BLACK CANYON BOATER PROGRAM RAMP RATE STUDY

BEAR RIVER HYDROELECTRIC PROJECT, FERC PROJECT NO. 20

FINAL REPORT – FISH STRANDING FOLLOWING BOATER-FLOW RELEASES

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1.0 INTRODUCTION

1.1 OVERVIEW

PacifiCorp engaged Cirrus Ecological Solutions (Cirrus) of Logan, Utah, to implement a fish stranding study plan developed by the Bear River Hydroelectric Project Environmental Coordination Committee (ECC). The purpose of the study was to measure fish stranding during the ramp-down following the release of flows provided for recreational boating on 6.2 miles of the Bear River through the Black Canyon below the Grace Dam in Grace, Idaho. These releases (700–1,200 cfs) are substantially greater than the minimum instream flow requirement (65 cfs) and are provided for whitewater recreation between April 1 and July 15, pursuant to the new operating license from the Federal Energy Regulatory Commission (FERC) granted on December 22, 2003.

The study plan, as designed by Oasis Environmental, Bigfork, Montana and modified in 2008 by the ECC, prescribed monitoring during three Scheduled Ramp Rate Test Flows in 2008, 2009, and 2010. A different ramp-down rate was to be used each year: 0.25 feet per hour (ft/hr) in Year 1, then rates of 0.5 or 1.0 ft/hr in Year 2 and Year 3, respectively. Five study plots of at least 1,000 square feet each were intended to represent areas of high, medium, and low fish stranding potential, with the distribution of plots roughly proportional to the actual amount of each of these classifications along the 6.2 miles. The potential for stranding was determined prior to the first Scheduled Ramp Rate Test Flow in Year 1 by evaluating variables including bank slope, vegetation, substrate composition, and presence of depressions that could hold water that might trap fish.

This report summarizes results from all three years of the study. Previous interim reports offer some additional detail on changes to conditions between years.

1.2 HYPOTHESES TESTED

The study plan called for testing three hypotheses:

- ***Hypothesis 1****: Fish stranding for the respective survey plots in study years 2008, 2009, and 2010 will be similar for the three ramping rates.*

- ***Hypothesis 2****: Fish stranding will not vary over time in a single year within a respective sample plot.*

The third hypothesis was originally articulated as: "The number of fish stranded will not change under different whitewater release flows (800 to 1,500 cfs)." However, there were not enough opportunities to vary flows, so an alternative hypothesis for statistical analysis was developed:

- ***Hypothesis 3****: The number of fish stranded will not vary with the potential stranding hazard.*

2.0 METHODS

This section describes the methods used to map high, medium, and low stranding hazard zones, the locations and sizes of the study plots used, the procedures used to search for stranded fish during and after each boater-flow event, and the statistical tools used for analysis. Some methods were modified slightly after Year 1.

2.1 STRANDING POTENTIAL MAPPING

PacifiCorp provided a series of 188 true-color aerial photographs that were taken July 28, 2006, during typical minimum instream flows through the Black Canyon section. These photos were integrated into 16 mosaics that were laminated for field use.

On April 8, 2008, prior to any releases, Cirrus met with PacifiCorp personnel to visit representative samples of the study area and discuss how to assess the four variables thought most relevant for fish stranding: bank slope, vegetation, substrate composition, and presence of depressions that could hold water that might trap fish. Cirrus personnel then applied these guidelines to map approximately 80 percent of the river banks on April 9 and 10, 2010, delineating the expected varial zones on the laminated maps as having high, medium, or low stranding potential.

On April 14, 2008, PacifiCorp provided a 1,200 cfs Varial Zone Mapping Flow through Black Canyon to enable mapping of the varial zones. During the release Cirrus, used a helicopter to acquire aerial photography of the extent of the varial zone. During the down-ramp following this release, Cirrus and PacifiCorp personnel visited portions of the river to evaluate possible study plot locations. Criteria used for the selection of plots included:

- Size: plots were to be at least 1,000 sq ft along the river bank above base flow and below the high flow river levels.

- Representation: the number of high, medium, and low stranding potential plots were to be distributed according to the relative total sizes of hazard zones.

- Safety: plots were to be safely accessible by monitoring personnel.

- Consistency: plots were preferred near sites being monitored for other purposes, such as macroinvertebrates, substrate, etc.

Cirrus presented the results of the stranding potential mapping to the ECC on April 18, 2008. As a result of discussion on how to improve the potential for detecting stranded fish, several adjustments to the study plan were approved, including:

1. Make plots larger than 1,000 sq ft and, if possible, cover an entire mapped stranding potential polygon; proceed with the original designation of 10 subplots in each plot.

2. Designate at least two high, one medium, and two low stranding potential plots.

3. Plan enough time to complete monitoring each plot during each hour.

4. Survey more than five plots if time allows, but always in the same sequence, noting the start and end times for each polygon to ensure similar levels of effort in future monitoring.

5. Complete plots in Reach 2 immediately below the Grace Dam on the same day as the down-ramp, even if it means working after dark, to preempt any taking of stranded fish by predators.

6. Return to the plots as early as possible the next morning to search again for stranded fish at the minimum flow level; begin with the plots that had not reached minimum flows the previous day (Reaches 3 and 4).

7. Quantify level of search effort by documenting start and end times.

8. Designate high, medium, and low stranding potential in Reach 2 and Reach 4 if possible, as these were more accessible.

9. Move the start of the down-ramp earlier to provide enough time for the river to return to normal flows in the section immediately below the dam on the same day.

2.2 STUDY PLOT DIMENSIONS AND LOCATIONS

The study plots from Year 1 were located again in Years 2 and 3 using GPS coordinates, detailed orthophotos, and the experience of the first year's observers. Boundaries of the subplots were adjusted only slightly.

The distributions and river-bank lengths of the final study plots are shown in Table 1. The width – horizontal distance between water lines at high and minimum flows – and the areal extent differed with each Scheduled Ramp Rate Test Flow, as a result of slightly different flows and minor changes in river boundaries between boater-flow events.

Table 1. Stranding plot distribution and river bank length.

