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Systematic Review of JSATS Passage and Survival Data at Bonneville and The Dalles Dams During Alternative Turbine and Spillbay Operations from 2008–2012

Final Report

December 2016

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CM Woodley
TJ Carlson
B Rayamajhi
J Kim

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
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Richland, Washington 99352

Preface

This analysis was conducted by the Pacific Northwest National Laboratory (PNNL) for the U.S. Army Corps of Engineers (USACE), Portland District (CENWP), using data acquired during Biological Opinion (BiOp) compliance and preliminary studies conducted from 2008 through 2012. The purpose of these studies was to obtain estimates of the dam passage survival of downstream-migrating juvenile salmonids and other metrics. The data collected to meet the needs of the compliance studies include dam operations, environmental conditions, and the behavior and survival rates of yearling Chinook salmon, juvenile steelhead trout (referred to herein as “steelhead”), and fall Chinook salmon (referred to herein as “subyearling Chinook salmon”). These large data sets can be analyzed to answer questions beyond those asked by the compliance studies. Of particular interest are details about how specific dam structural configurations and operations may affect or benefit juvenile salmonids. This report evaluates:

- turbine operations proposed to maximize the survival of juvenile salmonids that pass through the first and second Powerhouses at Bonneville Dam (BON),
- the differential effects of spillbay structural configuration and possible spillbay damage to the survival of juvenile salmonids passing at BON, and
- the impact on survival of juvenile salmonids that pass in spill at The Dalles Dam (TDA) through spillbays outside (southeast) of a new spillwall in the spillway tailrace.

The CENWP technical leads for the study were Mr. Jon Rerecich and Mr. M. Brad Eppard.

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Summary

From 2008 through 2012, 38 dam passage studies were conducted at the four main-stem dams on the lower Columbia River (LCR) to estimate survival rates of yearling Chinook (CH1), subyearling Chinook (CH0), and juvenile steelhead (STH). The primary passage tracking method was the Juvenile Salmon Acoustic Telemetry System (JSATS), which used acoustic micro-transmitters (AMTs). The goal of these studies was to determine if structural configurations and operations of LCR main-stem dams met the dam passage survival criteria detailed in the 2008 Biological Opinion (BiOp). During this period, over 75,000 juvenile salmonids were tagged with AMTs, released, and their detections recorded at downstream receiving arrays. In this report, we used the resultant multi-year, out-migration season of juvenile salmonids species-run data set to address USACE questions on the operation of turbines, and the operation and condition of spillways.

Details are provided within the report, and additional data provided in the Appendices. Generally, BON turbine passage survival rates for CH1, STH, and CH0 are not correlated with turbine discharge volume. The survival rates for juvenile salmonids that passed through BON spillbays with structural issues (i.e., damaged, rock presence in the stilling basin and tailrace) are not different from those for juvenile salmonids that passed through spillbays without structural issues. The survival rate of juvenile salmonids that passed through the outside of TDA's spillwall (spillbays 9–23) are not different from that of juvenile salmonids that passed through within the spillwall (spillbays 1–8).

Bonneville Dam (BON)

The Turbine Survival Program (TSP) of the U.S. Army Corps of Engineers (USACE) goals are to identify the best operations for Bonneville Dam (BON) first (B1) and second (B2) powerhouse turbines for greatest passage survival rates of CH1, STH, and CH0. Using passage survival data through B1 and B2 turbines, turbine passage survival was assessed by turbine discharge, by the presence of turbine intake fish diversion screens (herein referred to as "submerged traveling screens" [STS]), by tailwater elevation, and by tailrace egress time. The following operating ranges of B1 turbines were used in the analyses: lower quarter of 1% peak efficiency range (Q1), lower middle quarter of 1% peak efficiency range (Q2), upper middle quarter of 1% peak efficiency range (Q3), upper quarter of 1% of peak efficiency range (Q4), best operating range (BOR), and above best operating point to generator limit (ABOP). The following operating ranges of B2 turbines were used in the analyses: lower quarter of 1% peak efficiency range (Q1), lower middle quarter of 1% peak efficiency range (Q2), upper middle quarter of 1% peak efficiency range (Q3), and upper quarter of 1% of peak efficiency range (Q4).

Large sample size variations occurred when the data were parsed into quartiles within the 1% of peak efficiency range, thereby reducing the confidence in the utility of detected statistically significant differences in estimates of turbine passage survival rates. Therefore, several analytical methods have been included in this report so that the reader can assess the likelihood of Type I and Type II errors. It should also be noted that the statistical approaches use means, rather than the medians, which are often reported when assessing operations and discharges. High uniformity of turbine passage survival estimates for all juvenile salmonid runs for combined operating ranges (including high discharges above the best operating point for CH1 and STH and larger sample sizes for all combined operating ranges) suggests that the

survival rates for juvenile salmonids passing through B1 turbines are possibly independent of operating ranges. However, the analyses are likely confounded by several externalities and require more complicated approaches than the requested deterministic techniques for this report.

With the above caveat in mind, B1 turbine passage data for CH1, STH, and CH0 runs showed that the largest number of fish passed during turbine operation within the Q4 operating range. This outcome is framed by several intrinsic factors including Q4 as the dominant operating range, elevated river flow due to season, and juvenile salmon run-timing during the multi-year study time period. The turbine passage survival rate for CH1 was non-significantly lower when operating ranges were Q3, best operating range (BOR), or above best operating point (ABOP) compared to Q1 and Q2. Turbine passage survival was significantly lower for CH1 that passed within Q4 than CH1 that passed within Q1 and Q2.

Turbine passage survival rate for STH was significantly lower in Q4, supporting the statement that turbine operations may affect fish passage (i.e., Q1 has higher fish passage survival). STH passing in Q2 and Q3 also had lower survival than fish passing in Q1 but the power of the test was low. No significant differences were detected for survival estimates at other combinations of turbine operations, though survival of STH passing in Q2 and Q3 was lower than STH passing in Q4 through ABOP. No significant differences in turbine passage survival were detected for CH0 at any turbine operation condition, though survival of CH0 in Q1 and Q2 was lower than survival estimates at Q3 and Q4. For each run, there was a trend in lower tailrace egress time with increasing turbine discharge and higher tailwater elevations. Because B1 has its own tailrace channel, the increases in discharge through the B1 generally resulted in higher tailwater elevations and higher flow rates through the tailrace, with some possible influence by ocean tidal effects.

The B2 turbine passage survival rates for all juvenile salmonid runs, CH1, STH, and CH0, were quite uniform over all flow conditions, Q1, Q2, Q3, Q4, Q1 + Q2, and Q3 + Q4. The differences in the sample sizes for survival estimates were less pronounced than for juvenile salmonid B1 turbine passage survival estimates. Contrary to B1 turbine passage survival patterns, for the spring migration period the largest proportion of CH1 and STH passed through turbines when discharges were in the lower half of the 1% of peak efficiency operating range (Q1 and Q2). The opposite was true for the summer migration period when most CH0 passed through flows in the Q4. Tailrace egress times for all juvenile salmonid groups showed a decrease in egress time with increased Powerhouse discharge. The results of this analysis, particularly considering juvenile salmonid survival rates in grouped discharge ranges (Q1 + Q2 and Q3 + Q4), indicate that there is little evidence to support selection of any particular turbine operating range to optimize the rate of turbine passage survival at B2 for any juvenile salmonid run.

Survival rates for juvenile salmonids passing in spill over the last several years have been lower than those through other passage routes at BON. Potential causes for the lower spill passage survival rates include 1) erosion of the stilling basin and the ogees in several spillbays, and/or 2) accumulated rocks in stilling basins and the immediate tailrace region. Data for passage of CH1, STH, and CH0 through the BON spillway acquired from 2008 through 2012 were used to investigate the effect of spill passage on downstream migration of juvenile salmonids and to assess whether fish passing through damaged spillbays had an increased likelihood of mortality.

CH1 and STH passed through the spillbays at either end of the BON spillway more often than through spillbays toward the center of the spillway. CH0 passing through the spillway during the summer did not favor any part of the spillway. Passage survival rates through individual spillbays were not significantly different for any juvenile salmonid run. Likewise, when the BON spillbays were consolidated into five groups based on deflector elevation, spillway damage, and other factors, no significant difference in the rate of spill passage survival was observed for any juvenile salmonid run passing through damaged spillbays compared to other spillbay groups. Both CH1 and STH exhibited a subtle increase in passage survival rate with increased discharge up to 280 kcfs, and then a significant decrease in survival rate at the highest spill discharge (≥ 290 kcfs); whereas the CH0 survival rate noticeably increased with increasing spill. There were no significant differences between estimated survival rates relative to tailwater elevation for CH1 or STH. Given the relationship between higher discharge and high tailwater elevation for the BON spillway, and Powerhouse tailraces, CH0 showed steadily increasing survival rates with increases in tailwater elevation. Declining tailrace egress times were observed for CH1, STH, and CH0 with increasing spillway discharge.

The Dalles Dam (TDA)

In response to high river discharge at The Dalles Dam (TDA) in 2011 and 2012, it was necessary to spill using spillbays outside (southeast) of the new tailrace spillwall, which was designed to contain and direct discharge from spillbays inside (northwest) toward the river thalweg, bypassing shallow areas on the south side of the river that tend to have high piscivorous predator density. Concerns were raised about potential reduction in spillway survival rates for juvenile salmonids passing outside of the spillwall under high spill conditions in flow directed toward the south side of the river because of potential increased predation. Passage route-specific data acquired in 2010, 2011, and 2012 for CH1, STH, and CH0 at TDA spillway were used to investigate whether juvenile salmonids passing through the southeast spillbays (9–23) outside of the spillwall had lower survival rates than those passing through the northwest spillbays (1–8) inside of the spillwall.

