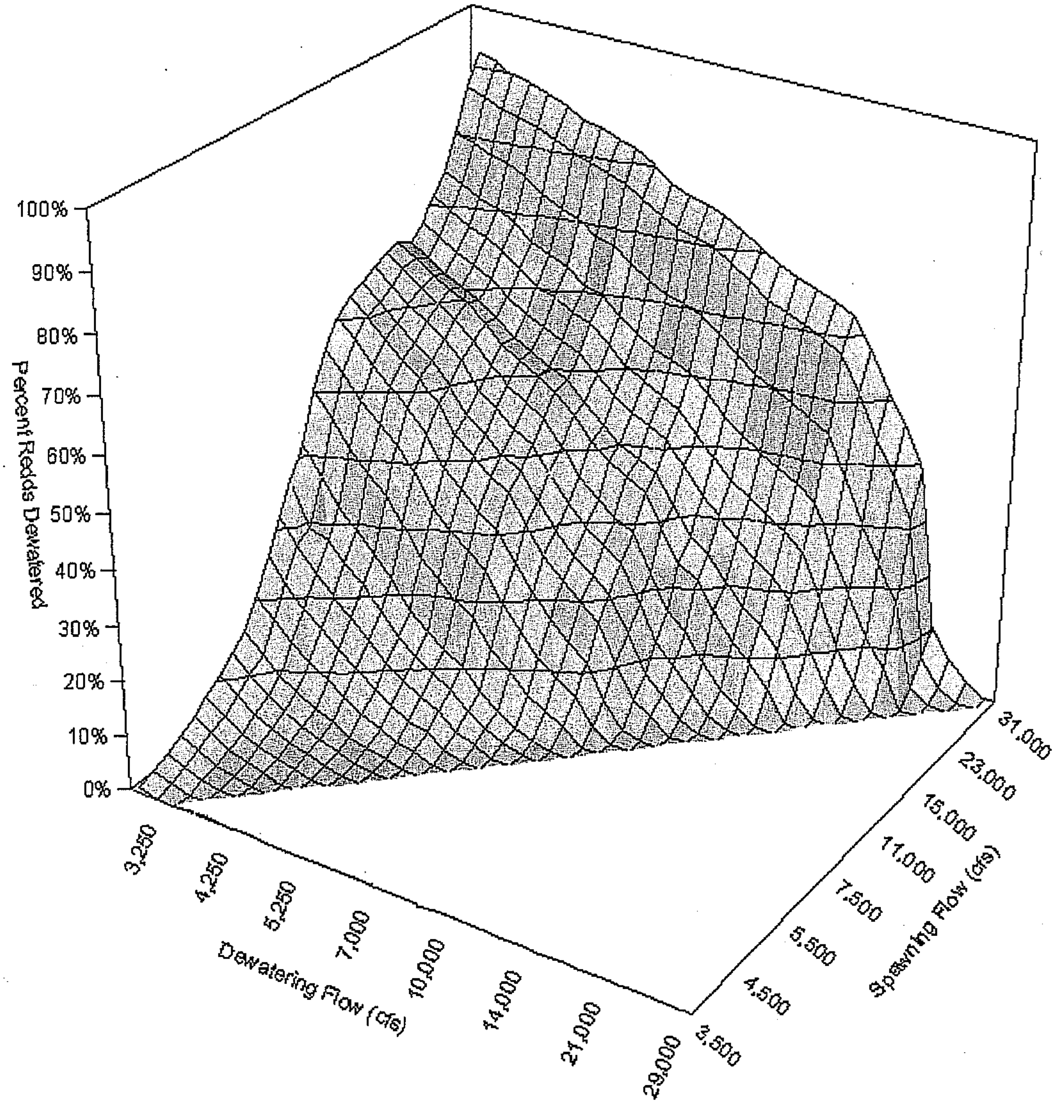


Figure 8
Dewatering of Fall-run Chinook Salmon Redds with ACID Dam in

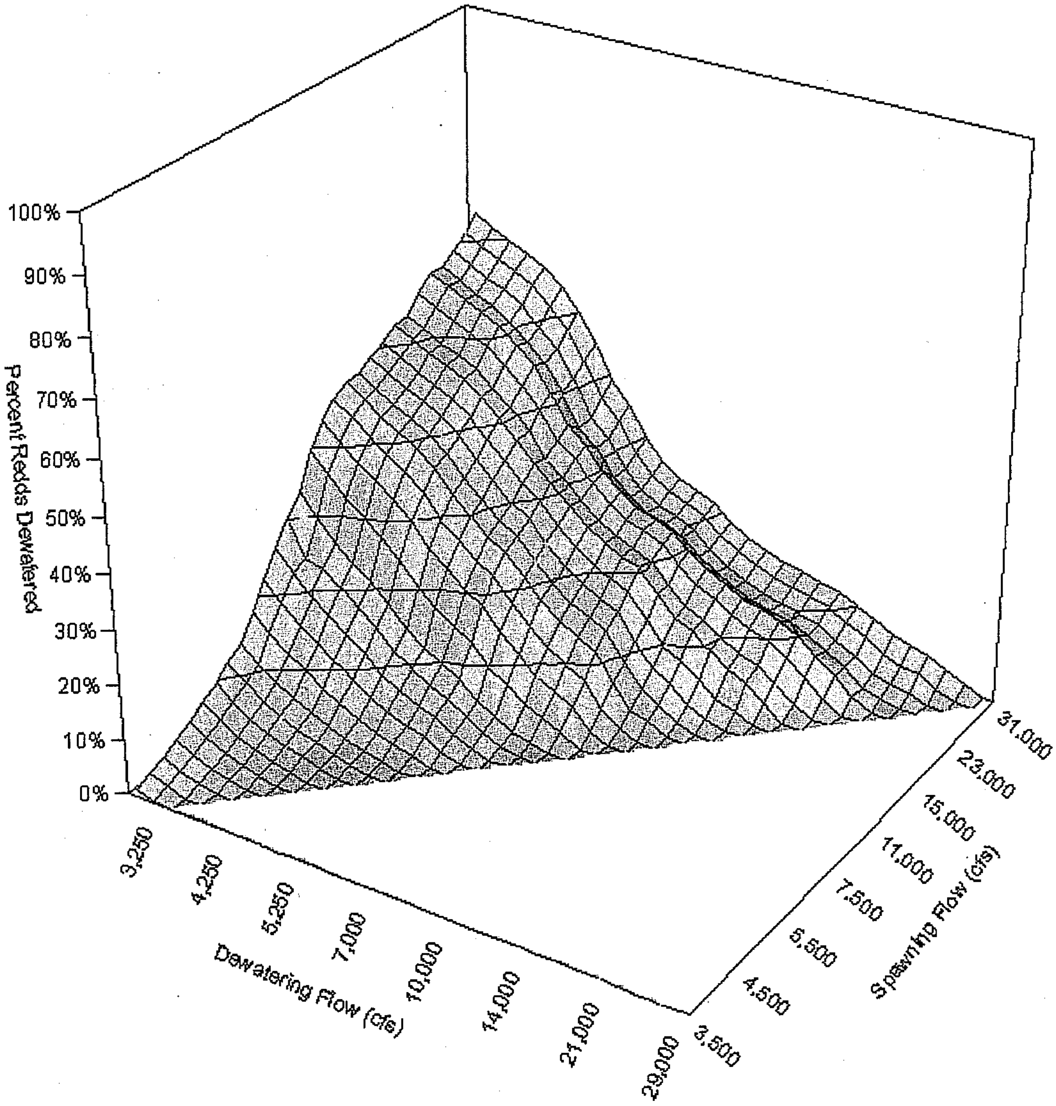


Figure 9
Dewatering of Late-Fall-run Chinook Salmon Redds with ACID Dam out

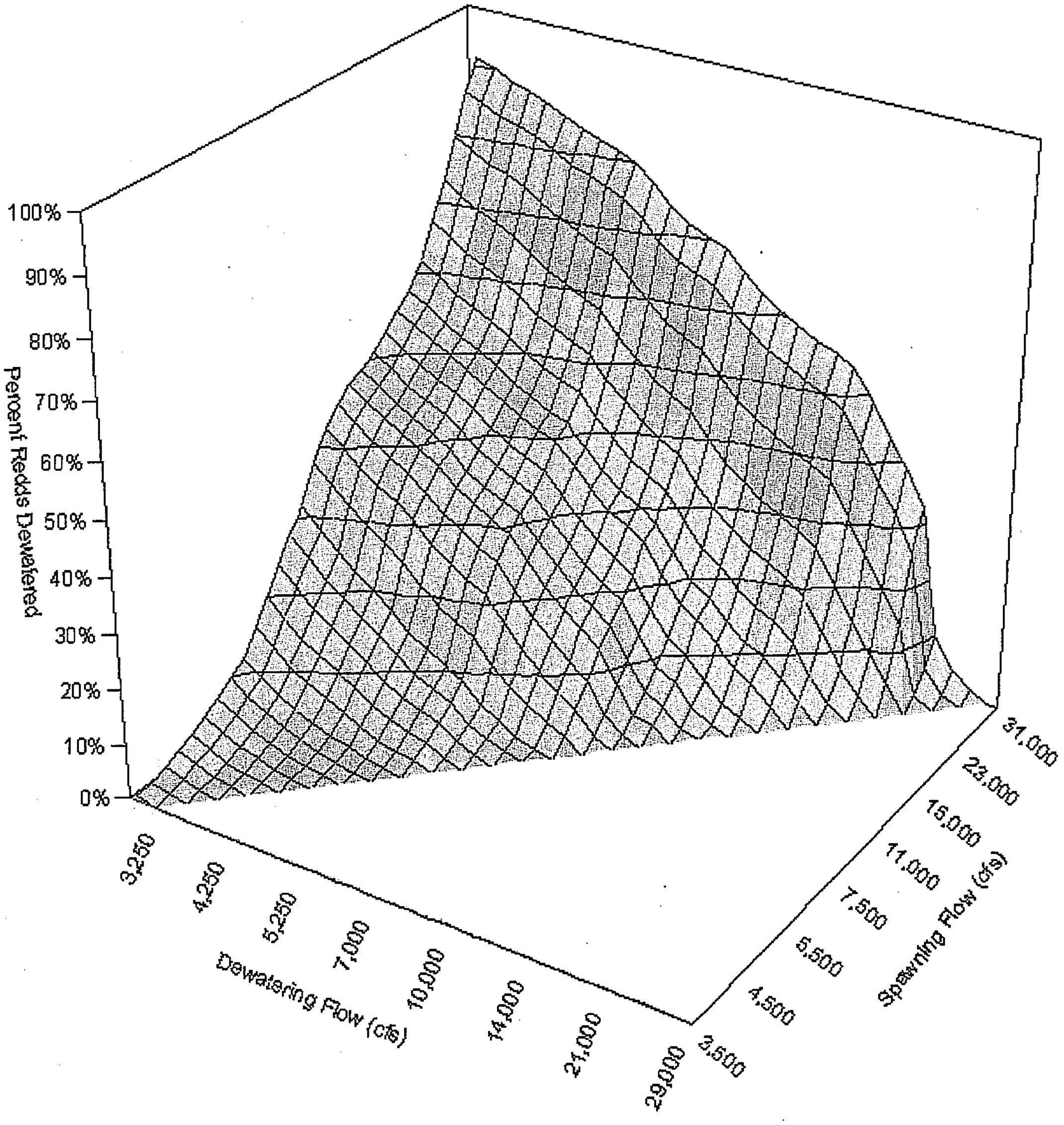


Figure 10
Dewatering of Late-Fall-run Chinook Salmon Redds with ACID Dam in .