Reach	Plot	River Bank Length (ft)	Stranding Potential
2 (0.25 mile below Grace Dam)	1	317	High
	2	270	Low
	3	317	High
	4	212	Medium
3 (3.4 miles below Grace Dam)	2	182	High
	4	217	High
4 (5.9 miles below Grace Dam)	1	260	Medium
	2	250	Low

The locations of the study plots in Reaches 2, 3 and 4 are shown in Figures 1, 2, and 3, respectively[1]. Two observers monitored the four study plots in Reach 2, each person monitoring two plots on one side of the river. In Year 3, an intern also participated, assisting the primary

[1] For consistency, this study used the same reach designations as in the 6-year Black Canyon Monitoring Study. Reach 1 is a control reach, above Alexander Reservoir at Soda Springs.

observer on river left[2] in holding measuring tapes and recording notes. Searches for stranded fish were carried out by the primary observer as in previous years to maintain a consistent level of effort. Due to the difficulty of access and consequent safety concerns, two observers were used to monitor the two study plots in Reach 3. Only one observer was needed for Reach 4 in Year 1. The faster ramp-down rates in subsequent years, however, were expected to result in more exposed varial zone during the daylight hours. Therefore, two observers were assigned to monitor the plots in Reach 4 in Years 2 and 3 to ensure that the newly exposed varial zone could be searched completely within each hour.

2.3 FISH STRANDING MONITORING

Following the 2008 Year 1 study, some concern was expressed by the ECC regarding the validity of the first study day. Two weeks prior to the first Scheduled Ramp Rate Test Flow, a test flow had been released to enable measuring the high water mark and establishment of the varial zone. The test flow resuspended large quantities of sediment that had not been disturbed for several years. It was possible that the suspended sediment had a detrimental effect on aquatic populations that may have confounded the results of that first study day. Therefore, the first Scheduled Ramp Rate Test Flow in 2009 Year 2 was designed to replicate the first event of 2008, using a ramp-down rate of 0.25 ft/hr at approximately the same time of year. The other three Scheduled Ramp Rate Test Flows in 2009 were conducted at 0.5 ft/hr. All three Scheduled Ramp Rate Test Flows in 2010 Year 3 were at 1.0 ft/hr.

In Year 1, an abnormally low "sag" in river level was discovered below Grace Power Plant from the time water was diverted from the flowline into Black Canyon until flows in the river reached Grace Power Plant almost 2 hours later. To prevent that sag in Years 2 and 3, PacifiCorp scheduled water releases from Soda Dam and Grace Dam operations to fill the 6.2 miles of Black Canyon before diverting water from the Grace flowline into Black Canyon. In essence, Grace Power Plant changes were made 2 hours later than in 2008, the approximate water travel time through Black Canyon. For each of the subsequent Scheduled Ramp Rate Test Flow days, PacifiCorp began releasing the Scheduled Ramp Rate Test Flows from Grace Dam at approximately 09:30 hours, reaching the maximum flow for the release (at least 700 cfs) by 11:00 hours. See Appendix A for an example detailed schedule.

Ramp-down began at Grace Dam at approximately 15:00 hours on study days. Monitoring crews reached each study plot during the maximum flow period in early to mid-afternoon to delineate the high water extent of the varial zone. Fish stranding monitoring commenced at Reach 2 and Reach 3 at 16:00 hours. Since it could take an hour or more for levels to begin to decline downstream following the initiation of ramp-down, monitoring began somewhat later in Reach 4, at 17:00 hours. Where an observer was assigned two study plots to monitor, they began monitoring the downstream plot on the top of the hour and started the next plot upstream at 30 minutes after the top of the hour.

[2] "River right" and "river left" refer to the respective sides of the river when facing downstream.