The majority of juvenile salmonids, CH1 (92.5%), STH (90.8%), and CH0 (97.3%), passed through spillbays inside the spillwall, leaving a small percentage of juvenile salmonids passing through spillbays outside of the spillwall exposed to potentially higher predation. The distribution of juvenile salmonids passing through spillbays within the spillwall was skewed toward the spillbays nearer the spillwall. The survival rate between 2010 and 2012 for CH1 passing through spillbay 2 was significantly lower than that of spillbay 3, and had the lowest or second lowest survival in all 3 years of studies. STH through spillbay 2 had the second lowest survival rates in 2011 and 2012, but had the second highest survival rate of the eight spillbays in 2010, and spillbay 3 had the lowest survival rate, none of which were significantly different. All other differences in spillway passage survival rates through spillbays 1–8 were not significantly different for CH1, STH, and CH0. No significant difference in spillway passage survival rates was detected for CH1, STH, or CH0 that passed at spillbays inside and outside of the spillwall. A discernable increase in spill passage survival rate with increasing discharge was noted for CH0 passing through spillbays inside the spillwall, where survival estimates for those passing in spill discharge levels ≤ 70 kcfs were significantly lower than for those passing at discharge levels ≥ 90 kcfs. A similar, less distinct, trend in survival rate with increasing discharge was observed for CH1 and STH. The survival rate of CH1 that passed in spill discharge ≤ 72 kcfs (survival = 0.9405) was significantly lower than for CH1 that passed in spill discharge ≥ 168 kcfs (survival = 0.9645). The egress times for all juvenile salmonid groups showed large proportional decreases with increasing discharge.

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- Sonic Concepts (Bothell, WA) produced the autonomous and dam-mounted hydrophones (2008–2012).

- Precision Acoustic Systems (Seattle, WA) made the quad channel receivers and conducted node acceptance tests (2008–2010).

- The Dalles Ironworks (The Dalles, OR) provided the anchors for autonomous nodes and various components required for successful completion of this project (2011 and 2012).
- Cascade Aquatics, Inc. (Ellensburg, WA) activated and delivered acoustic tags (2008–2010).
- Schlosser Machine Shop (Hood River, OR) fabricating anchors for autonomous nodes and frames for star clusters (2008–2010).

Acronyms and Abbreviations

°C	degree(s) Celsius or Centigrade
ABOP	above best operating point to generator limit
AFEP	Anadromous Fish Evaluation Program
AMT	acoustic micro-transmitter
ATS	Advanced Telemetry Systems, Inc.
B1	Bonneville Powerhouse 1
B2	Bonneville Powerhouse 2
BiOp	Biological Opinion
BON	Bonneville Dam
BOP	best operating point
BOR	best operating range
cfs	cubic feet per second
CH0	subyearling Chinook salmon
CH1	yearling Chinook salmon
CRFM	Columbia River Fish Mitigation Program
ERDC	U.S. Army Engineer Research and Development Center
FCRPS	Federal Columbia River Power System
FPP	Fish Passage Plan
ft	feet
h	hour(s)
HDC	Hydroelectric Design Center
JDA	John Day Dam
JSATS	Juvenile Salmon Acoustic Telemetry System
kcfs	thousands of cubic feet per second
kHz	kilohertz
LCR	lower Columbia River
LL	lower limit of 1% of peak efficiency operating range
max	maximum
MCN	McNary Dam
MGR	minimum gap runner
min	minimum
min	minute
mm	millimeter(s)
MN	Minnesota
MSL	mean sea level
N	sample size
NOAA	National Oceanic and Atmospheric Administration
NWP	U.S. Army Corps of Engineers, Portland District
NWW	U.S. Army Corps of Engineers, Walla Walla District
OR	Oregon
PIT	passive integrated transponder
PNNL	Pacific Northwest National Laboratory

Q1	lower quarter of 1% of peak efficiency operating range
Q2	lower middle quarter of 1% of peak efficiency operating range
Q3	upper middle quarter of 1% of peak efficiency operating range
Q4	upper quarter of 1% of peak efficiency operating range
rkm	river kilometer(s)
s	second(s)
SE	standard error
SRWG	Study Review Work Group
STH	juvenile steelhead
STS	submersible traveling screen
TDA	The Dalles Dam
TSP	Turbine Survival Program
UL	upper limit of 1% of peak efficiency operating range
USACE	U.S. Army Corps of Engineers
WA	Washington
yr	year(s)

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1.0 Introduction

The U.S. Army Corps of Engineers (USACE) Turbine Survival Program (TSP) is an element of the Columbia River Fish Mitigation Program (CRFM) and consists of a team of biologists and engineers from the Portland (NWP) and Walla Walla (NWW) Districts, the Hydroelectric Design Center (HDC), the Engineer Research and Development Center (ERDC), and the National Oceanic and Atmospheric Administration–Fisheries (NOAA). The primary objectives of the TSP are to 1) improve the understanding of the turbine passage environment and the impact of that environment on juvenile salmonids, 2) optimize turbine operations for safer fish passage, and 3) improve turbine designs for safer fish passage. The TSP uses physical and numerical hydraulic models and other information to estimate the best operating point (BOP) for turbine units at hydroelectric projects to optimize the survival of juvenile salmonids passing through turbines.

At Bonneville Dam (BON), the TSP developed a set of recommendations that included moving the lower limit of the 1% of peak efficiency operating range (LL) of BON Powerhouse 1 (B1) turbine units from the current LL at 7.3 kcfs to a new LL of 7.5 kcfs, and moving the upper operating limit of the 1% of peak efficiency operating range (UL) from 9.8 kcfs to a new UL at 11.5 kcfs, under the model head condition tested. The new operating range was recommended to improve hydraulic conditions (quality of flow) within the B1 minimum gap runner (MGR) units, provide the largest opening between turbine runner blades, and deliver a high water velocity through the runner; thus, providing safer turbine passage conditions for migrating juvenile salmonids.

Due to increased injury and mortality of juvenile salmonids in the gatewell environment of BON Powerhouse 2 (B2), the B2 turbines have been operated within the lower half of the range within 1% of peak efficiency. This operation reduces turbine intake water velocity, which is better for guided fish. Although, it may create conditions in the turbine environment that decrease the rate of turbine passage survival. In addition, modeling studies have indicated that operation of turbine units at an open geometry configuration (i.e., higher discharge where runner blades are at greater angles and wicket gates and stay vanes are aligned) improves hydraulic conditions in the turbine environment that improve passage survival for fish.

The research, monitoring, and evaluation studies managed under the Anadromous Fish Evaluation Program (AFEP) are coordinated through the Study Review Work Group (SRWG), whose participants include federal, state, and tribal fish agencies, as well as other interested stakeholders throughout the region. The SRWG objectives are often linked to recommendations for Federal Columbia River Power System (FCRPS) improvements to answer biological questions. At BON, the SRWG is concerned that erosion of the stilling basin and ogees (spillway chutes) in several spillbays and the accumulation of rock in the stilling basin could affect spillway survival rates. In addition, at The Dalles Dam (TDA), high river flows in recent years have forced operators to open spillbays outside of a new tailrace spillwall to pass water in excess of that safely passed through the spillbays within the spillwall. The SRWG is concerned that this spill operation may lead to a reduction in the survival rate for fish passing outside of the spillwall under high flow and high spill conditions, due to passage of juvenile salmonids near predatory fish habitat located adjacent to a group of islands downstream of the south side of the spillway.

From 2008 through 2012, the Pacific Northwest National Laboratory (PNNL) conducted 38 survival studies using the Juvenile Salmon Acoustic Telemetry System (JSATS) at the four lower Columbia River (LCR) main-stem dams (specifically, BON, TDA, John Day Dam (JDA), and McNary Dam (MCN)) to determine if fish passage and survival rates were in accordance with requirements of the 2008 Biological Opinion (BiOp) on operation of the FCRPS (NMFS 2008). The 2008 BiOp mandates that dam passage survival rates of 96% and 93% be achieved for spring (for species-run CH1 and STH) and summer (for species-run CH0) downstream-migrating juvenile salmonids, respectively. Since 2008, over 75,000 juvenile salmonids have been surgically implanted with JSATS acoustic micro-transmitters (AMTs) and passive integrated transponders (PITs), and released into the river as part of various BiOp studies. The data acquired in these studies, until now, have been mainly used to evaluate whether the structural configuration and operations at main-stem dams meet BiOp fish passage criteria and other juvenile salmonid dam passage criteria. Although the primary purpose of BiOp studies was to estimate the juvenile salmonid survival rates and passage behavior, additional processing and analysis of these large datasets can be used to answer other relevant fish management questions.

1.1 Study Objectives

The study included objectives to evaluate the survival rates of juvenile salmonids relative to operation levels at BON powerhouses and spillway and the TDA spillway.

1.1.1 Bonneville Dam Powerhouses 1 and 2

Using multi-year datasets, the survival of juvenile salmonids passing through turbines at B1 and B2 were analyzed across the operating ranges fish experienced during passage to identify operating conditions that provide the safest and most efficient passage conditions for juvenile salmonids.

B1 turbine operations analyses included the lower quarter of 1% of the peak efficiency operating range (Q1), lower middle quarter of the 1% of peak efficiency operating range (Q2), upper middle quarter of the 1% of peak efficiency operating range (Q3), upper quarter of the 1% of peak efficiency operating range (Q4), best operating range (BOR, from upper end of peak 1% of peak efficiency to BOP), and above BOP to the generator limit (ABOP). B2 operations analyses included Q1, Q2, Q3, and Q4. The effects of tailrace elevation and egress time on juvenile salmonid survival rates were also evaluated for the above turbine operations listed.

1.1.2 Bonneville Dam Spillway

BON juvenile salmonid spill passage survival data, factored by individual spillbays, groups of spillbays, tailrace elevations, and discharges, were analyzed to determine whether lower passage survival rates could be attributed to regions of the spillway that may have been damaged by erosion or other mechanisms. In addition, the effect of spillway discharge on tailrace egress time was investigated for passage survival rates.