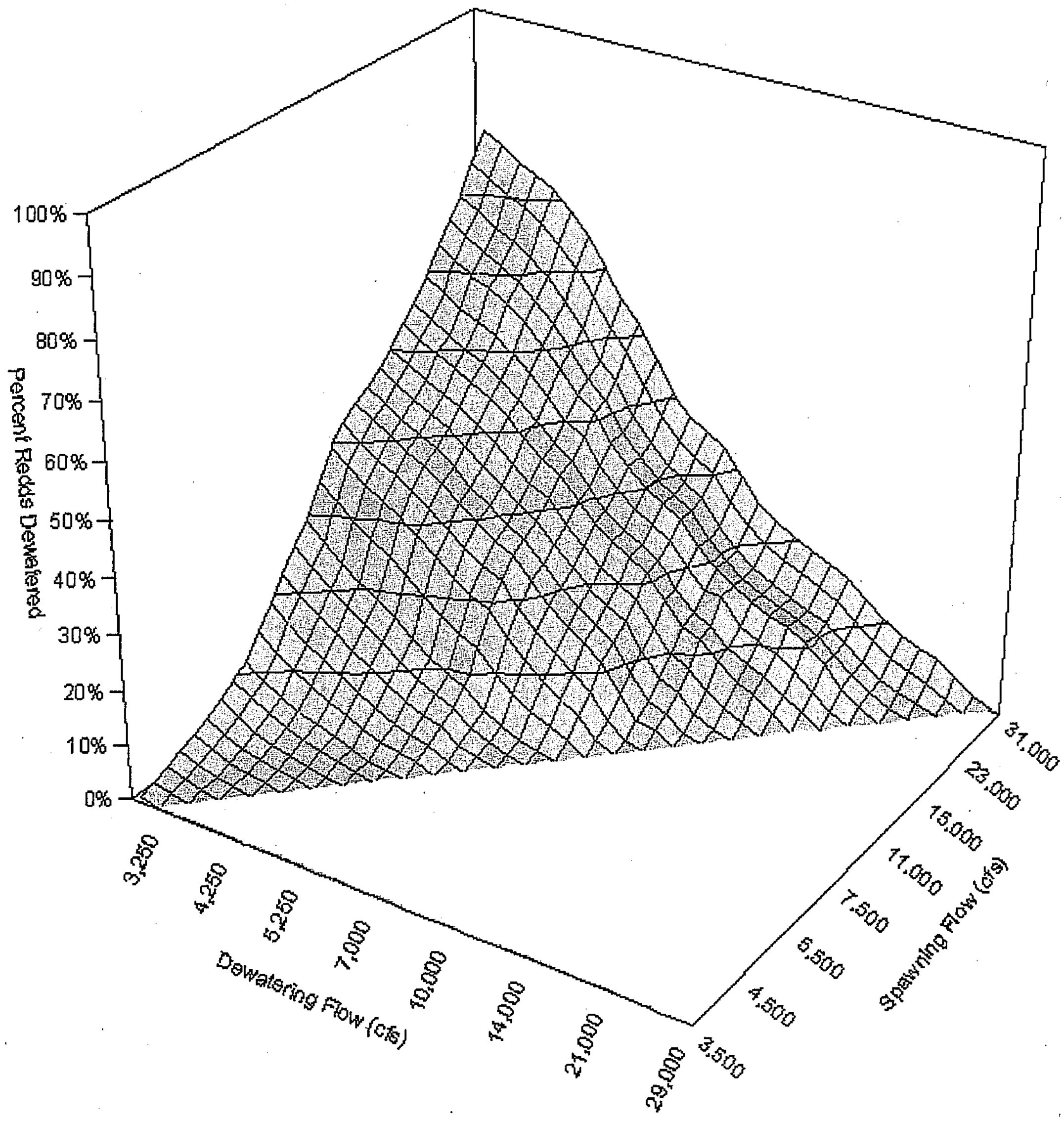


Figure 11

Dewatering of Winter-run Chinook Salmon Redds with ACID Dam out

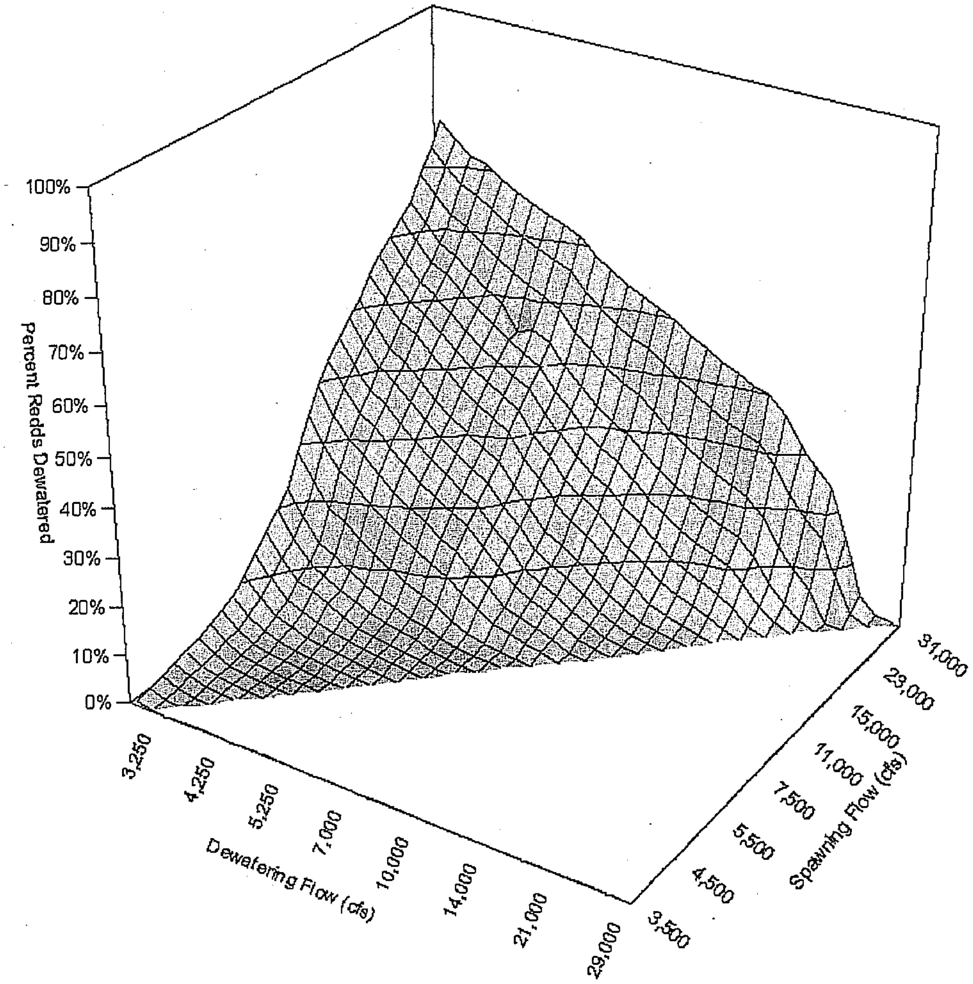


Figure 12
Dewatering of Winter-run Chinook Salmon Redds with ACID Dam in

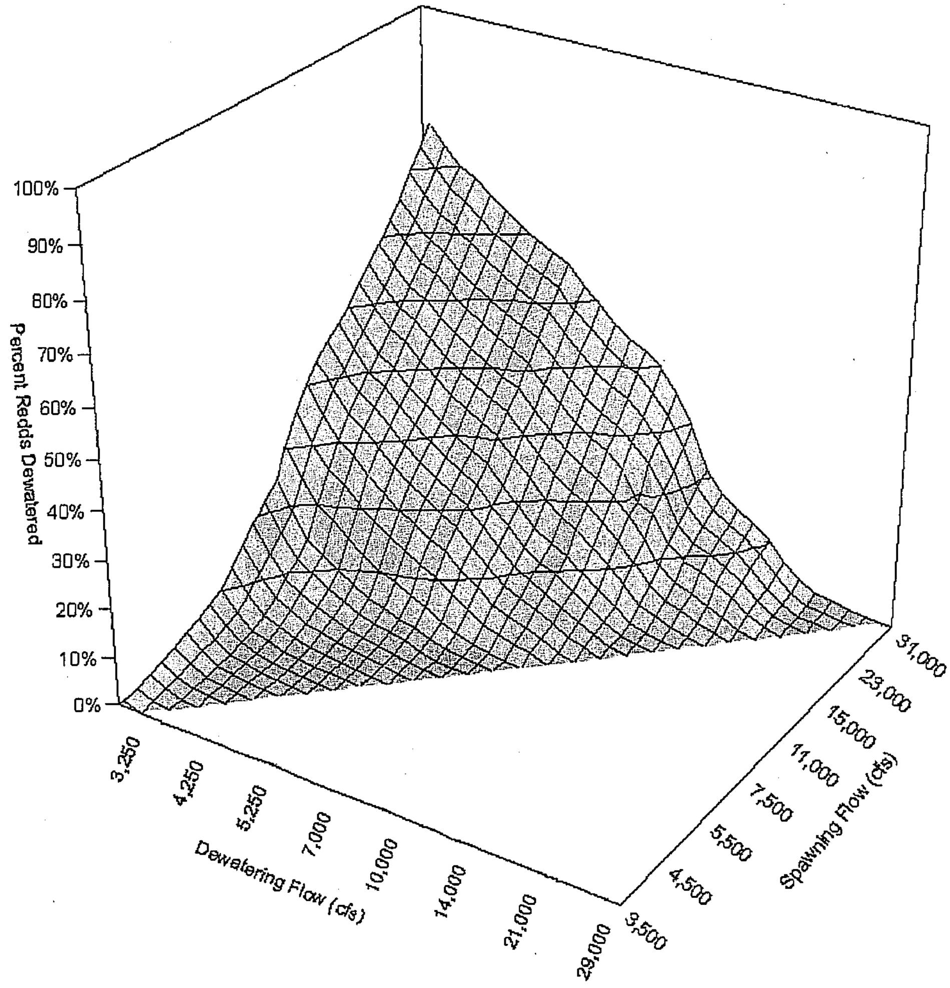


Figure 13
Dewatering of Steelhead Redds with ACID Dam out

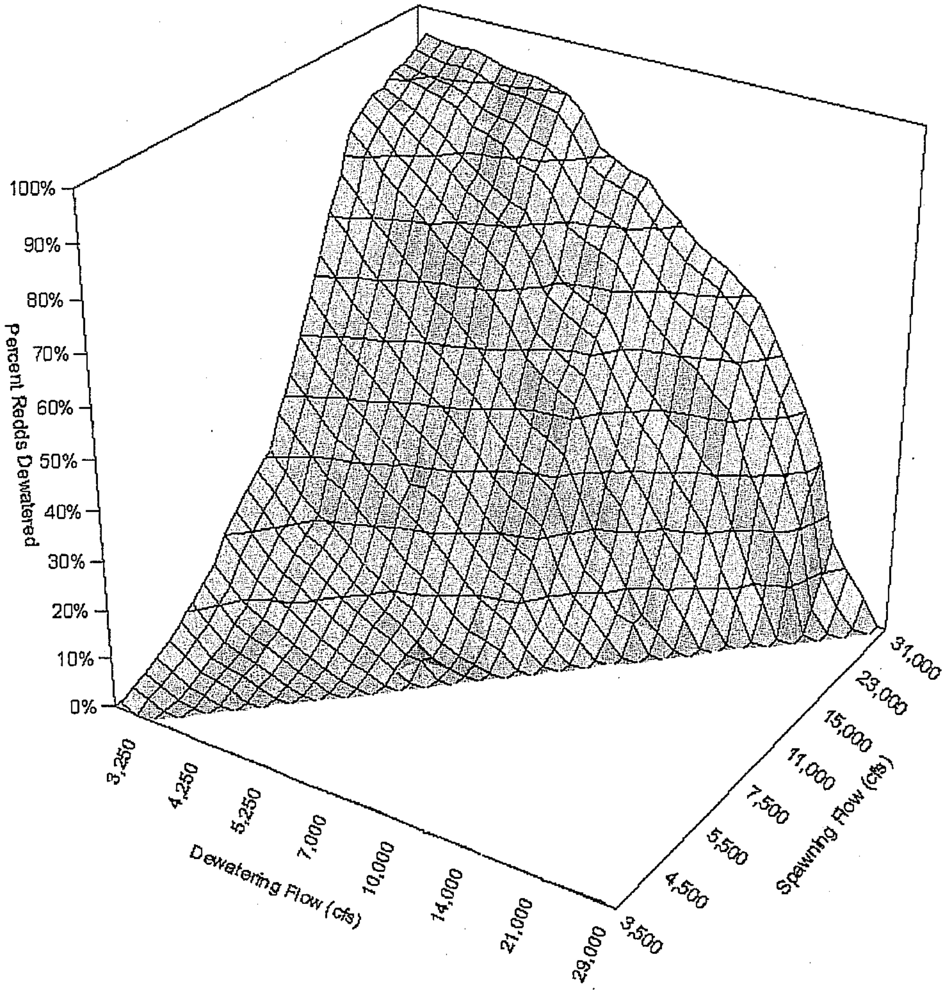
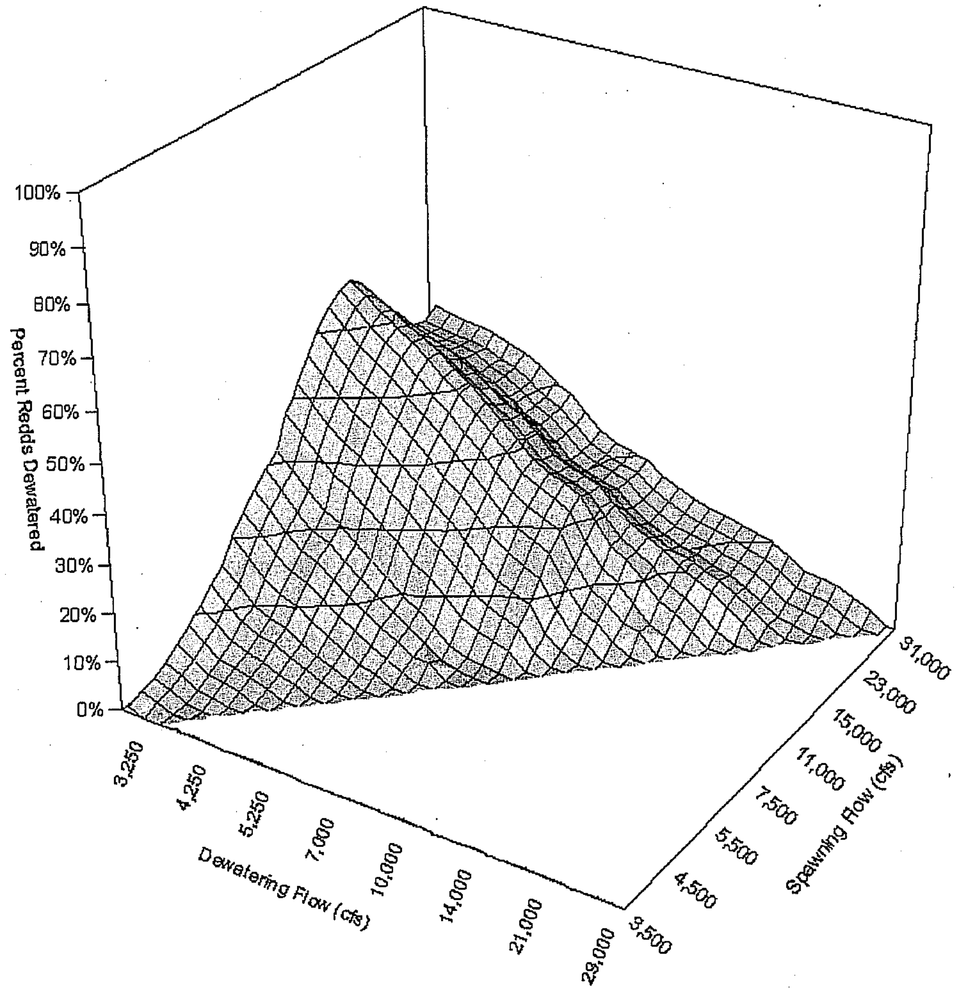


Figure 14
Dewatering of Steelhead Redds with ACID Dam in



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APPENDIX A
STRANDING SITE LOCATIONS

Stranding Site #	River Mile	River Bank	MHU #	Stranding Flow (cfs)[31]	Stranding Area (ft^2)	Type
1	298.8	Left	139	21,250/5,000	19,579	In
3A	300.6	Left	143	12,750/11,100	684	OCA
3B	300.6	Left	143	5,200/4,625	2,673	OCA
4	300.8	Left	143	7,400/6,580	4,838	OCA
5	301.4	Left	143	20,000/4,825	2,107	OCA
6	302.0	Right	143	8,128	1,200	In
7	300.2	Right	141	5,250/<3,250	2,850	In
8	299.9	Right	140	8,200/5,100	12,906	In
9	292.5	Left	100	6,409	1,319	OCA
10	294.0	Left	109	5,950	600	OCA
11	295.2	Left	113	<3,250	---	OCA
12	295.2	Left	113	<3,250	8,303	OCA
13	296.4	Left	129	4,500	1,056	OCA
14	296.5	Left	127	4,555	200,000	OCA
15	297.0	Left	127	<3,250	5,373	OCA
16	297.4	Left	133	<3,250	75,024	In
17	296.9	Right	132	4,844	1,296	OCA
18	296.7	Right	130	9,376	387	OCA
19	296.3	Right	123	5,950	3,164	In
20	295.5	N/A	114	9,337	13,640	OCA
21	295.3	N/A	114	6,050	47,611	OCA
22	294.9	Right	111	<3,250	594	OCA
23	291.7	Right	96	4,360	4,497	In
24	291.8	Left	97	6,032	2,640	In
25	291.8	Right	97	4,248	5,612	In

---

[31] Sites 1 to 5, 7 and 8 are located above ACID and have a different stranding flow depending on whether the boards are in or out at ACID. The first flow is the stranding flow with boards out, while the second flow is the stranding flow with boards out.