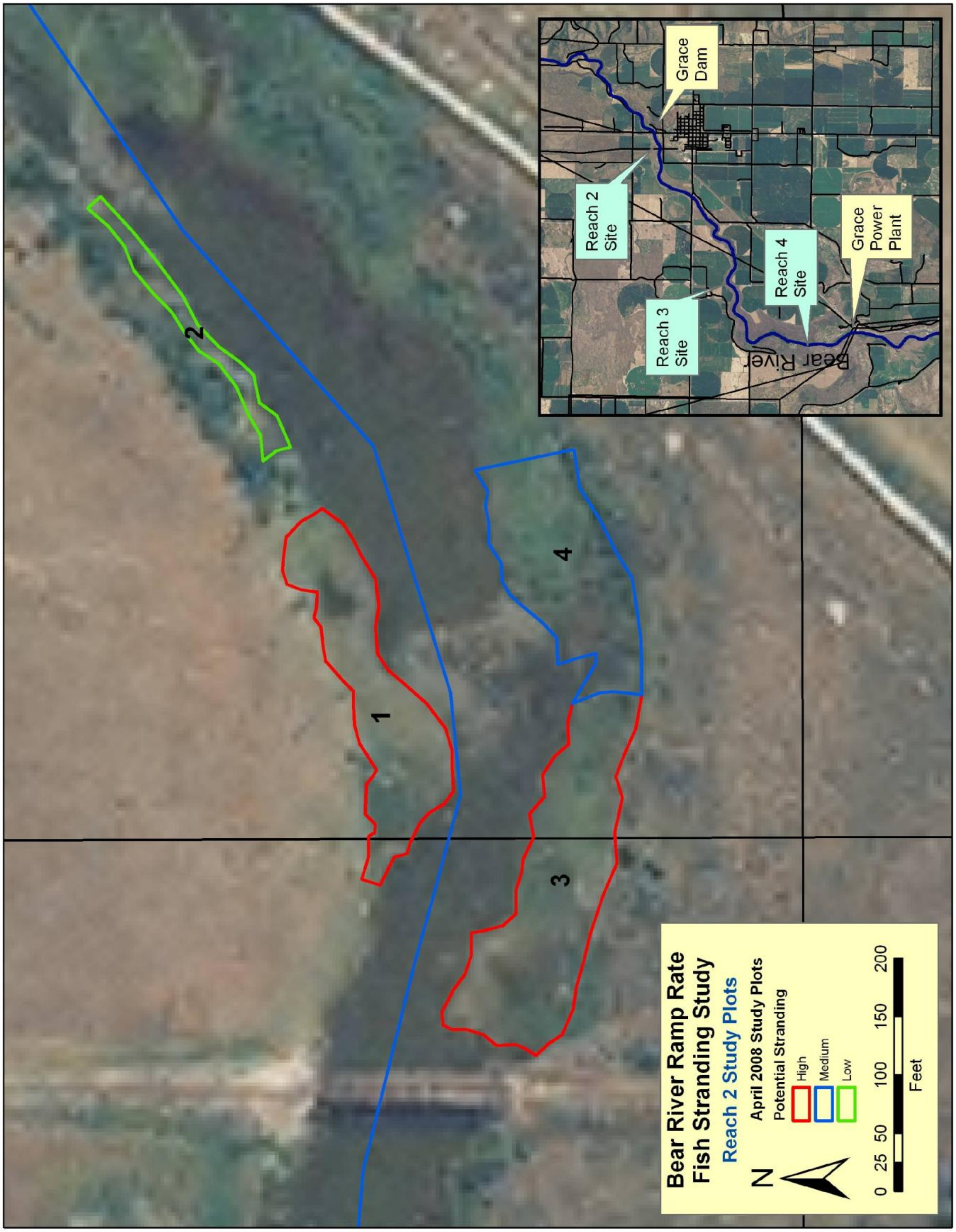

Figure 1. Location of study plots in Reach 2.

Figure 2. Location of study plots in Reach 3.

Figure 3. Location of study plots in Reach 4.

Observers followed the same procedure during each hourly monitoring period, placing stakes at the boundaries between subplots and at the river's edge on a line perpendicular to the direction of flow in the river. They measured the horizontal distance the river had receded from the previous stake to allow calculation of the areal extent of the varial zone. As they placed stakes at the river's edge, observers also searched for fish stranded in thick vegetation or in depressions or pools that had become separated from the main flow. These efforts continued until almost dark, as late as 21:30 hours at Reach 2, 20:00 hours at Reach 3, and 20:30 hours at Reach 4.

In Year 1, the 0.25 ft/hr ramp-down rate was not expected to reach minimum flows anywhere in the studied reaches by dark, so two observers returned to the study plots in the morning after the boater-flow day to search for stranded fish and measure final varial zones. This procedure was followed for the first study day in Year 2 because it, too, was conducted at a 0.25 ft/hr ramp-down rate. The faster 0.5 ft/hr ramp-down rate used for the other three study days in Year 2 was expected to result in minimum flows in Reaches 2 and 3 before dark, so on the second study day of Year 2 (first at 0.5 ft/hr) a crew returned only to monitor Reach 4 the morning following. After assessing the areal extents of varial zones following the first 0.5 ft/hr Scheduled Ramp Rate Test Flow, however, it became apparent that, even at Reach 2, the minimum flows had not quite been reached by dark, so for the balance of the Scheduled Ramp Rate Test Flows in both Years 2 and 3, observers returned to all three reaches the next morning.

Data, including species, size, and subplot location of stranded fish, and the time and horizontal distance the river had receded each hour in each subplot, were recorded electronically in Year 1, and on paper forms in Years 2 and 3.

2.4 STATISTICAL ANALYSIS

The primary hypotheses involved testing three categorical conditions within each of the three primary variables: ramp rate, season, and hazard class. Chi-square analyses were used to determine whether differences among the categories of each variable were significant.

Next, a model was developed to examine the effects of ramp-down rate, season, and hazard class collectively on the number of fish stranded, and to allow for contrasts between conditions affecting stranding. Due to the lack of normality, prevalence of zero cells, correlation among measures, and the count nature of the stranding data, the zero-inflated Poisson distribution was used with generalized estimating equations (GEE) to model the data. Goodness of fit tests indicated a good distributional fit with this model.

The last important question was how many fish might be stranded throughout the entire 6.2 miles of the Black Canyon varial zone following some combination of these variables. The application of this model enabled estimates of minimum and maximum numbers of fish per sq ft in the study plots with a 90 percent confidence interval. Counts and confidence intervals from the various test plots were then extrapolated to the entire varial zone based on the ratio of entire varial zone to areas in the study plots.

3.0 RESULTS

This section describes background conditions during monitoring, the sizes and characteristics of stranding potential zones and study plots, and the stranded fish (including species) found during the Scheduled Ramp Rate Test Flows. It includes a statistical analysis of significance among study variables and an extrapolation to the entire river varial zone.

3.1 WEATHER CONDITIONS

Weather conditions for the scheduled ramp-down rate study days are shown in Table 2.

Table 2. Weather conditions in 24 hours surrounding study periods.[1]

Study Day	Air Temp Min/Max (F)	Wind Speed Min/Max (mph)
4/14/2008	32–57	0–24
4/20/2008	28–33	7–18
6/1/2008	39–73	0–21
7/13/2008	66–77	Calm
4/11/2009	28–48	N/A
4/25/2009	50	13
5/31/2009	41–66	N/A
7/12/2009	50–87	10
4/18/2010	39–65	0–19
5/23/2010	27–47	4–30
7/11/2010	56–83	4–21

[1] Weather in 2008 from station at Soda Springs; in 2009 from Weather Underground (www.wunderground.com) because Soda Springs data incomplete; in 2010 from weather station at Grace, ID provided by: Bureau of Land Management & Boise Interagency Fire Center courtesy of MesoWest data network, http://mesowest.utah.edu.

3.2 FLOWS AND STUDY PLOT CHARACTERISTICS

In addition to Scheduled Ramp Rate Test Flow releases (three in 2008, four in 2009, and three in 2010), Inflow Dependent Boater Flow releases also occurred during which fish-stranding monitoring did not take place. The 5-minute resolution hydrographs for events in 2009 are shown in Figure 4 to illustrate the patterns of flow typical in the river. Note that the April 11th release was at the previous year's ramp-down rate of 0.25 ft/hr. The other ramp-down rates for 2009 were fairly consistent and very close to the target ramp-down rate of 0.5 feet per hour. Table 3 summarizes the dates and maximum flows during the study days.

The slight dips in flows mid-event shown in Figure 4 are minor deviations from balanced water conditions in the Grace forebay. The timing of these deviations coincide with decreasing generation at Grace as water passing through Black Canyon reaches the tailrace of the power plant (2 hours after start of recreational release into Black Canyon). In addition to this change, the upstream flow from Soda plant decreases, so the difference between these two changes causes the fluctuation.