1.1.3 The Dalles Dam Spillway

Juvenile salmonid spillway passage survival rates were estimated for passage through spillbays within the new spillwall at TDA (spillbays 1–8) and compared to survival rates for fish that passed in spill outside of the spillwall (spillbays 9–23) to determine whether high river flows and the resultant use of spillbays outside of the new tailrace spillwall affected survival rates. Survival rates were estimated for juvenile salmonids passing through spillbays 9–12 compared to other estimated spill passage survival rates to determine if fish that passed near the spillwall survived at a rate different from those passing further from the edge of the spillwall ("edge effect"). Spillway discharge and tailrace elevation were investigated for their effects on the survival rates for juvenile salmonids passing through spillbays.

1.2 Study Area Description

1.2.1 Bonneville Dam

BON is located on the Columbia River at river kilometer (rkm) 234 and is the last dam before the Pacific Ocean. BON consists of two powerhouses (B1 and B2), a spillway (18 spillbays), and a navigation lock (Figure 1.1). B1 has 10 turbine units with a sluiceway running along the top of the turbine intakes; normally only three of the sluice gates are open due to channel volume limitations. B2 has 8 turbine units with a surface flow outlet, a modified ice and trash sluiceway, located near the south end of the powerhouse (corner collector). The spillway has 18 spillbays with lift-type gates. At B1, B2, and the spillway, cabled hydrophones were deployed through large diameter pipes attached to spillway pier noses (see Ploskey et al. 2009 for detailed descriptions).

Juvenile salmonids tagged with AMTs and released at various sites between rkm 503 (Port Kelley, WA) and rkm 275 (Hood River, OR) from 2008 through 2012 were pooled to form the dataset used for the BON data analyses (see Section 2.4). All fish detected by JSATS detection arrays at BON were regrouped as a virtual release, and several arrays of autonomous nodes located downstream of BON were used as survival and detection arrays for survival analysis. The locations of downstream arrays varied between years due to differences in study designs, with the most downstream array deployed at rkm 86 (Oak Point, WA).

Table 1.1, Table 1.2, Table 1.3, Table 1.4, Table 1.5, and Table 1.6 show the locations at which fish were released and the locations of the detection arrays used for these analyses. The first two survival array locations below BON (i.e., primary and secondary arrays) varied by year, while the location of the tertiary survival array was always at rkm 86. The primary survival detection array was located 31 rkm downstream of BON in 2008, and 42, 81, 73, and 78 rkm downstream of BON in 2009, 2010, 2011, and 2012, respectively. The secondary array was located at rkm 192 (near Lady Island) in 2008, and at rkm 113 (Kalama, WA) from 2009 through 2012. The tertiary array was not present in 2011, or during spring 2012.

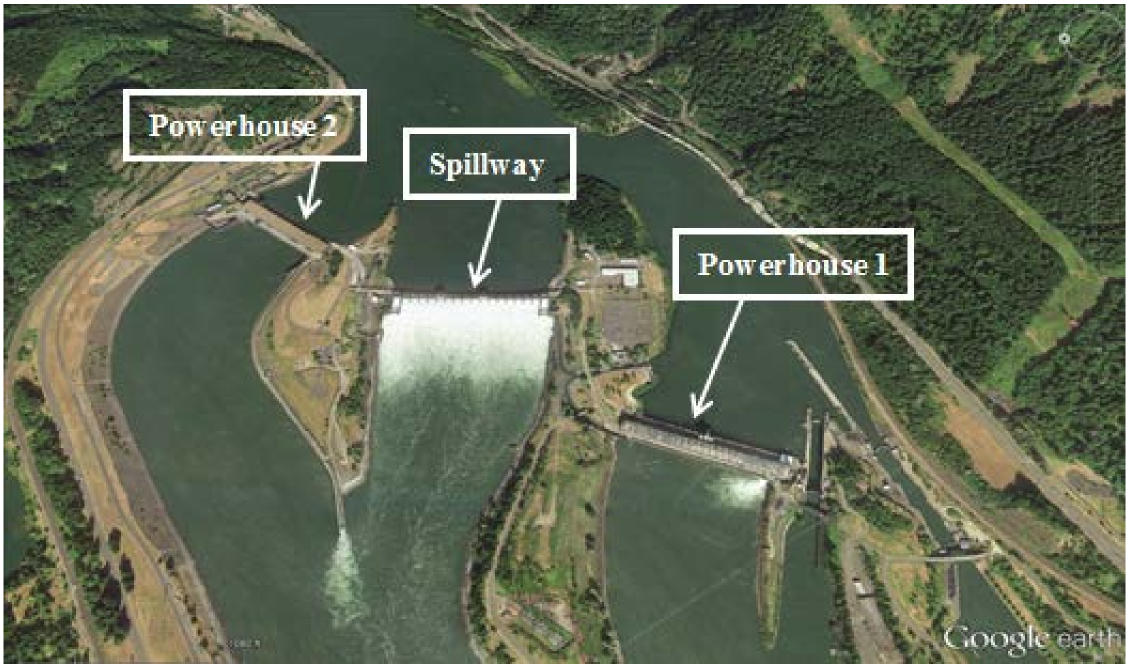

Figure 1.1. BON Study Area Photo Showing the Two Powerhouses and Spillway. The BON B1 is to the right. A modified image (45°38'34.64"N, 121°56'43.61"W) from Google Earth™ (V7.1.2.2041), Google Inc. (Accessed October 14, 2013).

Table 1.1. Release and Survival Detection Array Locations and Descriptions for BON, 2008

Columbia River Kilometer (rkm)	Release and Array Description	Location
390	Release 1	Arlington, OR
346	Release 2	JDA tailrace
306	Release 3	TDA tailrace
234	Virtual Release 1	BON[(a)]
203	Primary survival array	Reed Island, WA
192	Secondary survival array	Lady Island, WA
86	Tertiary survival array	Oak Point, WA[(b)]

(a) Spillway and B2 only

(b) Summer only

Table 1.2. Release and Survival Detection Array Locations and Descriptions for BON, 2009

Columbia River Kilometer (rkm)	Release and Array Description	Location
390	Release 1	Roosevelt, WA
234	Virtual Release 1	BON[(a)]
192	Primary survival array	Lady Island, WA
113	Secondary survival array	Kalama, WA
86	Tertiary survival array	Oak Point, WA[(b)]

(a) B2 only
(b) Summer only

Table 1.3. Release and Survival Detection Array Locations and Descriptions for BON, 2010

Columbia River Kilometer (rkm)	Release and Array Description	Location
390	Release 1	Roosevelt, WA
307	Release 2	TDA tailrace
275	Release 3	Hood River, OR
234	Virtual Release 1	BON[(a)]
153	Primary survival array	Knapp, WA
113	Secondary survival array	Kalama, WA
86	Tertiary survival array	Oak Point, WA[(b)]

(a) B1, spillway, and B2
(b) Summer only

Table 1.4. Release and Survival Detection Array Locations and Descriptions for BON, 2011

Columbia River Kilometer (rkm)	Release and Array Description	Location
390	Release 1	Roosevelt, WA
346	Release 2	JDA tailrace
325	Release 3	Celilo, OR
307	Release 4	TDA tailrace
275	Release 5	Hood River, OR
234	Virtual Release 1	BON[(a)]
161	Primary survival array	Reeder Point, WA
113	Secondary survival array	Kalama, WA

(a) B1, spillway, and B2

Table 1.5. Release and Survival Detection Array Locations and Descriptions for BON, Spring 2012

Columbia River Kilometer (rkm)	Release and Array Description	Location
503	Release 1	Port Kelley, WA
468	Release 2	MCN tailrace
422	Release 3	Crow Butte State Park, WA
346	Release 4	JDA tailrace
325	Release 5	Celilo, OR
234	Virtual Release 1	BON[(a)]
156	Primary survival array	Knapp, WA
113	Secondary survival array	Kalama, WA

(a) B1, spillway, and B2

Table 1.6. Release and Survival Detection Array Locations and Descriptions for BON, Summer 2012

Columbia River Kilometer (rkm)	Release and Array Description	Location
503	Release 1	Port Kelley, WA
468	Release 2	MCN tailrace
422	Release 3	Crow Butte State Park, WA
346	Release 4	JDA tailrace
325	Release 5	Celilo, OR
307	Release 6	TDA tailrace
275	Release 7	Hood River, OR
234	Virtual Release 1	BON[(a)]
156	Primary survival array	Knapp, WA
113	Secondary survival array	Kalama, WA
86	Tertiary survival array	Oak Point, WA

(b) B1, spillway, and B2

1.2.2 The Dalles Dam

TDA is located on the Columbia River at rkm 309 and is the second dam upstream from the Pacific Ocean. TDA Powerhouse has 22 turbine units, two fish units, and a sluiceway. TDA spillway has 23 spillbays (Figure 1.2). Only fish detected passing at the spillway from 2010 through 2012 were used in the data analysis to evaluate the survival rates and egress times of juvenile salmonids passing within the spillwall (spillbays 1–8) and outside the spillwall (spillbays 9–23). The newly installed spillwall was designed to improve egress conditions for and survival of out-migrating salmonids. Fish used in these data analyses were released between rkm 325 and 503 (Celilo, OR). The primary, secondary, and tertiary survival detection arrays for TDA were located at rkm 234 (BON cabled array), rkm 156 or 161 (Knapp or Reeder Point, WA), and rkm 113 (Kalama, WA), respectively. Table 1.7, Table 1.8, and Table 1.9 show the locations of tagged fish releases, detection arrays for virtual releases, and the locations of survival arrays used in the data analyses.

Figure 1.2. TDA Study Area Photo Showing TDA Spillbays and Spill Walls. A modified image (45°36'49.19"N, 121°8'0.61"W) from Google Earth™ (V7.1.2.2041), Google Inc. (Accessed October 14, 2013).