Stranding Site #	River Mile	River Bank	MHU #	Stranding Flow (cfs)	Stranding Area (ft^2)	Type
26	289.5	Right	80	4,849	423	OCA
27	293.7	N/A	107	3,946	106,000	OCA
28	293.7	Right	109	<3,250	1,352	OCA
29	293.7	Right	108	7,483	300	OCA
30	293.1	Right	104	5,921	26,978	In
31	292.8	Right	104	14,276	580	OCA
32	292.8	Right	104	7,683	26,371	In
33	291.5	Right	91	14,927	21,500	OCA
34	290.3	Right	85	5,934	11,606	OCA
35	289.3	Middle	75	7,898	4,397	In
36	289.3	Middle	75	3,450	36,320	In
37	288.5	Right	67	<3,250	4,700	OCA
38	288.5	Right	67	13,771	429	OCA
39A	291.7	Left	98	4,752	4,118	OCA
39B	291.7	Left	98	10,508	533	OCA
40	291.4	Left	91	10,747	13,739	OCA
41	290.3	Left	85	7,330	5,921	OCA
41A	290.3	Left	85	4,640	3,233	In
42	290.3	Left	85	7,683>Q>4,710	3,050	OCA
43	290.3	Left	85	4,440	9,020	OCA
44	290.0	Left	85	9,514	18,631	OCA
45A	290.0	N/A	84	<3,250	2,649	In
45B	290.0	N/A	84	3,502	87,352	In
46	289.8	N/A	83	4,108	34,126	In
47	289.5	Left	81	9,661	432	OCA
48	289.4	Left	75	8,277	333	In
49	289.8	Left	83	4,640	5,066	In
50	289.6	N/A	82	4,440	40,594	In

Stranding Site #	River Mile	River Bank	MHU #	Stranding Flow (cfs)	Stranding Area (ft^2)	Type
51	289.5	N/A	78, 80, 82	3,502	222,752	In
51A	289.5	N/A	79	3,502	64,688	OCA
52	289.4	N/A	76	6,180	3,827	In
53	289.4	N/A	76	4,666	17,375	In
54	289.4	N/A	76	4,766	4,261	In
55	289.8	Right	84	14,727	3,630	OCA
56	289.7	Right	84	4,440	2,088	In
57	285.2	Left	46	5,265	713	In
58	283.3	Left	45	<3,250	771	OCA
59	284.9	Left	46	6,086	760	In
60	287.7	N/A	61	<3,250	---	In
60A	287.7	Right	61	8,762	1,330	In
60B	287.7	Right	61	8,962	1,170	In
61	287.9	Left	63	5,752	30,437	In
61A	287.9	Left	63	3,568	11,727	In
61B	287.9	Left	63	6,286	624	In
62	287.8	N/A	61	<3,250	---	In
63	287.9	Right	64	8,762	480	In
64	287.6	Right	59	8,562	583	OCA
65	287.5	Right	60	8,762	943	OCA
66	286.3	Right	53	10,859	3,049	OCA
67	286.3	Right	53	5,986	924	In
68	285.4	Right	48	5,460	84,638	OCA
69	285.2	Right	47	4,450	2,345	OCA
70	285.2	Right	47	5,100	2,669	OCA
71	284.3	Right	45	3,664	493	OCA
72	283.6	Right	45	12,643	722	OCA

Stranding Site #	River Mile	River Bank	MHU #	Stranding Flow (cfs)	Stranding Area (ft^2)	Type
73	282.8	Right	43	5,750	364	OCA
74	282.6	Right	42	4,591	235	OCA
75	281.3	Right	36	<3,250	42,066	OCA
76	281.3	Right	36	8,826	5,918	In
77	281.0	Right	34	6,744	2,341	OCA
78	280.6	Right	33	6,672	2,331	OCA
79B	280.6	Right	33	8,364	120	OCA
79C	280.6	Right	33	8,926	1,691	OCA
79A	280.4	Left	31	8,926	693	In
80	279.9	Right	28	9,430	459	In
81	279.1	Right	26	13,546	1,814	OCA
82	273.0	Right	9	18,799	702	OCA
83	283.1	Left	44	< 3250	675	OCA
84	282.7	Left	43	9,100	3451	OCA
85	282.6	Left	41	28,422	7,097	OCA
86	280.8	Right	34	6,542	2,153	In
87	280.4	Right	30	6,417	2,129	In
88	280.3	Right	30	8,287	1,746	In
88A	280.3	Right	30	11,496	1,089	In
89	280.3	Right	30	7,937	50	OCA
90	280.2	Left	30	5,674	650	OCA
91	278.5	Left	20	9,333	3,683	OCA
92	276.9	Left	14	8,333	1,871	OCA
93	275.6	Left	12	15,071	738	OCA
94	275.6	Left	12	11,083	675	OCA
95	271.7	Right	6	5,542	27,003	In
96	287.6	Right	21	9,406	1,159	In
97	287.6	Right	21	9,568	564	In

APPENDIX B
PHABSIM WSEL CALIBRATION

Stage of Zero Flow Values

Stranding Site	SZF
6	61.3
9	85.2
11	85.7
12	89.5
13	80.8
14	92.7
15	95.8
16	81.6
17	87.7
20	86.8
22	89.2
24, 25	92.8
27, 28	89.4
30	89.1
31	86.8
34	85.3
37, 38	76.5
39	92.1
40	93.0
44, 45	88.5
46	91.8
48	87.1
57	79.8
58	86.6

Stranding Site	SZF
61	90.3
66	96.0
68	88.1
69, 70	78.0
71	88.7
72	87.3
74	89.3
77	88.5
78, 79B	80.2
81	90.7
85	90.4
86	87.0
87	95.0
88	94.3
88A	95.8
89	93.6
90	90.5
94	83.8
97	88.7

SITE	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
			6580 cfs	10045 cfs	12032 cfs	6580 cfs	10045 cfs	12032 cfs
6	3.88	0.3	0.2	0.5	0.4	0.01	0.04	0.03

SITE	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
			6152 cfs	9813 cfs	11822 cfs	6152 cfs	9813 cfs	11822 cfs
9	3.78	0.1	0.0	0.2	0.1	0.00	0.01	0.00
11	5.56	0.6	0.3	0.9	0.4	0.01	0.02	0.01
12	3.79	0.4	0.2	0.6	0.5	0.00	0.01	0.01
13	7.05	0.4	0.2	0.6	0.4	0.00	0.01	0.01
16	4.02	3.4	2.1	5.3	3.0	0.07	0.18	0.11
17	2.91	0.3	0.1	0.5	0.3	0.00	0.02	0.01
20	3.01	0.0	0.0	0.0	0.0	0.00	0.00	0.00
22	2.73	1.0	0.5	1.5	1.0	0.01	0.05	0.04

SITE	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
			6152 cfs	9812 cfs	11822 cfs	6152 cfs	9812 cfs	11822 cfs
14	2.72	1.9	0.9	3.0	2.0	0.01	0.05	0.04

SITE	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
			7910 cfs	11700 cfs	14990 cfs	7910 cfs	11700 cfs	14990 cfs
15	1.96	3.2	2.2	4.9	2.6	0.04	0.11	0.07

SITE	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
			6092 cfs	9808 cfs	2418 cfs	6092 cfs	9808 cfs	2418 cfs
24, 25	2.07	0.9	0.3	1.3	1.0	0.00	0.02	0.02

SITE	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
			7683 cfs	11700 cfs	14998 cfs	7683 cfs	11700 cfs	14998 cfs
27, 28	3.36	0.5	0.3	0.8	0.5	0.01	0.02	0.01

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	7683 cfs	11700 cfs	14987 cfs	7683 cfs	11700 cfs	14987 cfs
31	2.57	0.8	0.5	1.3	0.8	0.01	0.04	0.03
34	2.91	0.0	0.0	0.0	0.0	0.00	0.00	0.00

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	4710 cfs	8608 cfs	14987 cfs	4710 cfs	8608 cfs	14987 cfs
30	2.11	3.4	2.1	5.0	3.1	0.06	0.19	0.14

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	7898 cfs	12009 cfs	14986 cfs	7898 cfs	12009 cfs	14986 cfs
37, 38	6.05	0.1	0.0	0.1	0.1	0.00	0.00	0.00

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	7554 cfs	11700 cfs	14927 cfs	7554 cfs	11700 cfs	14927 cfs
39A, B	2.16	2.4	1.5	3.6	2.0	0.04	0.11	0.07

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	6150 cfs	7554 cfs	14927 cfs	6150 cfs	7554 cfs	14927 cfs
40	2.30	0.5	0.6	0.8	0.2	0.01	0.02	0.01

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	4710 cfs	7554 cfs	11700 cfs	4710 cfs	7554 cfs	11700 cfs
44; 45A, B	2.99	2.6	1.6	3.8	2.3	0.03	0.09	0.06
46	2.62	3.2	1.9	4.7	2.9	0.04	0.11	0.08

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	7554 cfs	11700 cfs	14927 cfs	7554 cfs	11700 cfs	14927 cfs
48	4.25	1.3	0.8	2.1	1.2	0.02	0.05	0.05

	BETA	%MEAN	Calculated vs. Given Disch. (%)		Difference (measured vs. pred. WSELs)	
SITE	COEFF.	ERROR	4936 cfs	6068 cfs	4936 cfs	6068 cfs
57	1.26	---	---	---	0.00	0.00

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	6244 cfs	8994 cfs	14988 cfs	6244 cfs	8994 cfs	14988 cfs
58	3.24	2.0	1.9	3.1	1.1	0.05	0.09	0.04

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	6106 cfs	8762 cfs	14986 cfs	6106 cfs	8762 cfs	14986 cfs
61, 61A	4.04	1.0	0.9	1.5	0.6	0.01	0.02	0.01

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	6086 cfs	8700 cfs	14986 cfs	6086 cfs	8700 cfs	14986 cfs
68	2.87	0.5	0.5	0.8	0.3	0.01	0.03	0.01
69, 70	6.17	2.0	1.9	3.0	1.0	0.06	0.10	0.04

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	6244 cfs	8926 cfs	14986 cfs	6244 cfs	8926 cfs	14986 cfs
71	3.01	2.1	2.0	3.2	1.1	0.05	0.09	0.04

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	6244 cfs	8926 cfs	14988 cfs	6244 cfs	8926 cfs	14988 cfs
72	1.88	2.2	2.2	3.4	1.2	0.04	0.09	0.04
74	1.83	1.1	1.1	1.7	0.7	0.03	0.05	0.03
77	2.42	2.9	2.9	4.4	1.4	0.09	0.13	0.06
78, 79B	4.33	0.4	0.4	0.7	0.3	0.01	0.02	0.01

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	6454 cfs	9428 cfs	15049 cfs	6454 cfs	9428 cfs	15049 cfs
81	1.97	1.1	0.9	1.7	0.8	0.02	0.06	0.03

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	6244 cfs	9035 cfs	14580 cfs	6244 cfs	9035 cfs	14580 cfs
85	3.16	2.7	2.6	4.2	1.5	0.04	0.07	0.03

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
SITE	COEFF.	ERROR	6244 cfs	9035 cfs	14988 cfs	6244 cfs	9035 cfs	14988 cfs
86	3.50	2.2	2.1	3.3	1.2	0.06	0.10	0.04

SITE	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%)		Difference (measured vs. pred. WSELs)	
			5977 cfs	10109 cfs	5977 cfs	10109 cfs
87	9.22	---	---	---	0.00	0.00
90	3.26	---	---	---	0.00	0.00

SITE	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
			6106 cfs	10109 cfs	14988 cfs	6106 cfs	10109 cfs	14988 cfs
88	4.83	4.1	1.8	6.4	4.3	0.01	0.05	0.04
89	2.36	4.6	2.0	7.2	4.8	0.01	0.10	0.10

SITE	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%)		Difference (measured vs. pred. WSELs)	
			10109 cfs	14988 cfs	10109 cfs	14988 cfs
88A	1.77	---	---	---	0.00	0.00

SITE	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
			6511 cfs	9606 cfs	15071 cfs	6511 cfs	9606 cfs	15071 cfs
94	2.72	0.6	0.5	1.0	0.4	0.02	0.03	0.02

SITE	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
			6106 cfs	9239 cfs	14988 cfs	6106 cfs	9239 cfs	14988 cfs
97	4.84	3.1	2.8	4.8	1.9	0.04	0.07	0.03

APPENDIX C
BRIDGE RIFFLE VELOCITY VALIDATION STATISTICS

Measured Velocities less than 3 ft/s

Difference (measured vs. pred. velocities, ft/s)

Number of Observations	Average	Standard Deviation	Maximum
87	1.72	1.67	6.15

Measured Velocities greater than 3 ft/s

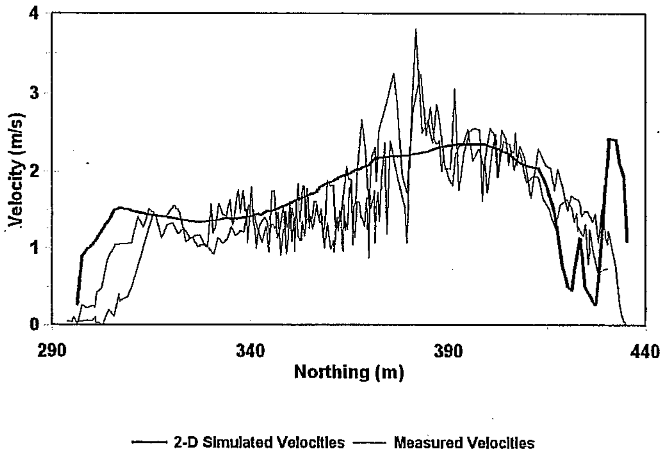
Percent Difference (measured vs. pred. velocities)

Number of Observations	Average	Standard Deviation	Maximum
304	30%	25%	107%

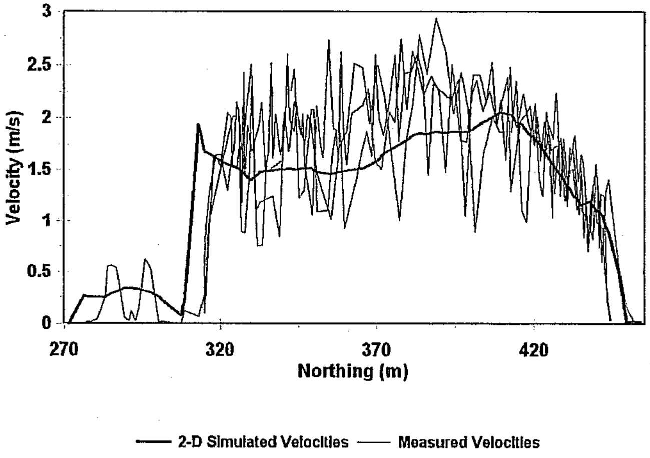
All differences were calculated as the absolute value of the difference between the measured and simulated velocity.