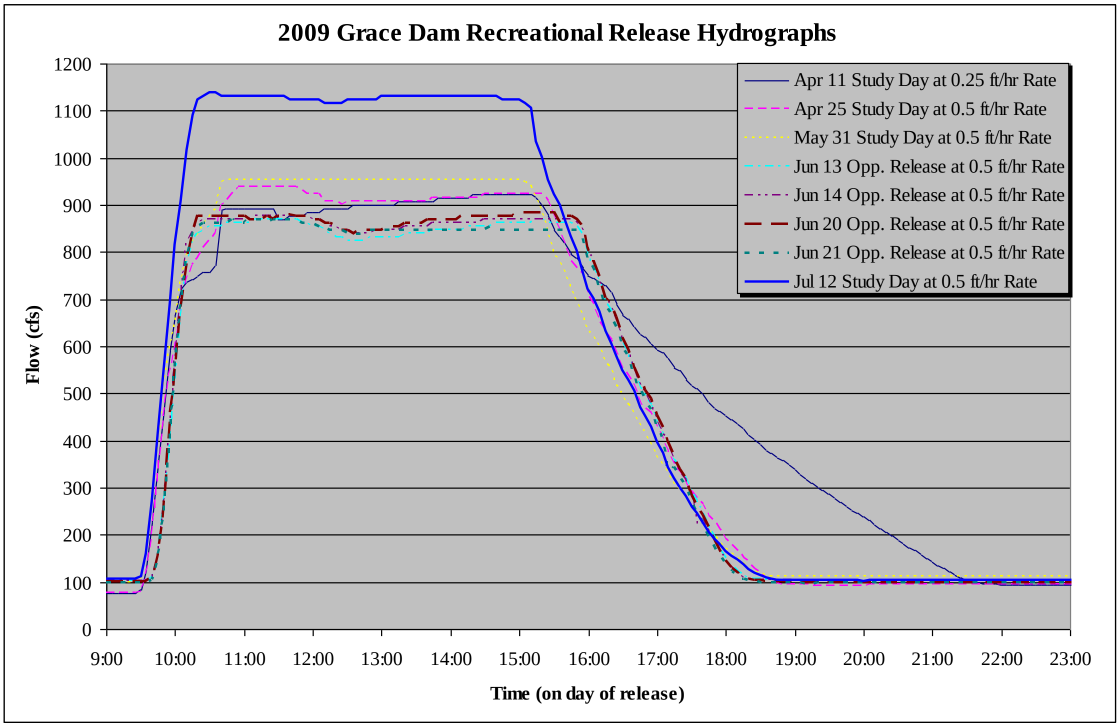

Figure 4. Recreational release hydrographs in 2009 at Grace Dam. The flow-dependent releases that were not monitored for stranded fish are termed "Opportunistic Releases" in the legend.

Table 3. Summary of target down-ramp rate and average flow rate for all recreational releases.

Date	Target Down-Ramp Rate (ft/hr)	Average Event Flow (cfs)
4/14/2008	0.25	1,145
4/20/2008	0.25	933
6/1/2008	0.25	915
7/13/2008	0.25	1,175
4/11/2009	0.25	889
4/25/2009	0.50	898
5/31/2009	0.50	954
7/12/2009	0.50	1,118
4/18/2010	1.00	879
5/23/2010	1.00	900
7/11/2010	1.00	1,100

The areal extents of the study plots are show in Table 4. They differed among study days as a result of differences in flow and channel configurations caused by shifting substrate and vegetation growth during the season.

Table 4. Areal extent (and hazard class assessment) of study plots (sq ft).

Date	Ramp-down rate (ft/hr)	Reach 2				Reach 3		Reach 4	
		Plot 1 - High	Plot 2 - Low	Plot 3 - High	Plot 4 - Medium	Plot 2 - High	Plot 4 - High	Plot 1 - Medium	Plot 2 - Low
4/20/2008	0.25	13,903	1,565	26,943	8,645	6,792	6,531	3,236	2,848
6/1/2008	0.25	16,184	1,647	23,538	6,823	6,787	7,566	3,305	2,968
7/13/2008	0.25	15,712	1,879	20,948	5,344	7,354	8,163	3,314	2,956
4/11/2009	0.25	16,872	1,747	22,840	9,000	6,815	8,200	3,491	3,251
4/25/2009	0.50	17,997	1,744	18,322	7,553	5,869	7,419	3,203	3,197
5/31/2009	0.50	17,070	1,709	21,921	10,958	6,800	7,368	3,153	3,015
7/12/2009	0.50	17,226	2,938	17,966	7,187	6,608	7,612	3,025	2,809
4/18/2010	1.00	16,642	1,626	23,210	6,664	6,542	8,105	3,572	2,839
5/23/2010	1.00	16,852	1,591	20,274	7,261	7,124	8,329	3,556	2,657
7/11/2010	1.00	16,136	1,715	20,111	6,475	6,359	8,233	3,439	3,057
Maximum		16,852	1,715	23,210	7,261	7,124	8,329	3,572	3,057
Minimum		16,136	1,591	20,111	6,475	6,359	8,105	3,439	2,657
Average		16,543	1,644	21,198	6,800	6,675	8,222	3,522	2,851

Vegetation patterns and types also differed among the plots. In Reach 2, the river banks on river right have been denuded of vegetation by heavy livestock grazing. On river left, shrubs and small trees are still growing on the banks, and wetland plants occupy the shallows. Flat areas with small pools are found after down-ramp on both sides, particularly in plots 1 and 3. Exposed areas on river right also include numerous small pockets created by the hooves of livestock.

Reach 3 lies in the bottom of a deep part of the canyon below steep basalt boulder fields. Dense, thick shrubs grow along the river's edge, some of which are inundated during high flows. Several wide, flat areas are exposed at low water with small pools remaining after releases. The two study plots were chosen from an initial survey of five plots in order to monitor these pools in particular. By the July release date, extensive nettle and wetland plants were growing throughout the shallows.

Reach 4 is different from either Reach 2 or 3. The river is wide but constrained by steep banks of basalt boulders, resulting in only small increases in river width during the Scheduled Ramp Rate Test Flows. Thick stands of wetland plants (primarily cattail and nettle) grow along the river's edge and are inundated during high flows. Lowering water levels left silt trapped amongst the cattails, but created only a few small isolated pools.