Table 1.7. Release and Survival Detection Array Locations and Descriptions for TDA, 2010

Columbia River Kilometer (rkm)	Release and Array Description	Location
390	Release 1	Roosevelt, WA
309	Virtual Release 1	TDA Spillway
234	Primary survival array	BON
153	Secondary survival array	Knapp, WA
113	Tertiary survival array	Kalama, WA

Table 1.8. Release and Survival Detection Array Locations and Descriptions for TDA, 2011

Columbia River Kilometer (rkm)	Release and Array Description	Location
390	Release 1	Roosevelt, WA
346	Release 2	JDA tailrace
325	Release 3	Celilo, OR
309	Virtual Release 1	TDA Spillway
234	Primary survival array	BON
161	Secondary survival array	Reeder Point, WA
113	Tertiary survival array	Kalama, WA

Table 1.9. Release and Survival Detection Array Locations and Descriptions for TDA, 2012

Columbia River Kilometer (rkm)	Release and Array Description	Location
503	Release 1	Port Kelley, WA
468	Release 2	MCN tailrace
422	Release 3	Crow Butte State Park, WA
346	Release 4	JDA tailrace
325	Release 5	Celilo, OR
309	Virtual Release 1	TDA Spillway
234	Primary survival array	BON
156	Secondary survival array	Knapp, WA
113	Tertiary survival array	Kalama, WA

1.3 Report Contents and Organization

The ensuing sections of this report present the study methods (Section 2.0) relative to each particular dam and passage route used by the three species/life stages studied. The associated results for each dam passage route are then presented in Sections 3.0 through 6.0 by species/life stage. Sections 7.0 and 8.0 contain discussion and the conclusions, respectively.

2.0 Methods

Data for the analysis described in this report were compiled from survival studies conducted from 2008 through 2012 at BON and from 2010 through 2012 at TDA. Significant differences between survival rate estimates were detected by comparing the 95% confidence intervals of survival estimates.

2.1 Species

Two species of juvenile salmonids that out-migrate in three runs were included in our study. They are yearling Chinook salmon (CH1) and juvenile steelhead (STH), which both out-migrate in the spring, and subyearling Chinook salmon (CH0), which out-migrate in summer. For brevity in figure or table titles, the term "each species-run" refers to the two runs of Chinook salmon and juvenile steelhead.

2.2 Array Locations and Study Functions

Two types of JSATS arrays, cabled (see Weiland et al. 2011a) and autonomous (see Titzler et al. 2010), were deployed to detect out-migrating salmonids double-tagged with JSATS AMTs and PITs as they passed through study reaches (Table 1.1 through Table 1.9).

Detailed descriptions of the design of each BiOp compliance study, details such as AMT tag-life, and the results of the studies can be found in the technical/compliance reports listed below.

2008

- *Survival Rates of Juvenile Salmonids Passing Through the Bonneville Dam and Spillway in 2008* (Ploskey et al. 2009)
- *Evaluation of a Behavioral Guidance Structure at Bonneville Dam Second Powerhouse including Passage Survival of Juvenile Salmon and Steelhead using Acoustic Telemetry, 2008* (Faber et al. 2010)
- *Acoustic Telemetry Evaluation of Juvenile Salmonid Passage and Survival at John Day Dam with Emphasis on the Prototype Surface Flow Outlet, 2008* (Weiland et al. 2009).

2009

- *Evaluation of a Behavioral Guidance Structure on Juvenile Salmonid Passage and Survival at Bonneville Dam, 2009* (Faber et al. 2011)
- *Acoustic Telemetry Evaluation of Juvenile Salmonid Passage and Survival Proportions at John Day Dam, 2009* (Weiland et al. 2011b).

2010

- *Survival and Passage of Juvenile Chinook Salmon and Steelhead Passing Through Bonneville Dam, 2010* (Ploskey et al. 2011a)
- *Survival and Passage of Yearling and Subyearling Chinook Salmon and Steelhead at The Dalles Dam, 2010* (Johnson et al. 2011)

- *Monitoring of Subyearling Chinook Salmon Survival and Passage at Bonneville Dam, Summer 2010* (Ploskey et al. 2011b)
- *Compliance Monitoring of Juvenile Subyearling Chinook Salmon Survival and Passage at The Dalles Dam, Summer 2010* (Skalski et al. 2010a)
- *Monitoring of Juvenile Yearling Chinook Salmon and Juvenile Steelhead Survival and Passage at Bonneville Dam, Spring 2010* (Ploskey et al. 2011c)
- *Compliance Monitoring of Yearling Chinook Salmon and Juvenile Steelhead Survival and Passage at The Dalles Dam, Spring 2010* (Skalski et al. 2010b).

2011

- *Compliance Monitoring of Yearling Chinook Salmon and Juvenile Steelhead Survival and Passage at Bonneville Dam, Spring 2011* (Skalski et al. 2012a)
- *Compliance Monitoring of Juvenile Yearling Chinook Salmon and Steelhead Survival and Passage at The Dalles Dam, Spring 2011* (Skalski et al. 2012b)
- *Route-Specific Passage Proportions and Survival Rates for Fish Passing through John Day Dam, The Dalles Dam, and Bonneville Dam in 2010 and 2011* (Ploskey et al. 2012)
- *Survival and Passage of Juvenile Chinook Salmon and Steelhead Passing through Bonneville Dam, 2011* (Ploskey et al. 2013)
- *Survival and Passage of Yearling Chinook Salmon and Steelhead at The Dalles Dam, Spring 2011* (Johnson et al. 2012).

2012

- *Compliance Monitoring of Subyearling Chinook Salmon Survival and Passage at Bonneville Dam, Summer 2012* (Skalski et al. 2013a)
- *Compliance Monitoring of Subyearling Chinook Salmon Survival and Passage at The Dalles Dam, Summer 2012* (Skalski et al. 2013b).

2.3 Division of Operation Levels

The turbine operating ranges used in the analysis of turbine passage survival data for BON were obtained from the B1 and B2 turbine output and discharge tables in annual USACE Fish Passage Plans (FPPs) (http://www.nwd-wc.usace.army.mil/tmt/documents/fpp/).

The operating range of B1 and B2 turbines within the lower and upper bounds of the 1% of peak efficiency operating range were divided into quartiles for analysis of fish turbine passage survival rates. The bounds for the quartiles in terms of turbine discharge were determined using head and discharge values from the turbine output and discharge tables in the 2013 FPP (USACE 2013), which included data identifying the BOP for B1 turbines.

The times when detected tagged fish passed through the turbines were merged with 5-min dam operation data. Fish were then assigned to an operation range bin that coincided with the operating condition of a turbine unit at the time of passage.

2.3.1 Bonneville Dam Powerhouse 1

Turbine discharge curves for B1 were developed for operations without submersible traveling screens (STSs) in the turbine intakes. The discharge curves for B1 turbines were divided into quartiles within the limits of the 1% of peak efficiency operating range.

Four treatments (herein referred to as “operation treatments”) were used to segment the turbine operating range for analysis of the survival rates of fish passing through B1 turbines as follows:

- Q1—the lower limit of 1% of the peak efficiency operating range to the first quartile
- Q2—lower quartile or 25th percentile up to the median
- Q3—median or 50th percentile to the 75th percentile
- Q4—75th percentile to the upper limit of 1% of peak efficiency operating range.

Two additional ranges above the upper 1% of peak efficiency operating limit were also defined:

- BOR—turbine operations from the upper 1% boundary of the peak efficiency operating limit to the BOP
- ABOP—turbine operations from BOP to the generator limit.

The turbine operation values used to construct the data ranges for the analysis are shown in Figure 2.1 and are provided in Appendix A (Table A.1).

In addition to the turbine operating ranges identified above, two operating range groups (herein referred to as “grouped operation treatments”) were defined for the analysis:

- LL to UL—lower limit through the upper limit of the 1% of peak efficiency operating range, which includes Q1, Q2, Q3, and Q4
- LL to BOP—lower limit of 1% of peak efficiency operating range to the best operating point, which includes ranges Q1, Q2, Q3, Q4, and BOR.

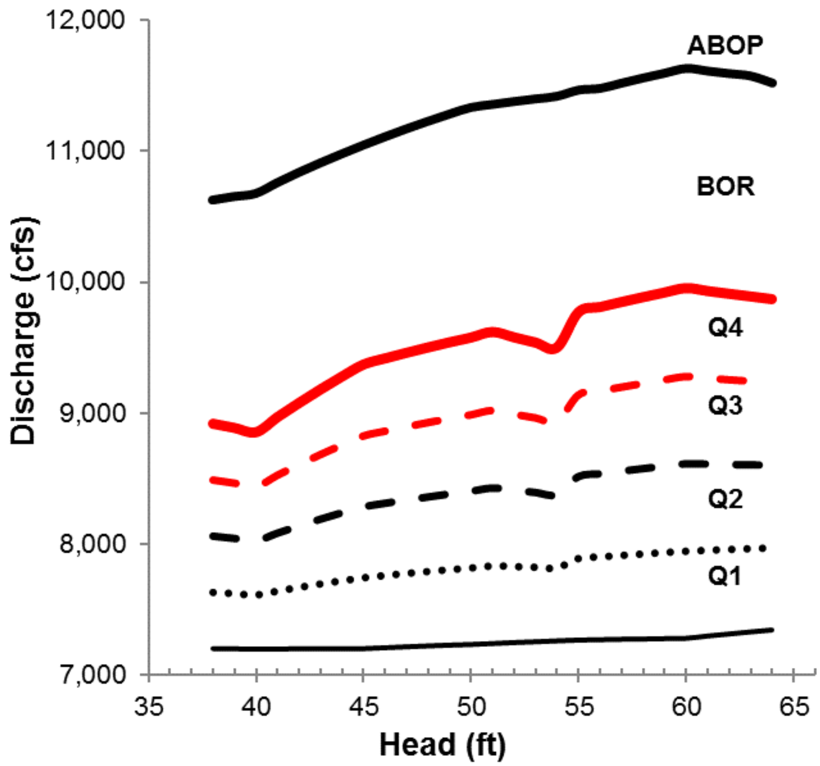

Figure 2.1. Turbine Operating Treatment Boundaries for B1 without Submersible Traveling Screens by Turbine Head and Discharge

2.3.2 Bonneville Dam Powerhouse 2

Discharge curves for B2 turbines were divided into four quartiles within the limits of the 1% of peak efficiency operating range (Q1, Q2, Q3, and Q4) for operation with and without STSs in turbine intakes (Figure 2.2 and Figure 2.3, respectively). The values used to construct the data ranges shown in the figures are provided in A, respectively). The values used to construct the data ranges shown in the figures are provided in Appendix A, Table A.2, and Table A.3, respectively.