Bridge Riffle Site

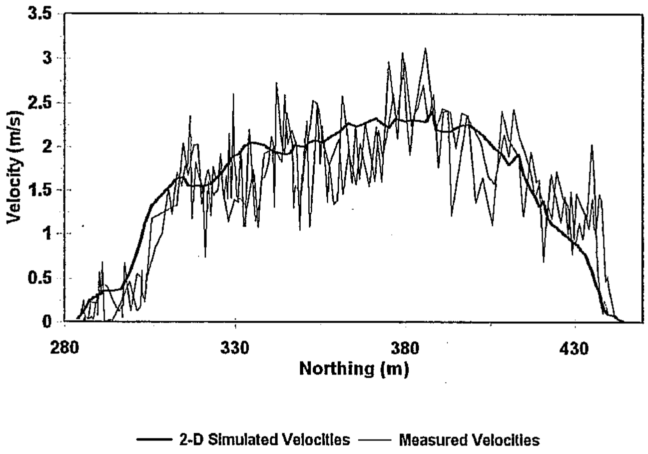
Bridge Riffle XS1, Q = 14454 cfs



Bridge Riffle XS3, Q = 15149 cfs



Bridge Riffle XS2, Q = 15149 cfs



APPENDIX D
JUVENILE STRANDING RESULTS

Number of juvenile salmon stranded - ACID Dam Boards Out

Rearing flow (cfs)

Stranding flow (cfs)	3500	3750	4000	4250	4500	4750	5000	5250	5500	6000	6500
14000											
13000											
12000											
11000											
10000											
9000											
8000											
7500											
7000											
6500											
6000											629
5500										2775	3385
5250									574	3330	3940
5000								139	694	3450	4060
4750							185	304	859	3615	4225
4500						2056	2222	2341	2896	5652	6262
4250					1503	3559	3725	3844	4399	7155	7765
4000				1200	2703	4759	4925	5044	5599	8355	8965
3750			668	1868	3371	5427	5592	5712	6267	9023	9633
3500		10130	10798	11998	13501	15557	15722	15842	16397	19153	19763
3250	1097	11227	11895	13095	14598	16654	16819	16939	17494	20250	20860

Number of juvenile salmon stranded - ACID Dam Boards Out (continued)

Stranding flow (cfs)	Rearing flow (cfs)									
	7000	7500	8000	9000	10000	11000	12000	13000	14000	15000
14000										167
13000									14	181
12000								9	23	190
11000							37	46	60	227
10000						109	146	155	169	336
9000					319	428	466	474	489	655
8000				811	1131	1240	1277	1286	1300	1466
7500			949	1760	2079	2188	2226	2234	2249	2415
7000		89	1018	1830	2149	2258	2295	2304	2318	2485
6500	114	183	1113	1924	2243	2353	2390	2399	2413	2579
6000	723	793	1723	2534	2853	2962	2999	3008	3022	3189
5500	3479	3549	4479	5290	5609	5718	5755	5764	5778	5945
5250	4034	4104	5033	5845	6164	6273	6310	6319	6333	6500
5000	4154	4224	5153	5964	6284	6393	6430	6439	6453	6620
4750	4319	4389	5319	6130	6449	6558	6595	6604	6618	6785
4500	6356	6426	7355	8167	8486	8595	8632	8641	8655	8822
4250	7859	7929	8858	9670	9989	10098	10135	10144	10158	10325
4000	9059	9129	10059	10870	11189	11298	11335	11344	11358	11525
3750	9727	9797	10726	11538	11857	11966	12003	12012	12026	12193
3500	19857	19927	20856	21668	21987	22096	22133	22142	22156	22323
3250	20954	21024	21953	22764	23084	23193	23230	23239	23253	23420

Number of juvenile salmon stranded - ACID Dam Boards In

	Rearing flow (cfs)										
Stranding flow (cfs)	3500	3750	4000	4250	4500	4750	5000	5250	5500	6000	6500
14000											
13000											
12000											
11000											
10000											
9000											
8000											
7500											
7000											
6500											
6000											629
5500										2775	3385
5250									574	3330	3940
5000								426	981	3737	4346
4750							789	1196	1751	4507	5116
4500						2073	2843	3249	3804	6560	7170
4250					1503	3576	4346	4753	5307	8063	8673
4000				1200	2703	4776	5546	5953	6507	9264	9873
3750			668	1868	3371	5444	6214	6620	7175	9931	10541
3500		10130	10798	11998	13501	15574	16344	16750	17305	20061	20671
3250	1097	11227	11895	13095	14598	16671	17441	17847	18402	21158	21768

Number of juvenile salmon stranded - ACID Dam Boards In (continued)

Stranding flow (cfs)	7000	7500	8000	9000	10000	11000	12000	13000	14000	15000
					Rearing flow (cfs)					
14000										167
13000									14	181
12000								5	19	185
11000							41	46	60	227
10000						109	151	155	169	336
9000					319	428	470	474	489	655
8000				421	741	850	891	896	910	1077
7500			949	1370	1690	1799	1840	1845	1859	2025
7000		58	988	1409	1729	1838	1879	1884	1898	2065
6500	144	183	1113	1534	1854	1963	2004	2009	2023	2190
6000	754	793	1723	2144	2463	2572	2614	2618	2633	2799
5500	3510	3549	4479	4900	5219	5329	5370	5375	5389	5555
5250	4065	4104	5033	5455	5774	5883	5925	5929	5943	6110
5000	4471	4510	5440	5861	6181	6290	6331	6336	6350	6517
4750	5241	5281	6210	6631	6951	7060	7101	7106	7120	7287
4500	7295	7334	8264	8685	9004	9114	9155	9160	9174	9340
4250	8798	8837	9767	10188	10508	10617	10658	10663	10677	10843
4000	9998	10037	10967	11388	11708	11817	11858	11863	11877	12044
3750	10666	10705	11635	12056	12375	12485	12526	12531	12545	12711
3500	20796	20835	21765	22186	22505	22614	22656	22660	22675	22841
3250	21893	21932	22861	23283	23602	23711	23753	23757	23771	23938

APPENDIX E
REDD DEWATERING RESULTS

Percentage of Fall-run Chinook Salmon Redds Dewatered - ACID Dam Boards Out

Spawning Flow (cfs)

Dewatering flow (cfs)	3500	3750	4000	4250	4500	4750	5000	5250	5500	6000	6500	7000	7500	8000	9000	10000	11000
29000																	
27000																	
25000																	
23000																	
21000																	
19000																	
17000																	
15000																	
14000																	
13000																	
12000																	
11000																	
10000																	0.9%
9000																2.2%	5.5%
8000															2.6%	6.6%	11.5%
7500														0.8%	4.4%	9.1%	14.1%
7000													0.9%	2.0%	6.6%	11.8%	17.3%
6500												1.3%	2.6%	4.2%	9.8%	15.6%	21.1%
6000											1.2%	2.8%	4.6%	6.5%	12.9%	19.7%	25.8%
5500										1.4%	3.2%	5.4%	7.7%	10.3%	17.6%	24.9%	31.0%
5250									0.7%	2.1%	4.2%	6.8%	9.4%	12.3%	19.8%	27.2%	33.1%
5000								0.7%	1.3%	3.2%	5.6%	8.6%	11.6%	14.7%	22.6%	30.2%	36.0%
4750							0.8%	1.6%	2.5%	4.8%	7.6%	10.8%	14.2%	17.6%	25.8%	33.2%	38.8%
4500						0.8%	1.7%	2.8%	4.0%	6.9%	10.4%	14.2%	18.2%	22.1%	30.9%	38.8%	44.2%
4250					0.8%	1.6%	2.7%	4.0%	5.4%	8.9%	13.0%	17.2%	21.6%	25.8%	34.9%	42.8%	48.0%
4000				0.9%	1.7%	2.8%	4.1%	5.7%	7.3%	11.4%	15.8%	20.3%	24.8%	29.0%	38.0%	45.7%	50.7%
3750			0.9%	1.6%	2.6%	3.9%	5.5%	7.3%	9.2%	13.6%	18.4%	23.1%	28.0%	32.4%	41.5%	48.7%	53.6%
3500		1.0%	2.1%	3.2%	4.6%	6.2%	8.1%	10.1%	12.2%	17.0%	22.2%	27.4%	29.2%	37.0%	45.9%	52.8%	57.3%
3250	1.0%	2.0%	3.4%	4.8%	6.6%	8.4%	10.6%	12.9%	15.3%	20.6%	26.2%	31.7%	37.0%	41.5%	50.2%	56.3%	60.4%

Percentage of Fall-run Chinook Salmon Redds Dewatered - ACID Dam Boards Out (continued)

Dewatering flow (cfs)	Spawning Flow (cfs)											
	12000	13000	14000	15000	17000	19000	21000	23000	25000	27000	29000	31000
29000												2.2%
27000											1.8%	5.3%
25000										2.3%	6.4%	10.7%
23000									6.7%	17.8%	31.2%	38.9%
21000								4.2%	11.7%	23.9%	38.4%	46.3%
19000							4.6%	10.8%	18.8%	30.4%	44.2%	51.1%
17000						4.1%	11.3%	18.5%	26.1%	37.8%	51.5%	57.9%
15000					5.3%	11.1%	18.5%	26.2%	33.5%	44.6%	57.6%	63.1%
14000				2.6%	9.5%	14.8%	22.1%	28.9%	36.2%	46.8%	59.5%	64.7%
13000			1.6%	4.8%	12.2%	16.9%	24.4%	31.3%	38.1%	48.4%	60.8%	65.9%
12000		1.6%	4.7%	9.0%	16.8%	20.6%	27.0%	32.9%	39.8%	50.0%	62.3%	67.2%
11000	2.7%	5.3%	9.0%	13.6%	21.4%	24.8%	30.2%	35.3%	41.8%	51.6%	63.7%	68.4%
10000	4.5%	7.7%	12.0%	16.4%	23.5%	26.9%	33.0%	38.5%	44.5%	54.1%	65.9%	70.5%
9000	10.6%	14.4%	18.4%	22.5%	29.2%	31.9%	37.4%	41.8%	47.7%	57.0%	68.2%	72.6%
8000	17.2%	20.9%	24.9%	28.9%	34.9%	36.6%	41.3%	45.4%	50.5%	59.3%	70.2%	74.7%
7500	20.0%	23.2%	26.9%	30.7%	36.4%	38.2%	42.8%	46.8%	51.9%	60.5%	70.9%	75.3%
7000	22.8%	25.8%	29.3%	32.9%	38.3%	40.0%	44.4%	48.3%	52.9%	61.3%	71.8%	76.1%
6500	26.5%	29.2%	32.7%	36.1%	41.0%	42.4%	46.5%	50.4%	54.8%	63.0%	73.3%	77.7%
6000	30.9%	33.8%	37.3%	40.6%	45.0%	45.8%	49.5%	53.2%	57.2%	65.0%	75.4%	80.0%
5500	35.8%	38.4%	41.7%	44.8%	48.3%	48.8%	52.3%	56.1%	60.1%	67.5%	77.3%	82.0%
5250	37.7%	40.2%	43.5%	46.5%	50.0%	50.2%	53.5%	57.4%	60.7%	68.0%	78.2%	83.0%
5000	40.6%	43.0%	46.1%	49.1%	52.2%	52.2%	55.2%	59.1%	63.3%	70.6%	79.4%	84.1%
4750	43.3%	45.6%	48.6%	51.4%	54.0%	53.7%	56.6%	60.4%	64.5%	71.7%	80.3%	85.0%
4500	48.3%	50.2%	52.8%	55.1%	57.1%	56.4%	59.0%	62.7%	66.2%	73.3%	81.8%	86.5%
4250	51.8%	53.6%	56.0%	58.1%	59.6%	58.8%	61.3%	65.0%	68.5%	75.7%	83.1%	87.8%
4000	54.3%	55.9%	58.2%	59.9%	61.2%	60.2%	62.7%	66.5%	70.4%	77.1%	84.1%	88.8%
3750	56.9%	58.3%	60.3%	61.8%	62.7%	61.7%	64.0%	67.7%	71.4%	77.7%	84.9%	89.6%
3500	60.1%	61.1%	63.0%	64.2%	64.9%	63.8%	66.0%	69.5%	73.0%	79.1%	86.2%	91.0%
3250	62.9%	63.7%	65.3%	66.4%	66.8%	65.7%	67.8%	71.3%	74.5%	80.4%	87.3%	92.0%

Percentage of Fall-run Chinook Salmon Redds Dewatered - ACID Dam Boards In

Spawning Flow (cfs)

Dewatering flow (cfs)	3500	3750	4000	4250	4500	4750	5000	5250	5500	6000	6500	7000	7500	8000	9000	10000	11000
29000																	
27000																	
25000																	
23000																	
21000																	
19000																	
17000																	
15000																	
14000																	
13000																	
12000																	
11000																	
10000																	1.2%
9000																1.6%	3.8%
8000															2.0%	4.9%	8.1%
7500														0.6%	3.4%	6.7%	9.9%
7000													0.7%	1.6%	5.0%	8.6%	12.1%
6500												1.1%	2.1%	3.3%	7.4%	11.5%	15.0%
6000											1.0%	2.3%	3.7%	5.1%	9.8%	14.5%	18.3%
5500										1.2%	2.7%	4.4%	6.2%	8.1%	13.5%	18.5%	22.3%
5250									0.6%	1.9%	3.5%	5.6%	7.7%	9.7%	15.3%	20.4%	24.1%
5000								0.7%	1.3%	2.9%	4.9%	7.2%	9.6%	11.9%	17.7%	23.1%	26.9%
4750							0.8%	1.6%	2.4%	4.3%	6.6%	9.1%	11.8%	14.3%	20.3%	25.7%	29.5%
4500						0.8%	1.6%	2.6%	3.7%	6.0%	8.9%	11.9%	15.0%	17.8%	24.4%	29.9%	33.6%
4250					0.8%	1.5%	2.5%	3.7%	5.0%	7.8%	11.1%	14.4%	17.8%	20.9%	27.5%	33.1%	36.6%
4000				0.9%	1.7%	2.6%	3.8%	5.3%	6.6%	10.0%	13.5%	16.9%	20.4%	23.5%	30.1%	35.4%	38.7%
3750			0.9%	1.6%	2.5%	3.6%	5.1%	6.7%	8.3%	11.9%	15.6%	19.3%	23.0%	26.2%	32.8%	37.7%	40.9%
3500		1.0%	2.0%	3.1%	4.4%	5.7%	7.4%	9.2%	10.9%	14.8%	18.8%	22.8%	23.9%	29.8%	36.2%	40.8%	43.6%
3250	1.0%	2.0%	3.3%	4.7%	6.2%	7.8%	9.7%	11.7%	13.6%	17.8%	22.2%	26.3%	30.2%	33.4%	39.5%	43.5%	46.0%

Percentage of Fall-run Chinook Salmon Redds Dewatered - ACID Dam Boards In (continued)

Dewatering flow (cfs)	12000	13000	14000	15000	17000	19000	21000	23000	25000	27000	29000	31000
				Spawning Flow (cfs)								
29000												1.5%
27000											1.2%	3.3%
25000										1.2%	3.0%	5.0%
23000									0.7%	1.6%	3.6%	5.7%
21000								1.9%	2.0%	2.6%	4.7%	6.6%
19000							2.3%	4.8%	4.6%	5.0%	6.9%	8.4%
17000						1.8%	5.0%	7.5%	6.5%	6.8%	8.5%	10.0%
15000					2.8%	4.8%	7.7%	10.2%	8.6%	8.7%	10.4%	11.5%
14000				1.8%	5.4%	7.0%	9.8%	11.8%	10.0%	9.9%	11.4%	12.4%
13000			1.0%	3.0%	6.9%	8.1%	11.1%	13.1%	11.0%	10.7%	12.1%	13.1%
12000		1.0%	2.8%	5.4%	9.4%	10.0%	12.5%	14.0%	11.9%	11.5%	12.9%	13.9%
11000	1.9%	3.4%	5.4%	8.2%	12.1%	12.2%	14.5%	15.6%	13.3%	12.8%	14.1%	15.0%
10000	3.0%	4.9%	7.2%	9.8%	13.3%	13.8%	16.2%	17.4%	14.9%	14.5%	15.9%	16.7%
9000	7.2%	9.2%	11.3%	13.6%	16.8%	16.8%	18.9%	19.6%	17.2%	16.8%	17.9%	18.5%
8000	11.8%	13.7%	15.7%	17.9%	20.7%	20.2%	21.9%	22.4%	19.8%	19.4%	20.5%	21.4%
7500	13.7%	15.3%	17.1%	19.3%	21.9%	21.5%	23.3%	23.9%	21.3%	21.0%	21.9%	22.7%
7000	15.6%	17.0%	18.7%	20.7%	23.2%	22.8%	24.5%	25.1%	22.4%	22.1%	23.2%	24.0%
6500	18.3%	19.5%	21.1%	23.0%	25.2%	24.7%	26.4%	27.1%	24.4%	24.2%	25.3%	26.3%
6000	21.5%	22.7%	24.4%	26.2%	28.2%	27.5%	29.0%	29.8%	27.1%	27.1%	28.7%	29.8%
5500	25.3%	26.4%	28.0%	29.7%	31.5%	31.0%	32.7%	33.8%	31.7%	31.9%	33.6%	35.1%
5250	27.1%	28.2%	29.9%	31.8%	33.9%	33.5%	35.4%	36.8%	34.6%	35.0%	37.4%	39.0%
5000	30.0%	31.2%	33.2%	35.3%	37.6%	37.6%	39.8%	41.7%	40.5%	41.3%	43.2%	45.1%
4750	32.6%	34.0%	36.1%	38.3%	40.8%	41.1%	43.6%	45.7%	44.9%	46.0%	48.3%	50.3%
4500	36.4%	37.6%	39.4%	41.4%	43.6%	43.9%	46.4%	48.7%	47.8%	49.1%	51.6%	53.7%
4250	39.2%	40.3%	42.1%	43.9%	46.0%	46.4%	49.0%	51.3%	50.8%	52.5%	54.4%	56.5%
4000	41.2%	42.2%	43.8%	45.5%	47.5%	47.9%	50.5%	53.1%	52.9%	54.5%	56.3%	58.5%
3750	43.1%	43.9%	45.5%	47.0%	48.7%	49.1%	51.8%	54.3%	54.1%	55.6%	57.6%	59.8%
3500	45.5%	46.0%	47.4%	48.8%	50.4%	50.8%	53.4%	55.9%	55.7%	57.2%	59.3%	61.6%
3250	47.6%	48.0%	49.3%	50.5%	52.0%	52.5%	55.1%	57.6%	57.4%	59.0%	61.1%	63.3%