There are also islands with shrubs and wetland-specific plants in Reaches 2 and 4. These were not surveyed due to the difficulty of safe access.

3.3 FISH STRANDING

3.3.1 HYPOTHESIS 1: RAMP-DOWN RATE

Appendix B provides a comprehensive list of numbers, species, and approximate size of fish found stranded in all years. Table 5 summarizes the number of fish found in the study plots by ramp-down rate, season, and stranding hazard. A chi-square test for homogeneity of proportions showed statistically significant differences in overall stranding across plots with variation in ramp-down rate. Only the 0.25 ft/hr rate was significantly different from the other rates in numbers of fish stranded. Forty-three percent of stranding occurred with a ramp-down rate of 0.25 ft/hr ($\chi^2 = 22.26$, $p < 0.0001$).

Table 5. Number of fish stranded in all study plots by ramp-down rate, season, and stranding hazard.

Hazard and Season	Ramp-down rate (ft/hr)		
	0.25	0.5	1.0
High			
Early Spring		2	2
Late Spring	1		
Summer	211	149	127
Medium			
Late Spring	1		
Summer			3
Low			
Mid-Spring	1		
Total	214	151	132

3.3.2 Hypothesis 2: Season

A chi-square test for homogeneity of proportions showed highly statistically significant differences in overall stranding across years and plots with seasonal variation, with 99 percent of stranding occurring in the summer ($\chi^2 = 953.40$, $p < 0.0001$). Numbers of fish stranded in early and late spring were not significantly different. Within-year (i.e., within ramp-down rate) analysis statistically supported the predominance of stranding in the summer, with 99 percent, 99 percent, and 98 percent of stranding occurring in the summer for years 2008, 2009, and 2010 respectively ($p < 0.0001$). Increased stranding in the summer was also apparent in individual plots for which sufficient stranding was present for within-plot analysis, with proportions stranded in the summer varying from 98 percent to 100 percent for these plots ($p < 0.0001$) for all years.

An exact permutation test for possible association between seasonal stranding variation and ramp-down rate differences yielded borderline significance ($p = 0.10$) with 43 percent of summer stranding occurring at the 0.25 ft/hr ramp-down rate, 30 percent of summer stranding at the 0.5 ft/hr rate, and 27 percent at the 1 ft/hr rate.

3.3.3 Hypothesis 3: Hazard Class

As the data does not meet parametric distributional assumptions, nonparametric methods were also necessary to analyze the possible effect of hazard differences on fish stranding. Overall differences in fish stranding by hazard class were calculated across plots. Possible associations between hazard and seasonal variation and hazard and ramp-down rate in the prevalence of stranding were also examined.

A chi-square test for homogeneity of proportions showed highly statistically significant differences in overall stranding across plots with hazard, with 99 percent of stranding occurring in the high hazard plots ($\chi^2 = 965.22$, $p < 0.0001$).

An exact permutation test for possible association between hazard variation and seasonal differences on stranding indicated a statistically significant association ($p < 0.0001$) with 99 percent of high hazard stranding occurring in the summer. The association between hazard and ramp-down rate was not statistically significant (exact test, $p = 0.15$) with 43 percent, 31 percent, and 26 percent of the high hazard stranding occurring at the 0.25, 0.5, and 1.0 ft/hr ramp-down rates respectively.

3.3.4 Risk of Stranding

Ramp-down rate, season, and hazard all remain highly significant in the combined Poisson model ($p < 0.0001$). Relative risks (i.e., risk ratios) were calculated for the significant effects of slow ramp-down rate (0.25 ft/hr) and the summer season, as compared with the other conditions. The relative risk of stranding of fish at the 0.25 ft/hr ramp-down rate versus other ramp-down rates is 2.39 (95 percent confidence interval: 1.93–2.76), meaning fish have more than twice the risk of stranding at this 0.25 ft/hr rate vs. other rates (assuming equal populations). The relative risk for stranding of fish during the summer season versus other seasons is 85.67 (95 percent confidence interval: 25.78–284.70), implying fish have 86 times the risk of being stranded in the summer season versus other seasons.

3.3.5 Species of Fish Stranding

Table 6 shows species of fish stranded during each of the study days. Details of species and sizes of stranded fish are provided in Appendix B. Nearly all of the stranded fish were common carp, redside shiners, or mottled sculpin, and very small indicating they were recently hatched.

Table 6. Species of fish stranded by season and hazard.

Hazard	Season		
	Early Spring	Late Spring	Summer
Ramp Rate 0.25 ft/hr			
High			
Longnose dace		1	
Redside shiner			211
Medium			
Longnose dace		1	
Low			
Unknown		1	
Total at 0.25 ft/hr		**3**	**211**
Ramp Rate 0.5 ft/hr			
High			
Common carp			82
Mottled sculpin			20
Redside shiner	2		25
Unknown			5
Utah sucker			17
Total at 0.5 ft/hr	**2**		**149**
Ramp Rate 1.0 ft/hr			
High			
Common carp			55
Redside shiner	1		72
Unknown	1		
Medium			
Redside shiner			3
Total at 1.0 ft/hr	**2**		**130**

3.3.6 Extrapolating Fish Stranding to Entire Varial Zone

The areal extent of the entire varial zone in the 6.2 mi of Black Canyon, from Grace Dam to the footbridge above Grace Power Plant was mapped with respect to stranding hazard. The number of fish stranded per sq ft was then calculated (Appendix C) and projected based on areas in the study plots (Table 4). Confidence intervals were extrapolated based on these same ratios.

Table 7 shows mean, minimum, and maximum (90 percent confidence) number of fish that might be stranded on a single day under different combinations of ramp-down rate and season in the entire varial zone. A critical assumption is that stranding on any one day is independent of stranding effects on any other day. Table 8 shows the number of fish that might be stranded for the entire season, assuming stranding on each day is independent, all 16 allowable boater flow days are possible (i.e., sufficient flows are available), and that the boater flow days are distributed evenly across the season, with a slight emphasis on summer events (because 16 flow days cannot be evenly distributed across 3 seasons).

Table 7. Mean, minimum, and maximum number of fish stranded on <u>one day</u> in entire varial zone at different ramp-down rates and seasons (90% confidence interval).