Four treatments (herein referred to as "operation treatments") were used to segment the turbine operating range for analysis of the survival rates of fish passing through B2 turbines as follows:

- Q1—the lower limit of 1% of the peak efficiency operating range to the first quartile
- Q2—lower quartile or 25th percentile up to the median
- Q3—median or 50th percentile to the 75th percentile
- Q4—75th percentile to the upper limit of 1% of peak efficiency operating range.

Grouped operation treatments BOR and ABOP were not included in the analyses of fish passage survival rates through B2 turbines because turbine operation is physically limited at the upper limit of the 1% of peak operating efficiency range.

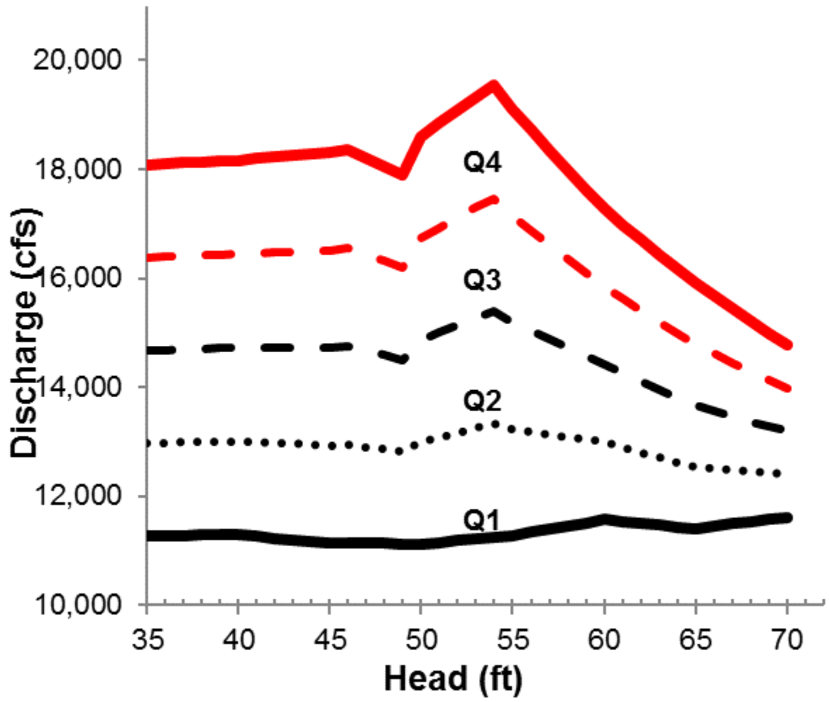

Figure 2.2. B2 Turbine Operating Treatments by Discharge as a Function of Operating Head for Turbines with Submersible Traveling Screens

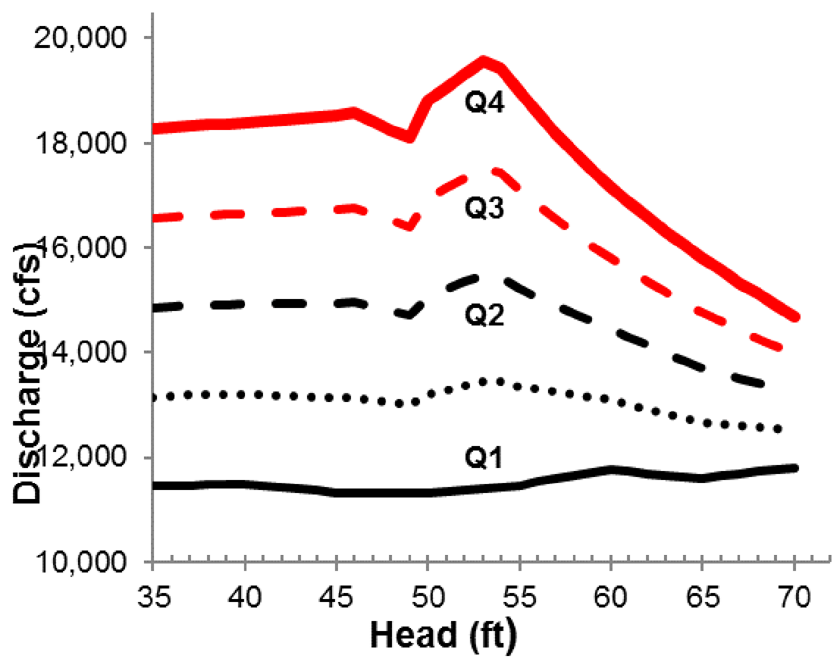

Figure 2.3. B2 Turbine Operating Treatments by Discharge as a Function of Operating Head for Turbines without Submersible Traveling Screens

2.3.3 Bonneville Dam Spillway

Survival rates for juvenile salmonids passing in BON spill were analyzed to determine if there were differences in rate of fish passage survival resulting from structural or operational differences between spillbays and groups of spillbays. The survival performance of fish that passed through individual spillbays were analyzed for differences in survival rates between individual spillbays, the proportion of fish passing through individual spillbays, the effects of discharge and tailwater elevation on survival rates, the effects of potential spillbay erosion or presence of rocks, and egress time of fish through the spillway tailrace. Spillbays were grouped by flow deflector type (shallow or deep) and by potential spillbay erosion or the presence of rocks in the stilling basin. The survival rates for fish that passed through spillways with deep-flow (spillbays 1–3 and 16–18) and shallow-flow (spillbays 4–15) deflectors were compared. Spillbays with shallow-flow deflectors were divided into three groups (spillbays 4–7, spillbays 8–12, and spillbays 13–15). Spillbays 8–12 are suspected of having structural damage and rock present in their stilling basins, and spillbays 4–7 and spillbays 13–15 bracket the spillbays having possible damage.

2.3.4 The Dalles Dam Spillway

The survival rates and fish distribution were examined for fish passing through individual spillbays 1–8 (spillbays northeast of the new spillwall) at TDA. In addition, the differences in survival rates for fish passing spillbays 1–8 and 9–23 (spillbays southwest of the new spillwall) were compared, as were those groups of spillbays 9–12 and 13–23. The spillway discharges were analyzed for the effects on fish survival and tailrace egress time.

2.4 Analytical Methods

A single-release-recapture model (Cormack-Jolly-Seber Model) was used to estimate turbine and spillbay passage survival probabilities, using at least two downstream detection arrays (Figure 2.4 and Figure 2.5) (see Burnham et al. 1987). Typically, the analyses used three survival arrays with the exception of BON in 2011 and spring 2012, when two survival arrays were used for the analyses (Table 1.1 through Table 1.9). Detection histories of survival estimates were based on detection at downstream detection arrays. When there were only two downstream detection arrays, the model has $2^2 = 4$ possible detection histories as follows:

- 11—detected on both the primary and secondary arrays
- 10—detected on the primary but not on the secondary array
- 01—not detected on the primary but detected on the secondary array
- 00—never detected.

When there are three detection arrays, the model has $2^3 = 8$ possible detection histories as follows:

- 111—detected on all three arrays
- 110—detected on the primary and secondary arrays, but not on the tertiary array
- 101—detected on the primary and tertiary arrays, but not on the secondary array

- 100—detected on the primary array, but not on the secondary or tertiary arrays
- 011—not detected on the primary array, but detected on the secondary and tertiary arrays
- 010—detected on the secondary array, but not on the primary or tertiary arrays
- 001—not detected on the primary or secondary arrays, but detected on the tertiary array
- 000—never detected.

The release-recapture designs and sample sizes for BON and TDA BiOp compliance studies are described in the following sections.

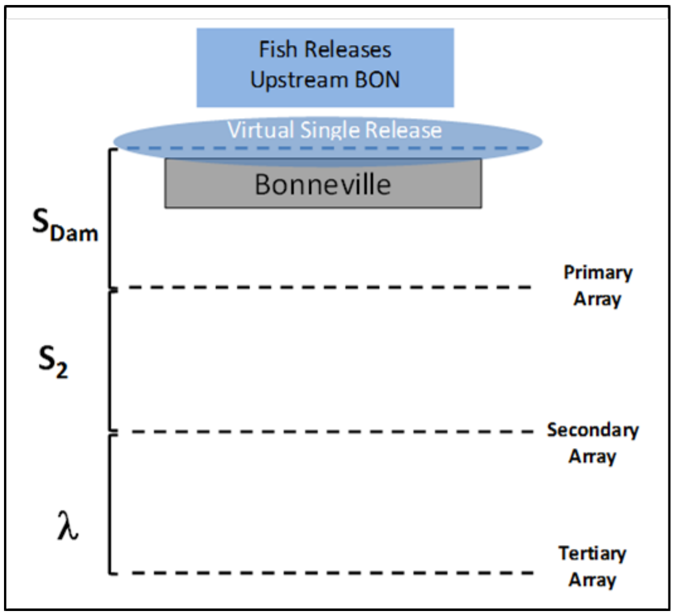

Figure 2.4. Schematic of the Single-Release-Recapture Model for Passage Survival Estimates at BON