Percentage of Late-Fall-run Chinook Salmon Redds Dewatered - ACID Dam Boards Out

Spawning Flow (cfs)

Dewatering flow (cfs)	3500	3750	4000	4250	4500	4750	5000	5250	5500	6000	6500	7000	7500	8000	9000	10000	11000
29000																	
27000																	
25000																	
23000																	
21000																	
19000																	
17000																	
15000																	
14000																	
13000																	
12000																	
11000																	
10000																	1.2%
9000																1.7%	3.9%
8000															2.2%	5.5%	8.9%
7500														0.7%	3.9%	7.9%	11.5%
7000													0.8%	1.8%	5.9%	10.4%	14.4%
6500												1.0%	2.1%	3.5%	8.3%	13.4%	17.6%
6000											0.9%	2.3%	3.8%	5.5%	11.2%	17.1%	21.7%
5500										1.3%	2.7%	4.6%	6.7%	8.9%	15.3%	21.5%	25.8%
5250									0.5%	1.8%	3.5%	5.6%	7.9%	10.4%	16.9%	23.1%	27.4%
5000								0.5%	1.0%	2.6%	4.6%	7.0%	9.6%	12.2%	18.9%	25.2%	29.3%
4750							0.6%	1.3%	2.0%	4.0%	6.3%	9.0%	11.8%	14.7%	21.5%	27.6%	31.5%
4500						0.6%	1.2%	2.1%	3.1%	5.5%	8.3%	11.3%	14.6%	17.7%	24.8%	30.8%	34.5%
4250					0.6%	1.1%	1.9%	3.0%	4.1%	6.9%	10.0%	13.4%	16.9%	20.1%	27.3%	33.3%	36.8%
4000				0.7%	1.2%	2.0%	3.0%	4.2%	5.5%	8.8%	12.1%	15.6%	19.2%	22.5%	29.5%	35.3%	38.7%
3750			0.8%	1.1%	2.0%	2.9%	4.1%	5.5%	7.0%	10.5%	14.2%	17.8%	21.6%	25.0%	32.0%	37.5%	40.7%
3500		0.9%	1.6%	2.4%	3.4%	4.5%	6.0%	7.6%	9.3%	13.1%	17.1%	21.0%	24.9%	28.2%	35.0%	40.2%	43.3%
3250	0.9%	1.6%	2.6%	3.6%	4.9%	6.3%	8.0%	9.8%	11.7%	15.9%	20.1%	24.1%	28.0%	31.5%	37.8%	42.7%	45.6%

Percentage of Late-Fall-run Chinook Salmon Redds Dewatered - ACID Dam Boards Out (continued)

Spawning Flow (cfs)

Dewatering flow (cfs)	12000	13000	14000	15000	17000	19000	21000	23000	25000	27000	29000	31000
29000												1.6%
27000											1.4%	4.4%
25000										1.8%	5.2%	9.4%
23000									5.1%	14.5%	25.7%	32.6%
21000								3.1%	9.3%	20.0%	32.1%	39.1%
19000							2.5%	7.1%	14.4%	25.2%	36.9%	43.2%
17000						3.5%	7.0%	13.1%	20.3%	31.1%	42.9%	49.1%
15000					3.3%	6.7%	11.7%	18.8%	26.0%	36.7%	48.2%	54.1%
14000				1.9%	6.4%	9.8%	14.6%	21.1%	28.3%	38.8%	50.1%	55.9%
13000			1.1%	3.4%	8.3%	11.3%	16.2%	22.7%	29.9%	40.3%	51.5%	57.2%
12000		1.2%	3.4%	6.5%	11.7%	14.2%	18.7%	24.5%	31.8%	42.2%	53.3%	58.9%
11000	2.3%	4.1%	6.7%	10.0%	15.2%	17.4%	21.8%	26.9%	34.0%	44.2%	55.1%	60.7%
10000	3.1%	5.6%	8.8%	12.1%	17.0%	19.6%	24.0%	29.8%	36.7%	46.7%	57.4%	62.9%
9000	7.8%	10.5%	13.6%	16.7%	21.5%	23.7%	28.1%	33.2%	40.2%	50.0%	60.5%	65.9%
8000	13.3%	16.0%	18.9%	21.9%	26.3%	28.3%	32.5%	37.6%	44.3%	53.7%	63.7%	69.0%
7500	16.0%	18.4%	21.1%	24.0%	28.3%	30.4%	34.5%	39.6%	46.3%	55.4%	65.2%	70.3%
7000	18.6%	20.7%	23.3%	26.1%	30.3%	32.4%	36.4%	41.6%	48.0%	57.0%	66.6%	71.6%
6500	21.7%	23.8%	26.4%	29.1%	33.1%	35.1%	39.2%	44.5%	50.9%	59.7%	69.1%	74.0%
6000	25.5%	27.5%	29.9%	32.6%	36.4%	38.3%	42.3%	47.7%	54.1%	62.7%	72.1%	77.3%
5500	29.4%	31.2%	33.2%	36.1%	39.7%	41.6%	45.7%	51.2%	57.7%	65.9%	74.9%	80.0%
5250	30.8%	32.5%	34.9%	37.5%	41.1%	42.9%	47.0%	52.6%	58.9%	67.0%	76.0%	81.1%
5000	32.6%	34.3%	36.7%	39.1%	42.6%	44.5%	48.6%	54.2%	60.8%	68.9%	77.3%	82.3%
4750	34.6%	36.3%	38.5%	40.9%	44.2%	46.0%	50.1%	55.3%	62.4%	70.2%	78.4%	83.3%
4500	37.5%	38.9%	41.0%	43.3%	46.5%	48.3%	52.4%	58.1%	64.5%	72.2%	80.2%	85.0%
4250	39.7%	41.1%	43.1%	45.3%	48.4%	50.2%	54.3%	60.2%	66.6%	74.2%	81.7%	86.5%
4000	41.5%	42.8%	44.8%	46.9%	49.9%	51.8%	55.9%	61.8%	68.3%	75.6%	82.9%	87.6%
3750	43.3%	44.6%	46.5%	48.6%	51.5%	53.3%	57.4%	63.3%	69.6%	76.6%	83.9%	88.5%
3500	45.6%	46.8%	48.6%	50.7%	53.6%	55.5%	59.6%	65.4%	71.5%	78.3%	85.4%	90.1%
3250	47.8%	48.9%	50.6%	52.6%	55.5%	57.5%	61.6%	67.3%	73.5%	79.8%	86.6%	91.1%

Percentage of Late-Fall-run Chinook Salmon Redds Dewatered - ACID Dam Boards In

Spawning Flow (cfs)

Dewatering flow (cfs)	3500	3750	4000	4250	4500	4750	5000	5250	5500	6000	6500	7000	7500	8000	9000	10000	11000
29000																	
27000																	
25000																	
23000																	
21000																	
19000																	
17000																	
15000																	
14000																	
13000																	
12000																	
11000																	
10000																	1.0%
9000																1.5%	3.3%
8000															2.0%	4.9%	7.7%
7500														0.7%	3.5%	6.9%	9.9%
7000													0.8%	1.6%	5.2%	9.1%	12.5%
6500												0.9%	1.9%	3.1%	7.4%	11.8%	15.4%
6000											0.9%	2.1%	3.4%	5.0%	10.0%	15.1%	19.0%
5500										1.2%	2.5%	4.3%	6.1%	8.1%	13.7%	19.1%	22.8%
5250									0.5%	1.7%	3.3%	5.2%	7.3%	9.5%	15.3%	20.7%	24.4%
5000								0.6%	1.1%	2.6%	4.4%	6.6%	8.9%	11.3%	17.4%	22.9%	26.7%
4750							0.6%	1.3%	2.1%	3.9%	6.0%	8.5%	11.1%	13.7%	19.9%	25.4%	29.1%
4500						0.6%	1.3%	2.1%	3.1%	5.3%	7.9%	10.7%	13.6%	16.4%	22.9%	28.4%	32.0%
4250					0.7%	1.2%	2.0%	3.0%	4.1%	6.7%	9.6%	12.6%	15.8%	18.7%	25.2%	30.8%	34.2%
4000				0.7%	1.3%	2.0%	3.0%	4.2%	5.4%	8.4%	11.5%	14.7%	17.9%	20.9%	27.3%	32.7%	36.0%
3750			0.8%	1.1%	2.0%	2.9%	4.1%	5.5%	6.9%	10.1%	13.4%	16.7%	20.1%	23.1%	29.5%	34.6%	37.8%
3500		0.9%	1.6%	2.4%	3.4%	4.5%	5.9%	7.4%	9.0%	12.5%	16.1%	19.6%	23.1%	26.1%	32.3%	37.1%	40.1%
3250	0.9%	1.7%	2.6%	3.7%	4.9%	6.2%	7.8%	9.5%	11.3%	15.1%	18.9%	22.5%	26.0%	29.1%	34.9%	39.4%	42.3%

Percentage of Late-Fall-run Chinook Salmon Redds Dewatered - ACID Dam Boards In (continued)

Dewatering flow (cfs)	Spawning Flow (cfs) 12000	13000	14000	15000	17000	19000	21000	23000	25000	27000	29000	31000
29000												1.5%
27000											1.3%	4.0%
25000										1.3%	3.4%	6.4%
23000									1.1%	2.1%	4.3%	7.4%
21000								2.0%	2.7%	3.5%	5.8%	8.4%
19000							1.7%	4.2%	5.1%	5.8%	8.1%	10.5%
17000						2.4%	4.3%	7.5%	7.7%	8.2%	10.6%	13.2%
15000					2.5%	4.2%	6.9%	10.6%	10.3%	10.8%	13.3%	16.0%
14000				1.7%	5.1%	6.7%	9.2%	12.4%	12.1%	12.4%	15.0%	17.7%
13000			0.9%	2.8%	6.5%	7.8%	10.4%	13.7%	13.3%	13.6%	16.3%	19.0%
12000		0.9%	2.7%	5.3%	9.1%	10.0%	12.3%	15.0%	14.7%	14.9%	17.7%	20.5%
11000	2.0%	3.4%	5.4%	8.1%	12.0%	12.6%	16.6%	17.0%	16.7%	17.0%	19.9%	22.6%
10000	2.7%	4.6%	7.0%	9.8%	13.3%	14.3%	16.7%	19.3%	19.0%	19.4%	22.3%	25.1%
9000	6.6%	8.7%	11.1%	13.6%	17.0%	17.7%	20.1%	22.2%	22.1%	22.8%	25.8%	28.7%
8000	11.4%	13.5%	15.7%	18.1%	21.3%	21.8%	24.1%	26.3%	26.2%	27.0%	30.1%	33.1%
7500	13.7%	15.5%	17.6%	20.0%	23.1%	23.8%	26.0%	28.3%	28.4%	29.2%	32.2%	35.2%
7000	16.0%	17.6%	19.6%	21.8%	24.9%	25.5%	27.8%	30.2%	30.2%	31.1%	34.3%	37.1%
6500	18.8%	20.3%	22.3%	24.5%	27.4%	28.1%	30.5%	33.0%	33.3%	34.5%	37.8%	40.8%
6000	22.2%	23.7%	25.6%	27.7%	30.6%	31.3%	33.7%	36.4%	37.0%	38.6%	42.4%	45.9%
5500	25.9%	27.3%	28.9%	31.4%	34.2%	35.1%	37.8%	41.0%	42.1%	43.9%	48.0%	51.9%
5250	27.5%	28.9%	30.9%	33.2%	36.3%	37.3%	40.2%	43.6%	44.8%	46.9%	51.4%	55.5%
5000	29.8%	31.4%	33.5%	35.9%	39.1%	40.5%	43.6%	47.5%	49.3%	51.9%	56.3%	60.6%
4750	32.2%	33.8%	36.0%	38.5%	41.9%	43.5%	46.8%	50.6%	53.2%	55.9%	60.6%	65.1%
4500	34.9%	36.5%	38.6%	41.1%	44.4%	46.1%	49.6%	53.9%	56.3%	59.2%	64.1%	68.7%
4250	37.1%	38.7%	40.8%	43.2%	46.5%	48.3%	51.9%	56.4%	59.0%	62.2%	66.9%	71.5%
4000	38.8%	40.4%	42.4%	44.8%	48.1%	50.0%	53.6%	58.3%	61.1%	64.3%	68.9%	73.5%
3750	40.5%	42.0%	44.0%	46.3%	49.6%	51.5%	55.1%	59.7%	62.6%	65.6%	70.4%	75.1%
3500	42.6%	44.0%	46.0%	48.2%	51.5%	53.5%	57.2%	61.8%	64.6%	67.8%	72.6%	77.3%
3250	44.6%	46.0%	47.9%	50.1%	53.4%	55.4%	59.2%	63.7%	66.8%	69.7%	74.4%	79.1%

Percentage of Winter-run Chinook Salmon Redds Dewatered - ACID Dam Boards Out

Spawning Flow (cfs)

Dewatering flow (cfs)	3500	3750	4000	4250	4500	4750	5000	5250	5500	6000	6500	7000	7500	8000	9000	10000	11000
29000																	
27000																	
25000																	
23000																	
21000																	
19000																	
17000																	
15000																	
14000																	
13000																	
12000																	
11000																	
10000																	0.4%
9000																1.2%	1.8%
8000															0.3%	1.9%	3.2%
7500														0.2%	0.7%	2.6%	4.3%
7000													0.2%	0.4%	1.2%	3.5%	5.6%
6500												0.1%	0.4%	0.8%	2.2%	5.5%	8.4%
6000											0.2%	0.6%	1.1%	1.7%	3.7%	7.7%	10.9%
5500										0.3%	0.8%	1.4%	2.1%	3.0%	5.8%	10.3%	14.1%
5250									0.2%	0.6%	1.1%	1.8%	2.7%	3.8%	7.0%	11.8%	15.7%
5000								0.2%	0.4%	0.9%	1.5%	2.4%	3.5%	4.8%	8.7%	13.8%	17.9%
4750							0.1%	0.3%	0.5%	1.2%	1.9%	2.9%	4.3%	5.8%	10.2%	15.5%	19.8%
4500						0.2%	0.3%	0.6%	0.8%	1.7%	2.6%	3.9%	5.5%	7.5%	12.2%	17.8%	22.3%
4250					0.1%	0.3%	0.5%	0.8%	1.2%	2.2%	3.4%	5.9%	7.0%	9.1%	14.3%	20.3%	25.0%
4000				0.2%	0.4%	0.7%	1.0%	1.4%	2.0%	3.2%	4.7%	7.6%	8.9%	11.3%	16.9%	23.1%	27.9%
3750			0.2%	0.5%	0.8%	1.2%	1.6%	2.1%	2.8%	4.3%	6.1%	8.3%	10.6%	13.1%	18.9%	25.1%	30.0%
3500		0.6%	1.0%	1.4%	2.0%	2.7%	3.4%	4.2%	5.1%	7.2%	9.5%	12.1%	14.7%	17.4%	23.4%	29.5%	34.3%
3250	0.8%	1.5%	2.2%	3.0%	3.9%	4.9%	5.8%	7.0%	8.2%	11.0%	13.8%	16.7%	19.7%	22.6%	28.8%	34.8%	39.4%