Ramp-down rate		Season		
		Early Spring	Late Spring	Summer
0.25	Mean (Min-Max)	0 (0-0)	139 (0-877)	508 (0-860)
0.50	Mean (Min-Max)	5 (0-5)	0 (0-0)	379 (18-652)
1.00	Mean (Min-Max)	5 (0-10)	0 (0-0)	364 (0-821)

Table 8. Mean, minimum, and maximum number of fish stranded over <u>entire season</u> and in entire varial zone at different ramp-down rates (90% confidence interval).

Ramp-down rate		Season			Total
		Early Spring	Late Spring	Summer	
	Days	5	5	6	
0.25	Mean (Min-Max)	0 (0-0)	695 (0-4,385)	3,048 (0-5,160)	3,743 (0-9,545)
0.50	Mean (Min-Max)	25 (0-25)	0 (0-0)	2,274 (108-3,912)	2,299 (108-3,937)
1.00	Mean (Min-Max)	25 (0-50)	0 (0-0)	2,184 (0-4,926)	2,209 (0-4,976)

4.0 DISCUSSION

The primary conclusions of this study can be summarized as follows:

- Very few fish were found stranded on any of the study days.
- Significantly more stranding occurred at the slowest, 0.25 ft/hr ramp-down rate.
- Nearly all stranded fish were found in summer and in high hazard class plots.
- Most of the stranded fish were common, non-game species (redside shiner and common carp) and recently hatched.

The effect of ramp-down rate is consistent with behavioral science findings that animals adapt to slow changes more readily than fast. The 0.25 ft/hr ramp-down rate was apparently more gradual enough than the other two rates that fish were perhaps caught unawares of their plight and failed to retreat to the river as pools became disconnected from the main flow.

The overwhelming percent of stranded fish were found in July and were very small in size (Appendix B). This is consistent with the life stage of these species. Redside shiners, in particular, probably did not spawn until water temperatures warmed in mid- to late June, and an ideal spawning area exists in the shallows created by a beaver dam just upstream of the Reach 2 study plots. Cutthroat and rainbow trout spawn earlier in the spring, but there is little or no suitable spawning habitat below the dam above Reach 2, consistent with none of these species having been found stranded.

It is still possible, of course, that not all fish that were stranded were detected. This is especially true in Reach 4 where vegetation grows in very thick stands along the edge of the river.

Note that, although the means are lower for the higher ramp-down rates, the maximums do not necessarily follow that pattern. This is because the maximum value within a given confidence interval is a direct result of the variance, which in this case is largely a function of the number of "zero cells" and ** It would be extremely unlikely to actually encounter the numbers at either end of the confidence interval in the model – the wide range reflects the mathematics more than a likely reality.

This analysis does not have the benefit of independent fish population data. Certainly, the stranding results must be viewed within the context of the populations of fish that were actually in the river.

Also unmeasured are the cumulative effects of multiple high flows and changes to river morphology, due to changes in number, depth, and distribution of livestock hoof imprints in Reach 2, connectedness of rivulets through pools and to the mainstem in Reach 3, and the increased sedimentation and vegetation density observed in Reach 4 over the course of the study.

It may be that, if boater flows – and fish mortality – will occur annually, that the management question is more directly addressed by looking at means. In other situations, e.g., where any mortality is critical – because humans are involved or perhaps because the action is affecting the only population of a sensitive species – the maximum possible stranding value might be more relevant. In the case of the Black Canyon boater flows, however, enough of these are anticipated that the measure of central tendency, i.e., the mean, is more relevant when making the decision as to what action to take.

APPENDIX A. EXAMPLE OPERATIONAL SCHEDULES FOR SCHEDULED RAMP-DOWN RATE TEST FLOWS AND INFLOW-DEPENDENT BOATER FLOWS

The tables below are examples of the water release schedules used in 2009, one for a ramp-down rate study day (Table A-1) and one for an Inflow-dependent Boater Flow day (Table A-2). The purpose for the change from the way it was done in 2008 was to keep the flows below Grace power plant stable. In 2008, it was discovered that due to the slower travel time of water through the Black Canyon relative to water passing through the Grace flowline, power generation flow needed to be offset to avoid an initial "sag" in the flows below Grace power plant. Since the Grace forebay has a very small volume, operations at the upstream Soda plant were adjusted to provide the necessary flows.

The main adjustment to the schedule was time-shifting the generation schedule by 2 hours to allow for the travel time of water through Black Canyon while still providing the required ramp-down rate in the Black Canyon. This required changes to the flow releases from Soda to provide "extra" water for the 2 hours that *both* recreational releases into the Black Canyon and power generation flows were being made (10 am through noon). And at the end of the period, flows from Soda were decreased to allow time for the water in the Black Canyon to drain out while the power plant remained off. The approximate two hour travel time from Soda to Grace informed the release schedule from Soda. Releases at Soda were also determined based on the current irrigation flow diverted by the Last Chance Canal Company (denoted LCCC in the tables) and the required ramp-down rate.

After each event, the actual flows were evaluated and the travel times were adjusted to match observed transient flow travel times, typical adjustments were relatively small, 15 to 30 minutes, but improved the result for both PacifiCorp operations and the stability of flows downstream of Grace power plant.

Table A-1. Operational schedule for May 31, study day.