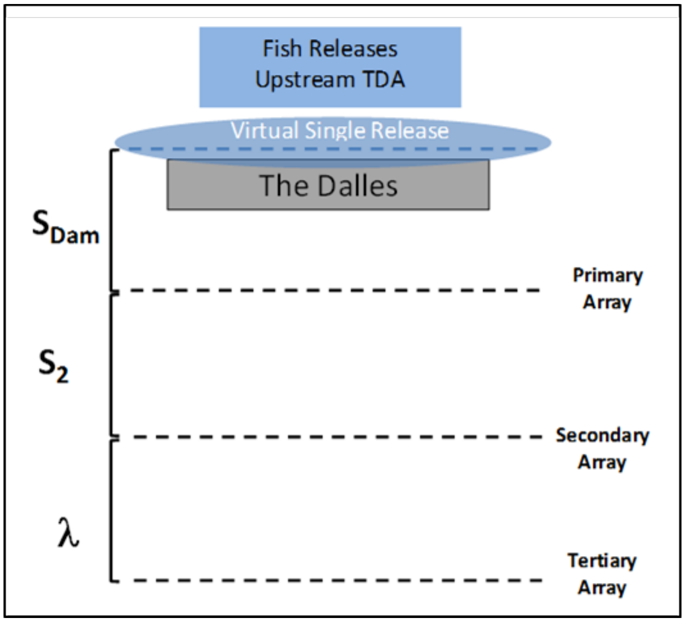

Figure 2.5. Schematic of the Single-Release-Recapture Model for Passage Survival Estimates at TDA

2.4.1 Release-Recapture Design and Sample Size

2.4.1.1 Bonneville Dam

All tagged fish released above BON detected on the BON dam-face cabled array were regrouped to form a virtual release (Figure 2.4 and Figure 2.5). These fish were used to estimate dam passage survival probability using the single-release-recapture model. A total of 13,360 CH1, 12,118 STH, and 13,094 CH0 (Table 2.1) were detected on the BON dam-face cabled array used in the analyses. Tag-life corrections were not applied to the model.

Table 2.1. The Numbers (N) of Fish Detected and Regrouped as a Virtual Release Fish at BON by Year, Species, and Dam Passage Route

	CH1			STH			CH0		
Year	B1	B2	Spillway	B1	B2	Spillway	B1	B2	Spillway
2008		274	1,514		130	1,473		759	2,279
2009		368			268			215	
2010	124	533	1,767	110	574	1,363	561	437	1,787
2011	1,162	446	3,170	1,298	162	3,111			
2012	1,164	613	2,225	1,301	202	2,126	1,229	1,295	4,532
Total	2,450	2,234	8,676	2,709	1,336	8,073	1,790	2,706	8,598

2.4.1.2 The Dalles Dam

At TDA, only tagged fish passing the spillway that were detected on the dam-face cabled array were used to estimate spillbay passage survival rates. Fish released upstream of TDA (rkm 309) and detected at the spillway were regrouped to form a virtual release. A total of 8,223 CH1, 9,056 STH, and 6,901 CH0 were used in the survival analyses (Table 2.2). Tag-life corrections were not applied to the model.

Table 2.2. The Numbers of Fish Detected Passing through Groups of Spillbays at TDA by Species and Year that were Regrouped as a Virtual Release

Year	CH1		STH		CH0	
	Spillbays 1–8	Spillbays 9–23	Spillbays 1–8	Spillbays 9–23	Spillbays 1–8	Spillbays 9–23
2010	1,715		1,796		1,720	
2011	2,401	391	2,700	544		
2012	3,620	96	3,894	122	5,040	141
Total	7,736	487	8,390	666	6,760	141

2.4.2 BON Tailwater Elevation Evaluation

The effect of tailwater elevation on the survival of juvenile salmonids after passage at BON was estimated over the observed range of tailwater elevations. Tailwater elevations obtained from USACE operations data (5-min intervals) were placed into 1-m depth bins relative to mean sea level (MSL). These elevation groups were identified as 5 m for tailrace elevations < 5.5 m; 6 m for tailrace elevations 5.5 m to < 6.5 m; 7 m for tailrace elevations 6.5 m to < 7.5 m; 8 m for tailrace elevations 7.5 m to < 8.5 m; and 9 m for tailrace elevations ≥ 8.5 m. Each juvenile salmonid was assigned to an elevation bin associated with the time of passage at the dam.

2.4.3 BON Spillway Discharge Evaluation

To evaluate the survival rates of juvenile salmonids passing the spillway relative to discharge levels, spillway discharge was incremented into 10 kcfs discharge bins. Spillway discharge volumes were calculated from USACE operations data (5-min intervals) and juvenile salmonids were assigned to a discharge bin associated with their spillway passage time. The 10 kcfs discharge bins include the 5 kcfs discharge range on either side of the 10 kcfs point (i.e., 100 kcfs = 95–104 kcfs; 110 kcfs = 105–114 kcfs). For the ≤ 90 kcfs discharge range, discharge encompassed all spillway discharge volumes ≤ 94 kcfs. In spring, ≥ 290 kcfs was the largest discharge bin and included discharge levels ≥ 285 kcfs. In summer, the largest discharge bin was ≥ 230 kcfs and included discharge levels ≥ 225 kcfs.

2.4.4 TDA Spillway Discharge Evaluation

To investigate the survival rates of juvenile salmonids passing TDA spillway relative to discharge levels, spillway discharge was incremented into 10 kcfs discharge bins. Spillway discharge was calculated from USACE dam operations data (5-min intervals) and juvenile salmonids were assigned to a discharge bin associated with when it passed at the spillway. The 10 kcfs discharge bins include the 5 kcfs discharge range on either side of the 10 kcfs point (i.e., 80 kcfs = 75–84 kcfs; 90 kcfs = 85–94 kcfs). For the ≤ 70 kcfs discharge range, discharge encompassed all spillway discharge volumes ≤ 74 kcfs. The upper end of the discharge range included all discharge ≥ 155 kcfs in the ≥ 160 kcfs bin.

2.5 Tag Specifications and Tag Life

The JSATS AMTs used in these studies were manufactured by Advanced Telemetry Systems Inc. (ATS). Two models of JSATS AMTs manufactured by ATS were used in the 2008 through 2012 studies (Table 2.3). Over time, the JSATS AMTs were reduced in size and weight. Both designs (SS130 and SS300) transmitted the same binary phase-shift keying coded signal type at a frequency of 416.7 kHz (Weiland et al. 2011a).

Table 2.3. Tag Sizes, Pulse Repetition Interval, and Expected Tag Life in Days by Year

Year	Manufacturer	Model Number	Mass In Air (g)	Dimensions (mm)	Pulse Repetition Interval (s)	Median Tag Life (d)
2008 spring	ATS		0.485	12.46 x 2.30 x 3.70	3	31
2008 summer	ATS	SS130	0.425	12.04 x 5.27 x 3.74	3	31
2009	ATS	SS130	0.439	12.02 x 5.21 x 3.72	3	35
2010	ATS	SS130	0.440	11.99 x 5.20 x 3.78	3	34
2011	ATS	SS130	0.438	11.88 x 5.08 x 3.74	3	30
2012[a]	ATS	SS130	0.438	11.88 x 5.08 x 3.74	3	32
2012[b]	ATS	SS300	0.303	10.69 x 5.20 x 3.02	3	24

(a) AMT implanted in STH during spring 2012.
(b) AMT implanted in CH1 and CH0 in 2012.

2.6 Environmental Conditions

Environmental conditions included in the analyses were project water discharge (kcfs), spillway discharge (kcfs), and water temperature (°C). All data were obtained from the Columbia River DART (Data Access in Real Time) website (http://www.cbr.washington.edu/dart).

2.6.1 Bonneville Dam

Fourteen years of BON environmental data, from 1999 through 2012, which included 9 years prior to 2008 and the passage survival study years 2008 through 2012, were averaged to provide a baseline for environmental conditions for this evaluation. BON project discharge in the spring was generally greater than the 14-yr average during 2011 and 2012, and lower than the 14-yr average in spring 2010 (Figure 2.6). Project discharge was greater than the 14-yr average during the summers of 2008, 2010, 2011, and 2012 (Figure 2.6) (BON spillway discharge is shown in Figure 2.7).

In general, water temperatures in 2008, 2010, 2011, and 2012 were cooler than the 14-yr average in both spring and summer (Figure 2.8). Water temperatures were above the 14-yr average only once during summer 2009.

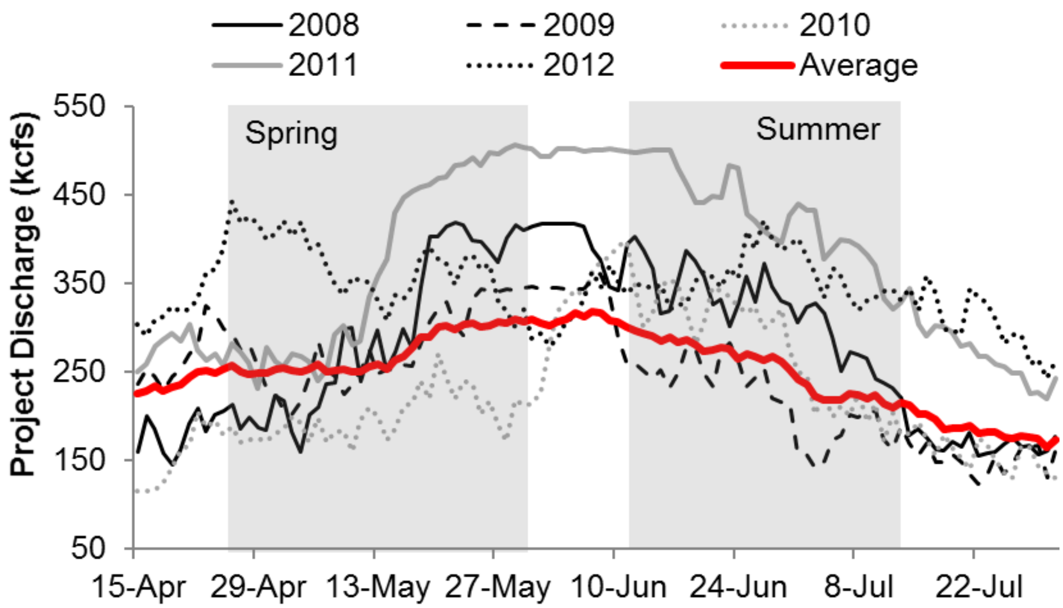

Figure 2.6. BON Project Discharge by Study Year (2008–2012) and 14-Year Average (1999–2012). The gray boxes identify the duration of the spring and summer portions of dam passage studies.