Percentage of Winter-run Chinook Salmon Redds Dewatered - ACID Dam Boards Out (continued)

Spawning Flow (cfs)

Dewatering flow (cfs)	12000	13000	14000	15000	17000	19000	21000	23000	25000	27000	29000	31000
29000												0.6%
27000											1.6%	3.6%
25000										-0.6%	8.3%	15.2%
23000									1.4%	6.2%	15.4%	24.6%
21000								1.3%	3.6%	9.2%	18.7%	28.0%
19000							1.4%	4.0%	7.1%	13.0%	22.5%	31.7%
17000						1.3%	3.9%	7.8%	11.8%	18.3%	28.1%	36.9%
15000					0.9%	2.8%	5.9%	10.6%	14.9%	21.8%	31.5%	40.1%
14000				0.4%	1.6%	4.2%	7.5%	11.8%	16.2%	23.0%	32.6%	41.0%
13000			0.4%	1.0%	2.8%	5.3%	8.7%	13.0%	17.5%	24.5%	34.0%	42.3%
12000		0.2%	0.9%	1.8%	4.1%	7.0%	10.5%	14.7%	19.3%	26.3%	35.7%	43.8%
11000	0.6%	1.2%	2.2%	3.5%	6.4%	9.5%	13.2%	17.1%	21.7%	28.5%	37.6%	45.6%
10000	1.3%	2.3%	3.7%	5.3%	8.6%	11.8%	15.4%	19.3%	23.8%	30.6%	39.7%	47.5%
9000	3.0%	4.4%	6.0%	7.8%	11.4%	14.7%	18.3%	22.1%	26.6%	33.6%	41.9%	49.5%
8000	4.9%	6.6%	8.6%	10.5%	14.3%	17.7%	21.2%	25.0%	29.3%	36.1%	44.1%	51.4%
7500	6.3%	8.1%	10.2%	12.4%	16.3%	19.7%	23.0%	26.7%	31.0%	37.6%	45.3%	52.5%
7000	7.9%	10.1%	12.4%	14.8%	19.0%	22.3%	25.6%	29.2%	33.3%	39.7%	47.2%	54.1%
6500	11.2%	13.6%	16.2%	18.8%	23.1%	26.2%	29.3%	32.7%	36.5%	42.6%	49.7%	56.4%
6000	14.0%	16.7%	19.4%	22.0%	26.4%	29.6%	32.6%	35.9%	39.6%	45.4%	52.2%	58.5%
5500	17.6%	20.6%	23.5%	26.2%	30.7%	33.9%	36.8%	40.1%	43.5%	49.0%	55.5%	61.5%
5250	19.4%	22.4%	25.4%	28.2%	32.7%	35.8%	38.6%	41.9%	45.2%	50.7%	57.0%	62.8%
5000	21.6%	24.7%	27.7%	30.4%	34.8%	37.9%	40.6%	43.8%	44.1%	52.3%	58.4%	64.1%
4750	23.7%	26.9%	29.9%	32.7%	37.0%	40.0%	42.7%	45.9%	48.8%	54.0%	59.9%	65.4%
4500	26.3%	29.6%	32.6%	35.3%	39.6%	42.5%	45.1%	48.2%	51.0%	56.0%	61.7%	66.9%
4250	29.1%	32.5%	35.5%	38.2%	42.4%	45.3%	47.8%	50.8%	53.4%	58.3%	63.8%	68.8%
4000	32.1%	35.5%	38.6%	41.2%	45.4%	48.2%	50.7%	53.6%	56.1%	60.8%	66.1%	70.8%
3750	34.1%	37.5%	40.6%	43.2%	47.2%	50.0%	52.5%	55.4%	57.7%	62.3%	67.4%	72.0%
3500	38.3%	41.5%	44.6%	47.1%	51.0%	53.6%	56.1%	58.8%	61.1%	65.4%	70.2%	74.5%
3250	43.2%	46.2%	49.1%	51.4%	55.0%	57.6%	59.9%	62.6%	64.7%	68.9%	73.3%	77.3%

Percentage of Winter-run Chinook Salmon Redds Dewatered - ACID Dam Boards In

Spawning Flow (cfs)

Dewatering flow (cfs)	3500	3750	4000	4250	4500	4750	5000	5250	5500	6000	6500	7000	7500	8000	9000	10000	11000
29000																	
27000																	
25000																	
23000																	
21000																	
19000																	
17000																	
15000																	
14000																	
13000																	
12000																	
11000																	
10000																	0.9%
9000																1.3%	2.4%
8000															0.4%	2.1%	3.7%
7500														0.3%	0.9%	2.9%	4.8%
7000													0.3%	0.5%	1.4%	3.8%	6.1%
6500												0.2%	0.5%	1.0%	2.4%	5.8%	8.8%
6000											0.3%	0.7%	1.3%	1.9%	4.0%	8.0%	11.3%
5500										0.4%	0.9%	1.5%	2.3%	3.2%	6.1%	10.5%	14.3%
5250									0.3%	0.7%	1.2%	1.9%	2.9%	3.9%	7.3%	11.9%	15.9%
5000								0.3%	0.5%	1.0%	1.6%	2.5%	3.7%	5.0%	9.0%	14.0%	18.1%
4750							0.2%	0.4%	0.7%	1.3%	2.1%	3.1%	4.5%	6.1%	10.5%	15.7%	20.0%
4500						0.3%	0.5%	0.8%	1.1%	1.9%	2.9%	4.3%	5.9%	7.9%	12.6%	18.1%	22.4%
4250					0.3%	0.5%	0.8%	1.1%	1.5%	2.6%	3.9%	5.6%	7.6%	9.7%	15.0%	20.7%	25.2%
4000				0.4%	0.7%	1.1%	1.4%	1.9%	2.5%	3.8%	5.4%	7.5%	9.8%	12.2%	17.7%	23.7%	28.3%
3750			0.4%	0.8%	1.2%	1.7%	2.2%	2.8%	3.5%	5.1%	7.0%	9.3%	11.7%	14.2%	19.9%	25.9%	30.5%
3500		0.9%	1.4%	2.0%	2.7%	3.6%	4.4%	5.3%	6.3%	8.5%	11.0%	13.6%	16.2%	18.9%	24.7%	30.4%	34.8%
3250	1.2%	2.2%	3.1%	4.1%	5.2%	6.4%	7.5%	8.8%	10.2%	13.0%	16.0%	18.9%	21.9%	24.7%	30.5%	35.9%	40.1%

Percentage of Winter-run Chinook Salmon Redds Dewatered - ACID Dam Boards In (continued)

Dewatering flow (cfs)	12000	13000	14000	15000	17000	19000	21000	23000	25000	27000	29000	31000
	Spawning Flow (cfs)											
29000												0.3%
27000											0.3%	0.7%
25000										0.3%	0.9%	1.6%
23000									0.4%	0.6%	1.1%	1.9%
21000								0.9%	1.6%	2.1%	3.0%	4.0%
19000							1.0%	2.5%	3.6%	4.4%	5.5%	6.6%
17000						0.9%	2.5%	4.9%	6.5%	7.7%	9.1%	10.4%
15000					0.7%	2.1%	3.9%	6.8%	8.6%	10.1%	11.6%	13.0%
14000				0.5%	1.7%	3.5%	5.5%	8.2%	10.1%	11.7%	13.4%	14.9%
13000			0.5%	1.1%	2.6%	4.4%	6.7%	9.6%	11.7%	13.5%	15.3%	17.0%
12000		0.5%	1.2%	2.2%	4.2%	6.4%	9.1%	12.1%	14.6%	16.8%	19.1%	21.1%
11000	1.1%	2.0%	3.1%	4.6%	7.6%	10.5%	13.8%	17.4%	20.6%	23.5%	26.7%	29.4%
10000	2.2%	3.6%	5.2%	7.0%	10.5%	14.0%	17.7%	18.6%	25.4%	28.9%	32.6%	35.8%
9000	4.0%	5.6%	7.4%	9.4%	13.3%	16.9%	20.8%	24.9%	28.7%	32.8%	36.3%	39.6%
8000	5.7%	7.6%	9.7%	11.8%	15.9%	19.6%	23.5%	27.7%	31.6%	35.7%	39.1%	42.4%
7500	7.0%	9.0%	11.2%	13.5%	17.7%	21.4%	25.2%	29.3%	33.2%	37.2%	40.7%	44.0%
7000	8.7%	10.9%	13.3%	15.7%	20.1%	23.7%	27.5%	31.5%	35.4%	39.4%	42.9%	46.2%
6500	11.8%	14.3%	16.8%	19.3%	23.7%	27.2%	30.7%	34.7%	38.4%	42.3%	45.9%	49.3%
6000	14.5%	17.1%	19.8%	22.3%	26.8%	30.2%	33.7%	37.5%	41.3%	45.2%	48.8%	52.2%
5500	17.9%	20.7%	23.5%	26.1%	30.5%	33.9%	37.4%	41.2%	44.8%	48.7%	52.4%	55.8%
5250	19.5%	22.5%	25.2%	27.9%	32.2%	35.6%	39.0%	42.8%	46.4%	50.3%	54.1%	57.5%
5000	21.7%	24.6%	27.4%	29.9%	34.2%	37.4%	40.8%	44.6%	48.0%	51.9%	55.7%	59.1%
4750	23.7%	26.7%	29.5%	32.1%	36.3%	39.5%	42.8%	46.6%	49.9%	53.9%	57.6%	61.1%
4500	26.3%	29.3%	32.0%	34.6%	38.6%	41.7%	45.0%	48.7%	52.0%	56.0%	59.8%	63.2%
4250	29.2%	32.2%	34.9%	37.4%	41.4%	44.4%	47.5%	51.2%	54.4%	58.5%	62.3%	65.7%
4000	32.2%	35.3%	38.0%	40.4%	44.2%	47.2%	50.3%	53.9%	57.0%	61.1%	65.0%	68.5%
3750	34.4%	37.3%	40.0%	42.4%	46.1%	49.0%	52.1%	55.7%	58.8%	62.8%	66.7%	70.2%
3500	38.5%	41.1%	43.9%	46.1%	49.6%	52.3%	55.3%	58.8%	61.9%	65.9%	69.9%	73.5%
3250	43.4%	46.0%	48.4%	50.3%	53.5%	56.0%	58.9%	62.4%	65.4%	69.5%	73.7%	77.2%

Percentage of Steelhead Redds Dewatered - ACID Dam Boards Out

Dewatering flow (cfs)	Spawning Flow (cfs)																
	3500	3750	4000	4250	4500	4750	5000	5250	5500	6000	6500	7000	7500	8000	9000	10000	11000
29000																	
27000																	
25000																	
23000																	
21000																	
19000																	
17000																	
15000																	
14000																	
13000																	
12000																	
11000																	
10000																	1.9%
9000																2.6%	5.3%
8000															2.8%	6.7%	10.9%
7500														0.7%	3.8%	8.1%	12.7%
7000													0.5%	1.3%	4.8%	9.4%	14.3%
6500												2.8%	1.3%	2.6%	6.9%	12.1%	17.2%
6000											1.3%	2.7%	3.8%	5.3%	10.2%	15.9%	21.2%
5500										1.5%	3.2%	5.0%	6.1%	7.8%	13.0%	19.1%	24.6%
5250									0.8%	2.4%	4.2%	6.2%	7.7%	9.4%	14.9%	21.1%	26.8%
5000								1.1%	1.8%	3.7%	5.8%	8.0%	9.7%	11.8%	17.7%	23.8%	26.6%
4750							0.8%	2.0%	2.8%	5.1%	7.4%	9.7%	11.6%	13.8%	19.8%	25.8%	31.4%
4500						1.1%	1.9%	3.3%	4.5%	7.1%	9.6%	12.0%	14.0%	16.3%	22.4%	28.5%	34.2%
4250					1.1%	2.2%	3.2%	4.8%	6.2%	9.3%	12.0%	14.6%	16.7%	19.1%	25.3%	31.5%	37.3%
4000				0.8%	1.9%	2.9%	4.0%	5.7%	7.3%	10.5%	13.4%	16.0%	18.2%	20.8%	27.1%	33.5%	39.5%
3750			0.5%	1.2%	2.5%	3.8%	5.3%	7.3%	9.1%	12.7%	15.9%	18.9%	21.2%	23.9%	30.3%	36.5%	42.4%
3500		1.6%	2.4%	3.2%	4.7%	6.4%	8.0%	10.2%	12.4%	16.5%	19.9%	22.8%	25.1%	27.7%	33.8%	40.1%	46.2%
3250	1.2%	2.6%	3.7%	4.9%	6.8%	8.9%	10.9%	13.3%	15.7%	19.9%	23.4%	26.2%	28.5%	31.1%	37.2%	43.5%	49.8%

Percentage of Steelhead Redds Dewatered - ACID Dam Boards Out (continued)

	12000	13000	14000	15000	17000	19000	21000	23000	25000	27000	29000	31000
Dewatering flow (cfs)	Spawning Flow (cfs)											
29000												5.1%
27000											3.9%	9.2%
25000										4.0%	9.3%	14.6%
23000									13.5%	20.5%	26.9%	31.2%
21000								6.8%	20.0%	29.2%	36.3%	39.9%
19000							7.3%	13.3%	26.4%	35.7%	43.1%	46.6%
17000						4.8%	13.4%	20.8%	34.1%	42.5%	49.7%	53.0%
15000					5.0%	10.9%	20.7%	29.5%	42.1%	49.3%	55.8%	58.8%
14000				3.0%	9.5%	15.6%	25.1%	32.3%	44.5%	51.7%	58.3%	61.5%
13000			5.4%	5.4%	12.7%	19.7%	29.1%	36.4%	48.0%	54.6%	61.2%	64.1%
12000		3.1%	6.3%	10.4%	18.9%	25.1%	33.9%	38.9%	50.3%	56.5%	63.0%	65.7%
11000	2.8%	6.8%	10.9%	15.7%	24.3%	29.5%	37.4%	42.0%	52.8%	58.7%	65.1%	67.7%
10000	4.6%	8.9%	13.4%	18.9%	27.7%	33.7%	41.4%	45.6%	55.7%	61.7%	68.3%	70.8%
9000	9.6%	14.5%	19.7%	25.7%	35.2%	40.4%	47.2%	50.7%	60.2%	65.3%	71.1%	73.5%
8000	16.3%	22.0%	27.7%	33.4%	42.1%	46.4%	52.7%	55.9%	64.6%	69.5%	75.0%	77.2%
7500	18.2%	24.1%	30.0%	35.8%	44.4%	48.2%	54.1%	57.3%	66.2%	71.1%	76.0%	78.2%
7000	19.9%	25.7%	31.6%	37.5%	46.2%	50.2%	56.0%	59.1%	67.5%	72.2%	77.3%	79.4%
6500	22.9%	28.7%	34.5%	40.4%	48.6%	52.6%	58.2%	61.0%	69.2%	74.0%	79.2%	81.4%
6000	26.6%	32.3%	38.4%	44.7%	53.8%	58.8%	64.6%	67.7%	74.9%	79.2%	84.3%	86.8%
5500	30.1%	36.0%	42.2%	48.8%	58.2%	63.6%	69.2%	71.9%	78.2%	82.1%	87.2%	89.9%
5250	32.6%	38.7%	45.2%	51.9%	61.3%	66.1%	70.8%	73.2%	79.3%	82.9%	88.1%	90.8%
5000	35.4%	41.7%	48.2%	55.0%	64.1%	68.2%	72.8%	75.2%	82.1%	85.0%	88.8%	91.6%
4750	37.3%	43.7%	50.2%	57.0%	66.1%	70.1%	74.6%	77.0%	83.1%	85.5%	89.2%	91.9%
4500	40.3%	46.9%	53.7%	60.5%	69.4%	73.1%	77.4%	79.4%	84.3%	86.3%	89.7%	92.2%
4250	43.6%	50.3%	57.3%	64.1%	72.3%	75.6%	79.8%	82.0%	86.8%	88.3%	91.0%	93.3%
4000	46.0%	52.9%	60.0%	66.8%	74.9%	78.2%	82.1%	84.1%	88.1%	89.4%	91.6%	93.7%
3750	49.0%	55.9%	63.0%	69.7%	77.8%	80.9%	84.3%	85.9%	88.9%	89.7%	91.7%	93.8%
3500	52.9%	60.0%	67.1%	73.6%	81.4%	84.0%	86.4%	87.4%	89.9%	90.5%	92.3%	94.0%
3250	56.6%	63.7%	70.7%	76.8%	84.2%	86.5%	88.5%	89.1%	91.0%	91.3%	93.1%	94.7%