Time	Soda Flow (CFS)	LCCC Irrigation Diversion (CFS)	Grace Bypass River Stage (ft)	Bypass Flow (CFS)	Grace Generation Flow (CFS)	Flow Below Grace (CFS)
7:00 AM	663	200	2.60	70	393	433
7:15 AM	663	200	2.60	70	393	433
7:30 AM	663	200	2.60	70	393	433
7:45 AM	663	200	2.60	70	393	433
8:00 AM	981	200	2.60	70	393	433
8:15 AM	981	200	2.60	70	393	433
8:30 AM	1408	200	2.60	70	393	433
8:45 AM	1408	200	2.60	70	393	433
9:00 AM	1581	200	2.60	70	393	433
9:15 AM	1581	200	3.26	285	393	433
9:30 AM	1652	200	3.65	490	393	433
9:45 AM	1652	200	3.97	695	393	433
10:00 AM	1722	200	4.25	900	428	468
10:15 AM	1722	200	4.25	900	464	504
10:30 AM	1310	200	4.25	900	499	539
10:45 AM	1310	200	4.25	900	534	574
11:00 AM	1200	200	4.25	900	569	609
11:15 AM	1200	200	4.25	900	605	860
11:30 AM	1200	200	4.25	900	640	1100
11:45 AM	1200	200	4.25	900	320	985
12:00 PM	1200	200	4.25	900	100	970
12:15 PM	1200	200	4.25	900	100	970
12:30 PM	1200	200	4.25	900	100	970
12:45 PM	1200	200	4.25	900	100	970
1:00 PM	1200	200	4.25	900	100	970
1:15 PM	1200	200	4.25	900	100	970
1:30 PM	1063	200	4.25	900	100	970
1:45 PM	1063	200	4.25	900	100	970
2:00 PM	892	200	4.25	900	100	970
2:15 PM	892	200	4.25	900	100	970
2:30 PM	739	200	4.25	900	100	970
2:45 PM	739	200	4.25	900	100	970
3:00 PM	608	200	4.25	900	100	970
3:15 PM	608	200	4.25	900	100	970
3:30 PM	501	200	4.12	806	100	970
3:45 PM	501	200	4.00	720	100	970
4:00 PM	421	200	3.87	631	100	970
4:15 PM	421	200	3.75	553	100	970
4:30 PM	429	200	3.62	474	100	970
4:45 PM	429	200	3.50	404	100	970

Table A-1. (cont.) Operational schedule for May 31, study day.						
Time	**Soda Flow (CFS)**	**LCCC Irrigation Diversion (CFS)**	**Grace Bypass River Stage (ft)**	**Bypass Flow (CFS)**	**Grace Generation Flow (CFS)**	**Flow Below Grace (CFS)**
5:00 PM	532	200	3.37	336	100	876
5:15 PM	532	200	3.25	279	100	790
5:30 PM	612	200	3.12	224	100	701
5:45 PM	612	200	3.00	179	100	623
6:00 PM	660	200	2.87	137	100	544
6:15 PM	660	200	2.76	105	100	474
6:30 PM	663	200	2.63	76	127	433
6:45 PM	663	200	2.60	70	184	433
7:00 PM	663	200	2.60	70	239	433
7:15 PM	663	200	2.60	70	284	433
7:30 PM	663	200	2.60	70	326	433
7:45 PM	663	200	2.60	70	358	433
8:00 PM	663	200	2.60	70	387	433
8:15 PM	663	200	2.60	70	393	433
8:30 PM	663	200	2.60	70	393	433

Table A-2. Operational schedule for June 13 and 14th, flow-dependent release days.

Time	Soda Flow (CFS)	LCCC Irrigation Diversion (CFS)	Grace Bypass River Stage (ft)	Bypass Flow (CFS)	Grace Generation Flow (CFS)	Flow Below Grace (CFS)
7:30 AM	955	135	2.60	70	750	790
7:45 AM	955	135	2.60	70	750	790
8:00 AM	1070	135	2.60	70	750	790
8:15 AM	1070	135	2.60	70	750	790
8:30 AM	1522	135	2.60	70	750	790
8:45 AM	1522	135	2.60	70	750	790
9:00 AM	1635	135	2.60	70	750	790
9:15 AM	1635	135	2.60	70	750	790
9:30 AM	1635	135	3.30	300	750	790
9:45 AM	1635	135	3.71	523	750	790
10:00 AM	1635	135	4.04	750	750	790
10:15 AM	1635	135	4.04	750	750	790
10:30 AM	1173	135	4.04	750	750	790
10:45 AM	1173	135	4.04	750	750	790
11:00 AM	1085	135	4.04	750	750	790
11:15 AM	1085	135	4.04	750	750	790
11:30 AM	1085	135	4.04	750	750	1020
11:45 AM	1085	135	4.04	750	375	868
12:00 PM	1085	135	4.04	750	100	820
12:15 PM	1085	135	4.04	750	100	820
12:30 PM	1085	135	4.04	750	100	820
12:45 PM	1085	135	4.04	750	100	820
1:00 PM	1085	135	4.04	750	100	820
1:15 PM	1085	135	4.04	750	100	820
1:30 PM	1025	135	4.04	750	100	820
1:45 PM	1025	135	4.04	750	100	820
2:00 PM	849	135	4.04	750	100	820
2:15 PM	849	135	4.04	750	100	820
2:30 PM	705	135	4.04	750	100	820
2:45 PM	705	135	4.04	750	100	820
3:00 PM	631	135	4.04	750	100	820
3:15 PM	631	135	4.04	750	100	820
3:30 PM	599	135	4.04	750	100	820
3:45 PM	599	135	3.87	631	100	820
4:00 PM	676	135	3.75	553	100	820
4:15 PM	676	135	3.62	474	100	820
4:30 PM	774	135	3.50	404	100	820
4:45 PM	774	135	3.37	336	100	820

Table A-2. (cont.) Operational schedule for June 13 and 14th, flow-dependent release days.

Time	Soda Flow (CFS)	LCCC Irrigation Diversion (CFS)	Grace Bypass River Stage (ft)	Bypass Flow (CFS)	Grace Generation Flow (CFS)	Flow Below Grace (CFS)
5:00 PM	867	135	3.25	279	100	820
5:15 PM	867	135	3.12	224	189	790
5:30 PM	935	135	3.00	179	267	790
5:45 PM	935	135	2.87	137	346	790
6:00 PM	955	135	2.76	105	416	790
6:15 PM	955	135	2.63	76	484	790
6:30 PM	955	135	2.60	70	541	790
6:45 PM	955	135	2.60	70	596	790
7:00 PM	955	135	2.60	70	641	790
7:15 PM	955	135	2.60	70	683	790
7:30 PM	955	135	2.60	70	715	790
7:45 PM	955	135	2.60	70	744	790
8:00 PM	955	135	2.60	70	750	790
8:15 PM	955	135	2.60	70	750	790

APPENDIX B. FISH STRANDING RECORD

Table B-1. Record of fish found stranded after Scheduled Ramp-down Rate Test Flows 2008–2010.