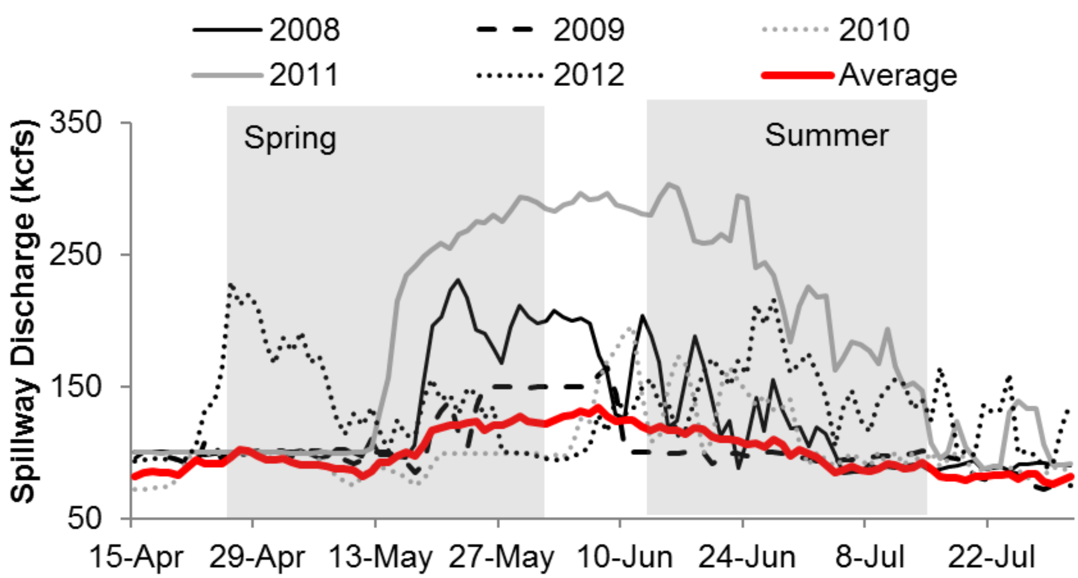

Figure 2.7. BON Spillway Discharge by Study Year (2008–2012) and 14-Year Average (1999–2012). The gray boxes identify the duration of the spring and summer portions of dam passage studies.

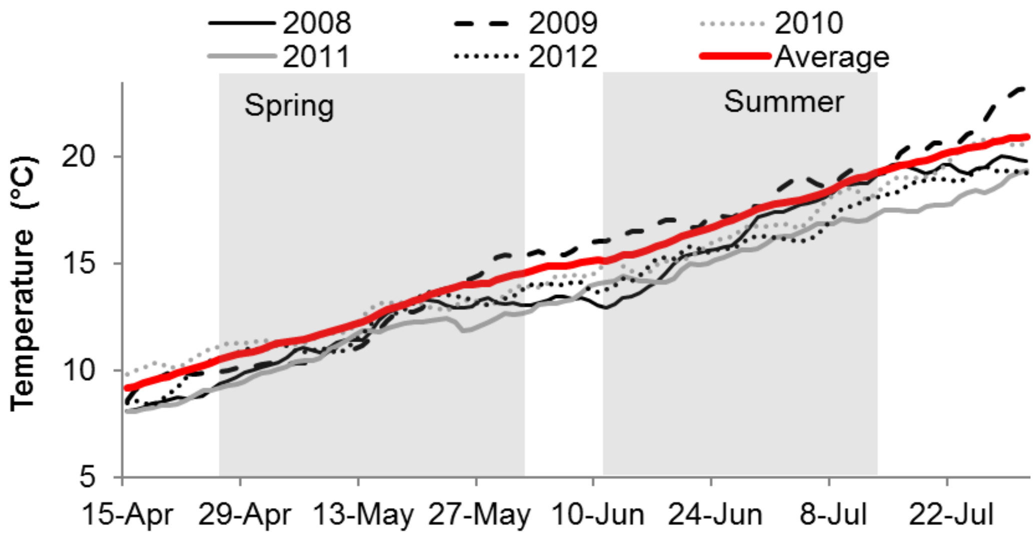

Figure 2.8. BON Forebay Water Temperature by Study Year (2008–2012) and 14-Year Average (1999–2012). The gray boxes identify the duration of the spring and summer portions of dam passage studies.

2.6.2 The Dalles Dam

Twelve years of TDA environmental data, 2001–2012, were averaged to provide a baseline of environmental conditions for comparison with those experienced during the study years included in this analysis, 2010–2012. In 2010, TDA project discharge was lower than the 12-yr average in spring, greater in early summer, and lower in late summer (Figure 2.9 and Figure 2.10). From the late spring through summer in 2011 the project discharge was nearly double the 12-yr average project discharge. The very high discharge in 2011 resulted in the cancellation of a planned summer study. In 2012, TDA total discharge was also higher than the 12-yr average during both the spring and summer studies. Generally, temperatures for the years 2010–2012 were below the 12-yr average (Figure 2.11).

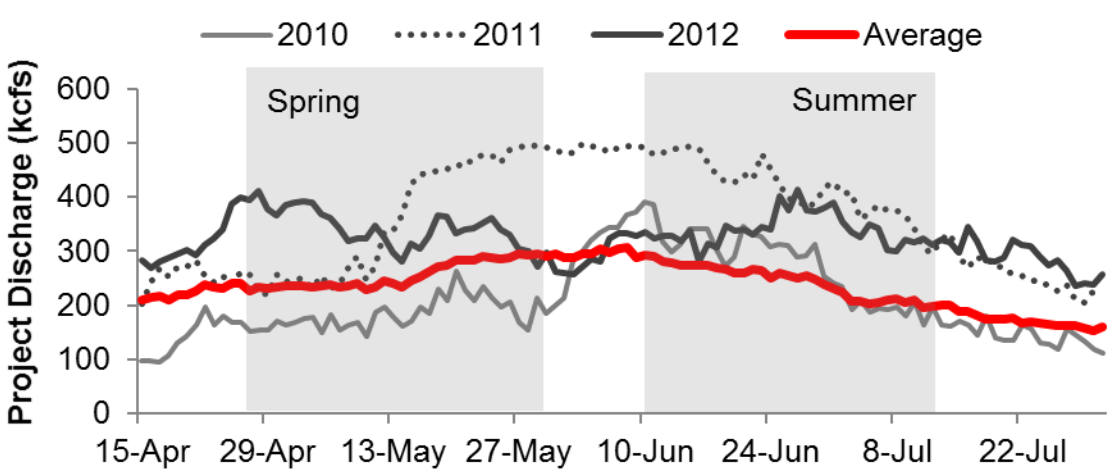

Figure 2.9. TDA Project Discharge by Study Year (2010–2012) and 12-Year Average (2001–2012). The gray boxes identify the duration of the spring and summer portions of dam passage studies.

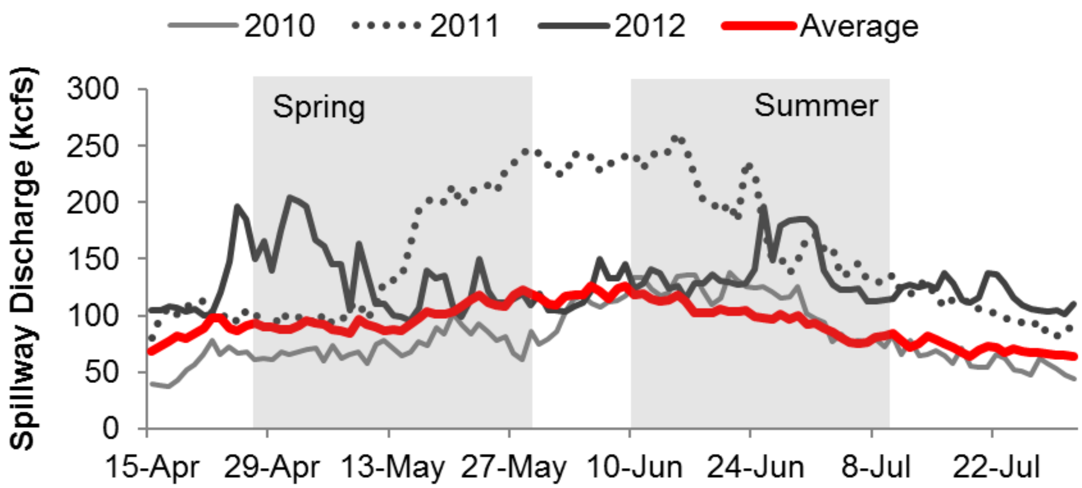

Figure 2.10. TDA Spillway Discharge by Study Year (2010–2012) and 12-Year Average (2001–2012). The gray boxes identify the duration of the spring and summer portions of dam passage studies.