Percentage of Steelhead Redds Dewatered - ACID Dam Boards In

Dewatering flow (cfs)	3500	3750	4000	4250	4500	4750	5000	5250	5500	6000	6500	7000	7500	8000	9000	10000	11000
							Spawning Flow (cfs)										
29000																	
27000																	
25000																	
23000																	
21000																	
19000																	
17000																	
15000																	
14000																	
13000																	
12000																	
11000																	
10000																	1.6%
9000																2.2%	4.4%
8000															3.0%	5.9%	9.2%
7500														0.7%	4.0%	7.3%	10.8%
7000													0.5%	1.3%	4.9%	8.4%	12.2%
6500												2.7%	1.4%	2.5%	6.9%	10.8%	14.8%
6000											1.3%	2.7%	3.8%	5.1%	9.9%	14.3%	18.3%
5500										1.5%	3.2%	4.8%	6.2%	7.7%	12.8%	17.5%	21.6%
5250									1.1%	2.6%	4.6%	6.5%	8.0%	9.6%	15.0%	19.7%	24.0%
5000								1.7%	2.4%	4.4%	6.5%	8.8%	10.6%	12.6%	18.3%	23.1%	27.5%
4750							1.5%	2.9%	3.8%	6.2%	8.5%	11.0%	12.9%	15.1%	20.9%	25.7%	30.0%
4500						1.4%	2.7%	4.2%	5.5%	8.2%	10.8%	13.3%	15.4%	17.6%	23.6%	28.4%	32.7%
4250					1.3%	2.6%	4.0%	5.8%	7.2%	10.3%	13.2%	15.9%	18.1%	20.5%	26.5%	31.3%	35.7%
4000				0.9%	2.1%	3.3%	4.7%	6.7%	8.3%	11.6%	14.6%	17.4%	19.7%	22.2%	28.3%	33.3%	37.8%
3750			0.6%	1.3%	2.6%	4.1%	5.9%	8.1%	10.0%	13.6%	17.0%	20.0%	22.5%	25.1%	31.2%	35.9%	40.3%
3500		1.4%	2.2%	3.2%	4.6%	6.4%	8.4%	10.8%	13.0%	17.1%	20.6%	23.7%	26.1%	28.6%	34.5%	39.2%	43.5%
3250	1.1%	2.3%	3.3%	4.7%	6.5%	8.7%	11.0%	13.6%	16.0%	20.3%	23.9%	26.9%	29.3%	31.8%	37.6%	42.3%	46.7%

Percentage of Steelhead Redds Dewatered - ACID Dam Boards In (continued)

	Spawning Flow (cfs)											
Dewatering flow (cfs)	12000	13000	14000	15000	17000	19000	21000	23000	25000	27000	29000	31000
29000												2.2%
27000											1.8%	3.8%
25000										1.7%	3.4%	5.4%
23000									0.9%	2.2%	3.8%	5.7%
21000								1.4%	1.8%	2.9%	4.4%	6.3%
19000							3.0%	3.7%	3.8%	5.1%	6.7%	8.4%
17000						1.9%	5.1%	5.8%	5.6%	6.8%	8.3%	10.0%
15000					2.6%	4.2%	7.2%	7.9%	7.4%	8.3%	9.4%	10.9%
14000				2.1%	5.1%	6.6%	9.1%	9.0%	8.3%	9.2%	10.3%	11.9%
13000			3.7%	3.6%	6.8%	8.3%	10.7%	10.5%	9.6%	10.3%	11.3%	12.7%
12000		2.2%	4.3%	6.7%	10.1%	10.9%	12.9%	11.4%	10.4%	10.9%	11.9%	13.2%
11000	2.3%	5.0%	7.5%	10.1%	13.1%	13.1%	14.5%	12.8%	11.5%	11.9%	12.8%	14.1%
10000	3.6%	6.6%	9.2%	12.1%	15.1%	15.3%	16.4%	14.5%	12.9%	13.4%	14.3%	15.5%
9000	7.6%	10.8%	13.6%	16.6%	19.4%	18.7%	19.3%	16.8%	15.2%	15.4%	15.9%	17.0%
8000	13.1%	16.6%	19.5%	21.9%	23.7%	22.2%	22.5%	19.7%	18.0%	18.1%	18.5%	19.5%
7500	14.8%	18.3%	21.2%	23.7%	25.2%	23.5%	23.5%	20.7%	19.1%	19.3%	19.4%	20.4%
7000	16.2%	19.6%	22.5%	24.9%	26.4%	24.7%	24.5%	21.7%	19.9%	20.2%	20.4%	21.4%
6500	18.7%	22.1%	24.8%	27.1%	28.1%	26.2%	25.9%	22.9%	21.2%	21.5%	21.7%	22.8%
6000	21.9%	25.1%	27.8%	30.2%	31.3%	29.7%	29.4%	26.3%	24.3%	24.5%	24.8%	26.0%
5500	25.3%	28.4%	31.1%	33.5%	34.5%	32.8%	32.3%	28.9%	26.8%	27.0%	27.3%	28.8%
5250	27.9%	31.1%	33.8%	36.2%	36.9%	34.8%	33.8%	30.3%	28.2%	28.4%	28.9%	30.4%
5000	31.2%	34.4%	37.2%	39.4%	39.8%	37.2%	36.2%	32.8%	31.1%	31.1%	31.1%	32.8%
4750	33.7%	37.0%	39.7%	41.8%	42.1%	39.4%	38.2%	34.8%	32.9%	32.8%	33.0%	34.8%
4500	36.6%	39.8%	42.6%	44.6%	44.5%	41.5%	40.1%	36.5%	34.2%	34.0%	34.0%	35.8%
4250	39.5%	42.8%	45.5%	47.3%	46.6%	43.2%	41.7%	38.2%	36.0%	35.6%	35.4%	37.1%
4000	41.7%	45.1%	47.7%	49.4%	48.3%	44.8%	43.2%	39.4%	37.0%	36.5%	36.2%	37.8%
3750	44.2%	47.4%	49.9%	51.4%	50.6%	46.3%	44.4%	40.4%	37.6%	37.0%	36.5%	38.1%
3500	47.4%	50.6%	52.9%	54.1%	52.3%	48.1%	45.6%	41.3%	38.2%	37.6%	37.0%	38.5%
3250	50.5%	53.5%	55.6%	56.3%	54.1%	49.5%	46.8%	42.3%	39.1%	38.3%	37.7%	39.2%

APPENDIX F
REVISED SITE SPAWNING HABITAT MODELING RESULTS

Salt Creek Study Site Boards Out WUA (ft^2)

Flow (cfs)	Fall-run	Late-fall-run	Winter-run	Steelhead
3,250	4,612	2,586	1,411	1,228
3,500	4,481	2,439	1,521	1,216
3,750	4,354	2,303	1,581	1,214
4,000	4,196	2,160	1,612	1,200
4,250	4,027	2,031	1,628	1,191
4,500	3,854	1,919	1,627	1,193
4,750	3,699	1,832	1,613	1,196
5,000	3,564	1,764	1,595	1,199
5,250	3,426	1,701	1,567	1,192
5,500	3,286	1,642	1,524	1,185
6,000	3,376	1,049	353	1,222
6,500	2,750	1,428	1,363	1,143
7,000	2,472	1,291	1,230	1,101
7,500	2,251	1,191	1,111	1,007
8,000	2,082	1,134	1,010	910
9,000	1,738	996	863	660
10,000	1,464	868	731	573
11,000	1,255	767	636	532
12,000	1,099	682	557	486
13,000	1,006	637	511	461
14,000	960	623	483	451
15,000	868	594	462	434
17,000	705	522	441	383
19,000	809	640	537	383
21,000	693	588	496	330
23,000	891	802	616	404
25,000	780	733	698	400
27,000	978	937	963	398
29,000	913	878	854	360
31,000	858	830	857	321

Salt Creek Study Site Boards In WUA (ft^2)

Flow (cfs)	Fall-run	Late-fall-run	Winter-run	Steelhead
3,250	4,601	2,489	1,239	1,282
3,500	4,519	2,367	1,338	1,240
3,750	4,412	2,235	1,408	1,234
4,000	4,397	2,178	1,407	1,209
4,250	4,219	2,035	1,454	1,227
4,500	4,110	1,955	1,459	1,241
4,750	3,976	1,876	1,463	1,238
5,000	3,819	1,795	1,449	1,227
5,250	3,648	1,709	1,417	1,221
5,500	3,478	1,623	1,371	1,207
6,000	3,640	1,270	509	1,210
6,500	3,433	1,099	418	1,195
7,000	3,226	960	330	1,190
7,500	2,939	767	250	1,162
8,000	2,214	1,115	955	1,040
9,000	1,832	936	771	789
10,000	1,547	816	640	603
11,000	1,348	734	545	573
12,000	1,225	695	492	558
13,000	1,142	704	499	546
14,000	1,007	643	453	490
15,000	1,422	848	522	801
17,000	1,156	808	569	598
19,000	1,048	823	615	520
21,000	981	834	622	486
23,000	1,134	1,030	936	502
25,000	1,046	977	879	446
27,000	1,083	1,028	1,048	534
29,000	892	853	920	377
31,000	873	842	893	444

Upper Lake Redding Study Site Boards Out WUA (ft^2)

Flow (cfs)	Fall-run	Late-fall-run	Winter-run	Steelhead
3,250	205,573	187,719	144,932	48,196
3,500	199,927	182,105	152,226	46,763
3,750	193,214	175,813	158,530	45,653
4,000	185,327	168,820	164,003	44,769
4,250	177,601	162,053	168,119	44,112
4,500	169,639	155,168	171,384	43,606
4,750	161,428	148,229	173,808	43,207
5,000	150,847	139,932	176,103	42,938
5,250	143,725	133,845	176,545	42,862
5,500	135,913	127,606	176,685	42,851
6,000	119,816	115,290	175,220	42,841
6,500	105,647	104,548	171,934	42,754
7,000	92,469	94,883	167,505	42,399
7,500	80,488	86,220	162,376	41,731
8,000	70,069	78,667	156,030	40,707
9,000	53,400	66,211	142,066	37,820
10,000	41,117	56,837	127,929	33,768
11,000	32,055	49,284	113,868	28,661
12,000	25,698	43,433	100,691	23,241
13,000	20,979	38,886	88,343	17,315
14,000	17,541	35,126	77,460	11,723
15,000	14,686	31,743	67,418	7,114
17,000	11,292	26,571	50,825	1,444
19,000	9,734	22,390	38,509	292
21,000	8,861	18,619	29,738	183
23,000	7,706	14,822	22,993	140
25,000	6,662	11,217	18,263	128
27,000	5,491	8,265	14,643	111
29,000	3,867	5,226	11,637	82
31,000	2,014	2,870	9,404	65

Upper Lake Redding Study Site Boards In WUA (ft^2)

Flow (cfs)	Fall-run	Late-fall-run	Winter-run	Steelhead
3,250	151,666	125,042	39,306	78,678
3,500	164,283	133,532	44,252	76,016
3,750	175,511	140,956	49,198	73,226
4,000	185,553	147,399	54,219	70,263
4,250	193,612	152,431	59,035	67,310
4,500	200,110	156,224	63,948	64,476
4,750	205,260	158,788	68,765	61,837
5,000	208,977	160,318	73,301	59,369
5,250	211,499	160,879	77,568	57,106
5,500	213,158	160,803	81,759	54,973
6,000	213,524	158,325	89,258	51,385
6,500	210,195	153,724	96,090	48,691
7,000	204,420	147,507	101,660	46,720
7,500	196,791	140,417	106,315	45,136
8,000	188,193	132,789	110,043	43,961
9,000	169,240	117,025	114,353	43,002
10,000	149,770	102,490	115,064	42,938
11,000	131,733	89,689	112,457	42,938
12,000	114,806	78,484	108,233	42,948
13,000	100,012	68,991	102,641	42,959
14,000	86,996	60,932	96,197	42,970
15,000	76,361	54,133	89,528	42,981
17,000	59,445	42,884	75,219	42,895
19,000	46,838	34,393	61,287	42,259
21,000	38,035	27,411	48,131	41,030
23,000	32,023	21,690	35,999	39,231
25,000	27,788	16,992	25,127	36,667
27,000	23,995	12,951	15,602	33,068
29,000	21,377	9,331	7,783	29,620
31,000	19,308	6,164	2,929	26,646

Lower Lake Redding Study Site Boards Out WUA (ft^2)

Flow (cfs)	Fall-run	Late-fall-run	Winter-run	Steelhead
3,250	19,287	30,008	22,972	5,732
3,500	18,910	29,598	23,037	5,657
3,750	18,640	29,167	23,069	5,463
4,000	18,490	28,726	23,047	5,269
4,250	18,403	28,273	23,144	4,967
4,500	18,188	27,627	23,144	4,698
4,750	17,940	26,905	23,241	4,579
5,000	17,660	26,064	23,392	4,472
5,250	17,347	25,288	23,608	4,310
5,500	17,164	24,696	23,931	4,202
6,000	16,561	23,327	24,340	4,051
6,500	15,149	21,377	23,952	3,771
7,000	13,565	19,384	23,306	3,491
7,500	12,111	17,574	22,325	3,362
8,000	11,033	16,076	21,313	3,308
9,000	9,719	13,921	19,265	3,125
10,000	8,835	12,510	17,337	3,049
11,000	8,781	12,003	15,699	3,028
12,000	8,200	11,109	14,460	2,855
13,000	8,275	10,850	13,275	2,888
14,000	8,361	10,656	12,316	2,823
15,000	8,361	10,408	11,583	2,715
17,000	9,072	10,408	10,753	2,942
19,000	10,861	11,982	10,658	3,834
21,000	12,553	13,900	10,947	4,881
23,000	14,955	16,776	12,391	6,196
25,000	26,969	29,803	16,098	11,454
27,000	41,451	45,879	25,159	12,833
29,000	48,519	54,176	37,981	12,176
31,000	45,017	50,846	48,745	11,346

Lower Lake Redding Study Site Boards In WUA (ft^2)