Date	Ramp-down rate	Reach	Plot	Subplot	Species	Number	Size (mm)	Hazard	Notes
6/1/2008	0.25	2	1	3	Longnose dace	1	76	High	2–3 in.
6/1/2008	0.25	4	1	3	Longnose dace	1	76	Medium	Released to river
6/1/2008	0.25	4	2	10	Unknown	1	102	Low	Unknown species; perhaps carp or catfish; could not catch before water too clouded
7/14/2008	0.25	2	1	4	Redside shiner	10	13	High	Approx. count
7/14/2008	0.25	2	1	7	Redside shiner	50	6	High	Approx. count
7/14/2008	0.25	2	3	6	Redside shiner	30	6	High	Approx. count
7/14/2008	0.25	2	3	7	Redside shiner	10	19	High	0.75 inch, approx. count
7/14/2008	0.25	2	3	8	Redside shiner	20	6	High	Approx. count
7/14/2008	0.25	2	3	8	Redside shiner	1	13	High	1 fish
7/14/2008	0.25	2	3	10	Redside shiner	50	13	High	Approx. count
7/14/2008	0.25	2	3	10	Redside shiner	40	6	High	Approx. count
4/25/2009	0.50	2	3	4	Redside shiner	1	19	High	Originally thought leatherside chub; later reviewed and typed as redside shiner; photographed
4/25/2009	0.50	2	3	4	Redside shiner	1	19	High	Photographed, released to river
7/12/2009	0.50	2	1	7	Common carp	1	17	High	Collected 1
7/12/2009	0.50	2	1	7	Common carp	1	19	High	Collected 1
7/12/2009	0.50	2	1	7	Common carp	6	19	High	Released to river
7/12/2009	0.50	2	1	7	Common carp	20	19	High	Not caught
7/12/2009	0.50	2	3	9	Redside shiner	5	25	High	Released to river
7/13/2009	0.50	2	1	2	Unknown	5	19	High	Not caught
7/13/2009	0.50	2	3	2	Common carp	35	12	High	Collected 5; approx. count
7/13/2009	0.50	2	3	2	Common carp	7	19	High	Collected 1; approx. count
7/13/2009	0.50	2	3	3	Common carp	7	14	High	Collected 1; approx. count
7/13/2009	0.50	2	3	3	Redside shiner	7	19	High	Collected 1; approx. count
7/13/2009	0.50	2	3	3	Utah sucker	7	32	High	Collected 1; approx. count

Table B-1. Record of fish found stranded after Scheduled Ramp-down Rate Test Flows 2008–2010.

Date	Ramp-down rate	Reach	Plot	Subplot	Species	Number	Size (mm)	Hazard	Notes
7/13/2009	0.50	2	3	6	Redside shiner	8	18	High	Collected 1
7/13/2009	0.50	2	3	8	Common carp	5	17	High	Collected 1
7/13/2009	0.50	2	3	8	Redside shiner	5	19	High	Collected 1
7/13/2009	0.50	3	4	4	Mottled sculpin	10	9	High	Collected 2
7/13/2009	0.50	3	4	4	Mottled sculpin	10	11	High	Collected 2
7/13/2009	0.50	3	4	4	Utah sucker	3	21	High	Collected 1
7/13/2009	0.50	3	4	4	Utah sucker	3	23	High	Collected 1
7/13/2009	0.50	3	4	4	Utah sucker	4	27	High	Collected 1
4/18/2010	1.00	2	3	3	Unknown	1	76	High	Not caught
4/18/2010	1.00	2	3	4	Redside shiner	1	89	High	Not caught
7/11/2010	1.00	2	1	6	Redside shiner	3	13	High	Collected sample
7/11/2010	1.00	2	1	7	Redside shiner	6	19	High	Collected sample
7/11/2010	1.00	2	3	1	Common carp	1	724	High	Released to river
7/11/2010	1.00	2	3	2	Redside shiner	12	13	High	Collected sample
7/11/2010	1.00	2	3	4	Common carp	4	19	High	Collected sample
7/11/2010	1.00	2	3	4	Redside shiner	16	16	High	Collected sample, 0.5-0.75 in
7/11/2010	1.00	2	3	9	Redside shiner	35	22	High	Collected sample; 0.5-1.25 in
7/11/2010	1.00	2	4	10	Redside shiner	3	13	Medium	Collected sample
7/12/2010	1.00	2	3	8	Common carp	20	19	High	Collected sample
7/12/2010	1.00	3	4	4	Common carp	30	15	High	Collected sample; 0.5-0.75 in

APPENDIX C. FISH STRANDING CALCULATIONS

Table C-1. Number of fish stranded by study plot.

Date	Ramp-down rate	Reach 2				Reach 3		Reach 4	
		Plot 1 - High	Plot 2 - Low	Plot 3 - High	Plot 4 - Medium	Plot 2 - High	Plot 4 - High	Plot 1 - Medium	Plot 2 - Low
4/20/2008	0.25								
6/1/2008	0.25	1						1	1
7/13/2008	0.25	60		151					
4/11/2009	0.25								
4/25/2009	0.50			2					
5/31/2009	0.50								
7/12/2009	0.50	33		86			30		
4/18/2010	1.00			2					
5/23/2010	1.00								
7/11/2010	1.00	9		88	3		30		
Maximum		60	0	151	3	0	30	1	1
Minimum		1	0	2	3	0	30	1	1
Average		26		66	3		30	1	1

Table C-2. Fish stranded per unit area (sq ft).

Date	Ramp-down rate	Reach 2				Reach 3		Reach 4	
		Plot 1 - High	Plot 2 - Low	Plot 3 - High	Plot 4 - Medium	Plot 2 - High	Plot 4 - High	Plot 1 - Medium	Plot 2 - Low
4/20/2008	0.25								
6/1/2008	0.25	0.00006						0.00030	0.00034
7/13/2008	0.25	0.00382		0.00721					
4/11/2009	0.25								
4/25/2009	0.50			0.00011					
5/31/2009	0.50								
7/12/2009	0.50	0.00192		0.00479			0.00394		
4/18/2010	1.00			0.00009					
5/23/2010	1.00								
7/11/2010	1.00	0.00056		0.00438	0.00046		0.00364		
Maximum		0.00356		0.00651	0.00041		0.00360	0.00028	0.00033
Minimum		0.00006		0.00010	0.00046		0.00370	0.00029	0.00038
Average		0.00156		0.00310	0.00044		0.00365	0.00028	0.00035