Flow (cfs)	Fall-run	Late-fall-run	Winter-run	Steelhead
3,250	31,549	29,232	6,820	16,464
3,500	34,199	31,441	7,876	16,593
3,750	36,516	33,359	8,978	16,572
4,000	38,595	35,040	10,161	16,593
4,250	40,481	36,527	11,303	17,013
4,500	42,270	37,970	12,391	17,229
4,750	43,929	39,296	13,372	17,962
5,000	45,782	40,912	14,330	19,265
5,250	47,592	42,528	15,203	20,224
5,500	49,068	43,821	16,044	20,709
6,000	51,385	45,847	17,595	21,517
6,500	53,012	47,215	18,942	22,034
7,000	54,187	48,174	20,063	22,595
7,500	55,145	48,971	21,032	23,177
8,000	56,104	49,747	21,765	23,769
9,000	56,449	50,060	22,703	24,728
10,000	58,787	52,085	23,963	24,373
11,000	62,386	55,372	26,635	25,547
12,000	64,994	57,193	29,297	25,245
13,000	67,569	58,744	31,064	24,879
14,000	69,788	59,876	32,400	24,254
15,000	71,523	60,522	33,564	23,511
17,000	73,215	59,994	35,320	21,884
19,000	72,579	57,311	36,182	20,429
21,000	69,972	53,077	36,246	19,071
23,000	66,028	47,980	35,600	17,929
25,000	61,373	42,539	34,415	17,046
27,000	56,492	37,281	32,626	16,485
29,000	51,730	32,454	30,288	16,119
31,000	47,161	28,165	27,821	15,828

Bridge Riffle Study Site WUA (ft^2)

Flow (cfs)	Fall-run	Late-fall-run	Winter-run	Steelhead
3,250	3,416	4,525	3,200	1,562
3,500	3,453	4,649	3,267	1,684
3,750	3,069	4,312	2,971	1,647
4,000	3,088	4,353	2,807	1,766
4,250	3,307	4,589	2,851	1,766
4,500	3,794	5,081	3,022	1,961
4,750	4,291	5,539	3,295	2,028
5,000	4,839	6,079	3,314	2,155
5,250	5,182	6,378	3,215	2,402
5,500	5,145	6,352	3,313	2,370
6,000	5,882	6,957	3,575	2,578
6,500	6,499	7,514	4,167	2,653
7,000	6,667	7,646	4,495	2,697
7,500	6,791	7,698	4,736	2,725
8,000	7,153	7,973	5,320	2,660
9,000	6,624	7,406	6,067	2,506
10,000	4,909	6,519	10,446	2,116
11,000	3,987	5,691	9,652	1,823
12,000	3,506	5,193	8,512	1,534
13,000	3,109	4,722	7,385	1,214
14,000	2,971	4,392	6,382	1,018
15,000	2,889	4,101	5,475	985
17,000	2,695	3,617	4,797	881
19,000	2,555	3,095	4,167	908
21,000	2,230	2,644	3,436	905
23,000	2,475	2,659	3,255	901
25,000	2,047	2,178	2,197	787
27,000	2,100	2,106	2,400	622
29,000	448	868	1,687	112
31,000	318	608	1,477	125

Posse Grounds Study Site WUA (ft^2)

Flow (cfs)	Fall-run	Late-fall-run	Winter-run	Steelhead
3,250	32,594	58,647	30,730	8,318
3,500	35,428	64,035	34,016	8,501
3,750	37,949	68,474	37,011	8,491
4,000	40,050	72,094	39,824	8,447
4,250	41,688	74,766	42,367	8,329
4,500	42,701	76,232	44,791	8,286
4,750	43,315	77,137	47,269	8,254
5,000	43,272	76,867	49,489	8,243
5,250	43,207	76,350	51,859	8,297
5,500	42,560	74,960	53,993	8,534
6,000	40,599	71,060	57,839	8,814
6,500	38,046	66,621	60,878	9,019
7,000	35,525	62,742	62,968	9,245
7,500	33,025	59,455	64,563	9,331
8,000	30,557	56,341	65,435	9,266
9,000	26,506	51,234	65,349	9,266
10,000	22,950	46,019	62,860	8,394
11,000	20,052	41,612	59,197	7,305
12,000	17,595	37,496	54,564	6,053
13,000	14,912	33,854	49,607	4,946
14,000	13,005	31,010	45,211	4,148
15,000	11,367	28,413	41,278	3,459
17,000	8,932	23,855	34,307	2,554
19,000	6,950	19,610	27,724	1,681
21,000	5,937	16,227	22,713	1,153
23,000	4,816	12,876	18,597	813
25,000	3,933	9,676	15,300	638
27,000	2,985	6,691	12,628	584
29,000	1,659	3,556	10,215	398
31,000	1,065	2,047	8,340	255

Above Hawes Hole Study Site WUA (ft^2)

Flow (cfs)	Fall-run	Late-fall-run	Winter-run	Steelhead
3,250	75,294	91,651	84,905	22,940
3,500	77,277	93,277	87,168	23,866
3,750	78,839	94,420	89,355	24,340
4,000	79,669	94,894	90,993	24,200
4,250	80,693	95,616	92,879	24,157
4,500	81,371	95,939	94,549	24,243
4,750	81,393	95,659	95,723	24,179
5,000	81,317	95,379	96,575	24,039
5,250	80,682	94,624	96,725	23,985
5,500	80,617	94,312	97,221	24,254
6,000	79,604	93,288	97,189	24,082
6,500	78,354	91,521	96,736	23,726
7,000	75,725	88,817	95,971	22,950
7,500	71,868	85,078	94,926	22,131
8,000	67,192	80,757	93,935	21,463
9,000	58,270	72,848	94,948	20,192
10,000	48,326	63,875	94,646	18,885
11,000	39,331	55,242	89,952	17,495
12,000	32,114	47,693	83,867	15,717
13,000	26,349	41,387	77,192	13,910
14,000	21,311	35,706	70,592	11,968
15,000	17,675	31,101	62,942	9,841
17,000	13,845	26,125	52,391	7,246
19,000	12,061	23,028	44,034	5,367
21,000	11,192	20,900	37,879	4,216
23,000	9,707	18,135	33,473	3,065
25,000	7,841	15,001	29,257	2,247
27,000	6,787	12,846	25,495	1,952
29,000	5,996	11,086	22,330	1,730
31,000	5,171	9,494	19,463	1,474

Powerline Riffle Study Site WUA (ft^2)

Flow (cfs)	Fall-run	Late-fall-run	Winter-run	Steelhead
3,250	47,420	60,414	74,206	10,764
3,500	45,427	58,540	75,402	10,727
3,750	43,649	56,826	76,566	10,650
4,000	41,354	54,617	77,191	10,443
4,250	39,177	52,495	77,557	10,287
4,500	36,591	49,995	77,439	10,057
4,750	34,135	47,625	77,094	9,833
5,000	31,624	45,179	76,361	9,592
5,250	29,146	42,711	75,337	9,357
5,500	26,862	40,449	74,282	9,119
6,000	22,530	36,096	71,308	8,534
6,500	18,974	32,454	67,720	7,827
7,000	16,033	29,307	63,787	6,950
7,500	13,587	26,625	59,649	6,033
8,000	11,610	24,308	55,286	5,103
9,000	8,791	20,698	47,097	3,404
10,000	7,010	18,048	39,748	2,110
11,000	6,004	16,184	33,833	1,414
12,000	5,330	14,621	29,200	1,025
13,000	4,869	13,275	25,332	782
14,000	4,395	11,949	22,164	533
15,000	3,958	10,623	19,276	339
17,000	3,551	8,458	15,031	238
19,000	3,149	6,616	12,068	217
21,000	2,745	5,007	9,726	227
23,000	1,733	3,159	7,904	196
25,000	967	1,751	6,614	143
27,000	637	1,088	5,408	71
29,000	376	713	4,392	25
31,000	266	463	3,537	0.11

Price Riffle Study Site WUA (ft^2)

Flow (cfs)	Fall-run	Late-fall-run	Winter-run	Steelhead
3,250	38,078	63,162	48,110	5,183
3,500	40,298	66,276	52,894	6,260
3,750	40,729	66,384	54,402	7,106
4,000	40,686	65,974	55,727	7,730
4,250	40,082	65,241	57,925	8,254
4,500	39,468	64,703	60,285	8,915
4,750	38,552	63,787	62,731	9,603
5,000	38,024	63,280	65,522	10,253
5,250	37,852	63,140	66,858	10,904
5,500	37,119	62,612	68,183	11,335
6,000	35,050	60,414	69,390	11,971
6,500	33,456	58,701	69,702	12,714
7,000	32,669	57,257	70,500	13,188
7,500	32,712	56,288	69,702	13,081
8,000	32,421	55,210	68,851	12,887
9,000	34,318	54,779	64,972	12,790
10,000	35,869	55,016	65,478	13,565
11,000	33,844	52,085	67,030	13,328
12,000	31,452	49,133	67,558	13,996
13,000	27,206	43,789	66,330	14,341
14,000	25,084	40,686	65,522	14,374
15,000	24,416	38,391	64,390	14,320
17,000	20,806	33,111	58,109	11,626
19,000	15,009	25,547	49,402	8,552
21,000	11,626	20,677	42,323	6,930
23,000	8,788	15,419	33,402	4,831
25,000	6,493	11,928	28,155	3,722
27,000	5,050	9,203	23,597	3,130
29,000	4,727	7,844	20,278	2,938
31,000	4,364	6,767	17,972	2,898

APPENDIX G
REVISED SEGMENT SPAWNING HABITAT MODELING RESULTS

Segment 6 Boards Out WUA (ft^2)

Flow (cfs)	Fall-run	Late-fall-run	Winter-run	Steelhead
3,250	279,956	268,782	372,493	67,290
3,500	272,448	261,253	388,925	65,436
3,750	263,774	252,885	402,996	63,843
4,000	253,776	243,641	415,056	62,510
4,250	244,038	234,676	424,360	61,329
4,500	233,851	225,351	431,541	60,386
4,750	223,342	215,899	437,056	59,758
5,000	209,927	204,667	442,398	59,303
5,250	200,688	196,217	443,784	59,004
5,500	190,763	187,812	444,708	58,850
6,000	170,499	170,393	439,809	58,699
6,500	150,726	155,371	433,948	58,155
7,000	132,377	140,981	422,490	57,329
7,500	115,717	128,082	408,786	56,242
8,000	101,484	116,970	392,377	54,809
9,000	79,126	98,976	356,827	50,758
10,000	62,728	85,662	321,193	45,616
11,000	51,351	75,706	286,447	39,310
12,000	42,696	67,373	254,558	32,430
13,000	36,917	61,455	224,684	25,210
14,000	32,772	56,614	198,570	18,296
15,000	29,176	52,149	174,819	12,521
17,000	25,704	45,751	136,442	5,818
19,000	26,113	42,715	109,349	5,501
21,000	26,971	40,391	90,598	6,581
23,000	28,733	39,528	79,200	8,223
25,000	41,981	50,939	77,130	14,618
27,000	58,462	67,199	89,683	16,277
29,000	65,025	73,542	111,038	15,394
31,000	58,425	66,546	129,813	14,313

Segment 6 Boards In WUA (ft^2)

Flow (cfs)	Fall-run	Late-fall-run	Winter-run	Steelhead
3,250	229,136	191,251	104,203	117,637
3,500	247,661	204,155	117,625	114,496
3,750	264,056	215,391	131,085	111,059
4,000	278,825	225,233	144,731	107,439
4,250	290,741	233,011	157,942	104,371
4,500	300,718	239,302	171,156	101,194
4,750	308,861	243,951	183,920	98,865
5,000	315,465	247,691	195,976	97,430
5,250	320,542	250,242	207,214	95,832
5,500	324,159	251,621	218,183	93,805
6,000	327,630	250,639	236,196	90,417
6,500	325,301	246,486	253,990	87,742
7,000	319,436	239,902	268,517	86,016
7,500	310,948	231,989	280,713	84,760
8,000	300,743	224,054	292,079	83,899
9,000	277,576	204,986	303,219	83,593
10,000	256,327	189,577	307,267	82,855
11,000	238,470	177,870	307,201	84,251
12,000	220,851	166,374	303,648	83,876
13,000	205,842	156,696	295,249	83,428
14,000	192,505	148,170	283,910	82,611
15,000	182,153	140,914	271,951	82,097
17,000	163,256	126,497	244,438	79,760
19,000	146,967	112,883	215,785	77,114
21,000	132,965	99,213	186,998	73,916
23,000	121,006	86,254	159,577	70,348
25,000	110,053	73,820	132,926	66,074
27,000	99,515	62,537	108,407	61,106
29,000	90,279	52,018	85,780	56,262
31,000	82,157	42,909	69,615	52,360

Segment 5 WUA (ft^2)

Flow (cfs)	Fall-run	Late-fall-run	Winter-run	Steelhead
3,250	517,564	493,885	569,220	152,613
3,500	540,135	516,656	596,120	158,337
3,750	557,335	533,387	619,524	160,323
4,000	571,053	546,578	640,059	160,020
4,250	584,449	558,157	661,485	159,272
4,500	594,577	565,434	681,914	160,379
4,750	599,845	568,889	700,715	160,244
5,000	601,840	568,857	715,521	160,132
5,250	600,180	565,753	727,117	161,281
5,500	596,697	560,241	740,184	163,485
6,000	586,295	546,463	759,708	164,954
6,500	571,480	528,443	774,931	164,601
7,000	548,314	507,864	782,849	162,248
7,500	519,331	485,617	786,638	158,970
8,000	487,794	462,776	788,865	155,259
9,000	425,010	419,447	796,884	148,633
10,000	354,260	371,357	804,490	136,687
11,000	294,671	327,119	760,657	123,797
12,000	247,450	288,319	703,857	108,364
13,000	206,321	255,082	642,741	93,326
14,000	173,385	226,835	585,266	79,673
15,000	148,479	202,932	525,439	66,425
17,000	118,445	170,974	438,261	49,667
19,000	100,282	145,888	363,681	36,995
21,000	90,019	126,869	306,694	29,174
23,000	79,041	107,407	265,007	22,222
25,000	64,268	85,667	223,952	17,075
27,000	55,205	69,041	194,105	14,685
29,000	37,679	49,477	163,971	10,416
31,000	30,476	38,755	140,251	8,621

Segment 4 WUA (ft^2)

Flow (cfs)	Fall-run	Late-fall-run	Winter-run	Steelhead
3,250	276,159	594,401	183,474	51,509
3,500	276,892	600,365	192,444	54,868
3,750	272,541	592,640	196,452	57,352
4,000	264,989	580,043	199,377	58,699
4,250	256,007	566,310	203,223	59,887
4,500	245,671	551,697	206,586	61,280
4,750	234,779	535,892	209,738	62,778
5,000	224,963	521,688	212,825	64,099
5,250	216,404	509,143	213,293	65,443
5,500	206,659	495,723	213,698	66,066
6,000	185,983	464,213	211,047	66,231
6,500	169,349	438,456	206,133	66,347
7,000	157,307	416,373	201,431	65,046
7,500	149,546	398,812	194,027	61,738
8,000	142,220	382,482	186,206	58,108
9,000	139,242	363,044	168,104	52,307
10,000	138,499	351,438	157,839	50,630
11,000	128,709	328,374	151,295	47,617
12,000	118,806	306,657	145,137	48,518
13,000	103,602	274,478	137,493	48,847
14,000	95,217	253,174	131,529	48,150
15,000	91,648	235,757	125,499	47,349
17,000	78,673	199,947	109,710	38,321
19,000	58,650	154,704	92,205	28,324
21,000	46,418	123,540	78,074	23,117
23,000	33,983	89,360	61,959	16,237
25,000	24,096	65,796	52,154	12,484
27,000	18,369	49,500	43,508	10,339
29,000	16,483	41,159	37,005	9,570
31,000	14,955	34,776	32,264	9,361