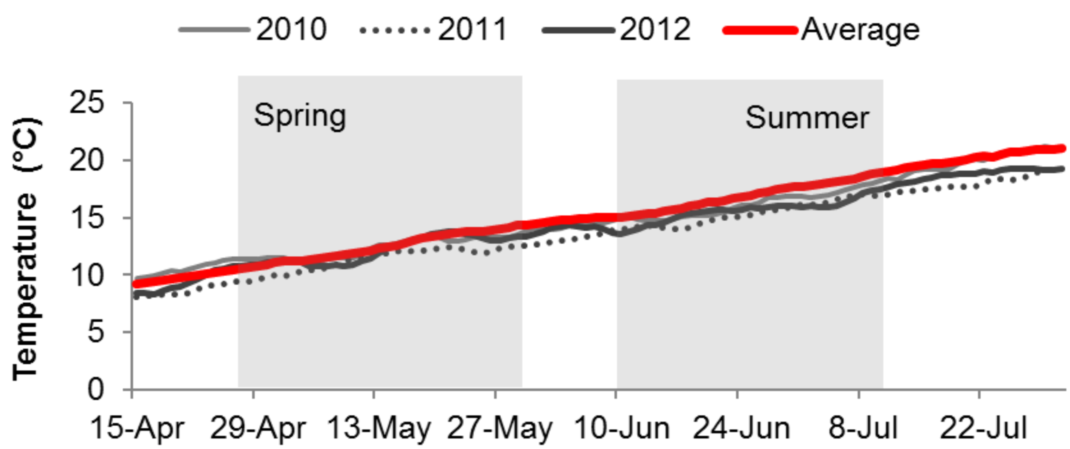

Figure 2.11. TDA Forebay Water Temperature by Study Year (2010–2012) and 12-Year Average (2001–2012). The gray boxes identify the duration of the spring and summer portions of dam passage studies.

2.6.3 River Discharge and Forebay/Tailrace Elevation

Dam discharge data (dam operations) by spillbay and turbine unit and forebay and tailrace elevations used in these analyses were in 5 min increments using automated data-acquisition systems at BON (2008–2012) and TDA (2010–2012).

2.6.4 Spillway Conditions

Scheduled spillway discharges for BON and TDA are included in the FPP for each year (http://www.nwd-wc.usace.army.mil/tmt/documents/fpp/).

2.6.4.1 Bonneville Dam

The planned spillway discharge at BON in spring was 100 kcfs day/night for all study years. There were two treatment spillway discharges at BON in summer, 85 kcfs/121 kcfs (day/night) and 95 kcfs/95 kcfs (day/night) in 2010 and 2012. Spill discharges planned for BON 2008 through 2012 are presented in Table 2.4.

BON spillway discharge was greater than the 14-yr average, and discharge was greater than the spill pattern set in the FPP for much of the spring fish passage season in 2008, 2011, and 2012. Spill during the summer out-migration season was above the 14-yr average for the first half of the season in 2008 and 2010, and the entire summer season in 2011 and 2012 (Figure 2.7). The planned spill pattern was achieved after July 4 and July 1, during 2008 and 2010 study years, respectively, but not achieved during the 2012 study. The 2011 summer study was canceled due to high river discharge.

Table 2.4. BON Spillway Discharge (2008–2012) as Specified in the FPP and Special Operations for Spill Treatment Tests

Year	Spring Day/Night (kcfs)	Summer Day/Night (kcfs)	Spill Pattern Met
2008	100/100	85/gas cap[(a)]	Before May 18 and after July 3
2009	100/100	85/gas cap[(a)]	No study at spillway
2010	100/100	85/121 or 95/95	Before June 5 and after July 1
2011	100/100	85/121 or 95/95	Before May 13 but not after
2012	100/100	85/121 or 95/95	Not met during study

(a) Approximately 120 kcfs at night.

During early spring 2011, TDA spillway discharge was maintained near 40% of total project discharge during day and night at spillbays 1–8. Beginning in late spring 2011, river flows were higher than observed for normal water years. As a result, some spillbays outside of the spillwall were opened; spillbays 10, 11, 13, 16, 18, 19, and 23 were not opened (due to structural or operational issues). Figure 2.12, Figure 2.13, and Figure 2.14 show total spillway discharge as a percent of total project discharge, percent of total spill discharge for spillbays 1–8, and percent of total spill for spillbays 9–23 for spring 2011, spring 2012, and summer 2012, respectively. Spill discharge percentages were calculated from hourly spill discharge divided by hourly project discharge (kcfs). Project operating plans recommended not using spillbays 14–22, because discharge from this portion of the spillway is believed to create poor tailrace egress conditions for spillway-passed fish.

Operators attempted to maintain TDA spillway discharge as near 40% of total project discharge as specified in the FPP, even when the total discharge was greater than the 12-yr average discharge during 2011 and 2012 (Figure 2.10). The spillway discharge in 2010 was lower in the spring than the 12-yr average.

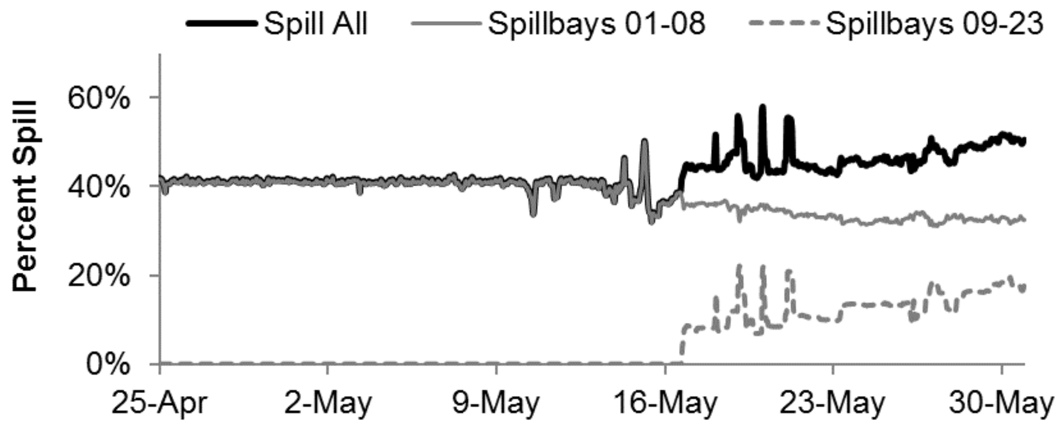

Figure 2.12. TDA 2011 Spring Percent Spill of Total Project Discharge for All Spillbays, Spillbays 1–8, and Spillbays 9–23

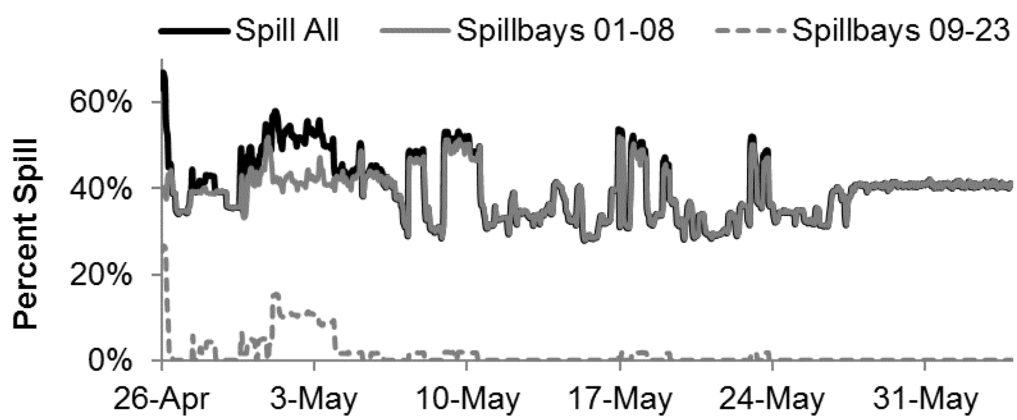

Figure 2.13. TDA 2012 Spring Percent Spill of Total Project Discharge for All Spillbays, Spillbays 1–8, and Spillbays 9–23

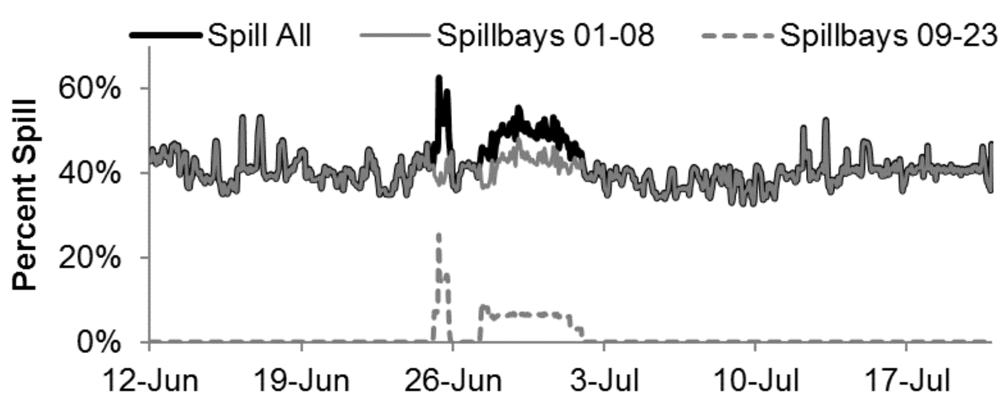

Figure 2.14. TDA 2012 Summer Percent Spill of Total Project Discharge for All Spillbays, Spillbays 1–8, and Spillbays 9–23

In late spring 2011, spillbays 9, 12, 14, 15, 17, 20, and 21 were opened in response to high river flow (Table 2.5). Among those spillbays, spillbay 12 was open the longest (40% of the study season, 342 of 864 total hours), followed by spillbays 9, 14, and 15 (Figure 2.12). Average discharge for each spillbay inside the spillwall was 15.64 kcfs and for operating spillbays within the range of spillbays 9–23 average discharge was 16.38 kcfs per spillbay (Table 2.6).

In 2012, spillbays 12, 14, 15, 17, 20, 21, and 22 were open a total of 806 and 565 h during spring and summer study periods, respectively (Figure 2.12, Figure 2.13; Table 2.5). Spillbay 12 was open longer than other spillbays outside of the spillwall, 29% of total spill time in spring and 14% in summer (269 and 133 h, respectively). In general, spillbays outside of the spillwall close to the spillwall were open more hours than spillbays outside of the spillwall and further away from the spillwall. For details on the hours individual spillbays were open and average spillbay and total spillway discharge, refer to Table 2.5 and Table 2.6.

Table 2.5. TDA Operation Hours for Open Spillbays 9–23 for 2011 and 2012. Percentage of hours individual spillbays were open relative to the total spillway operating hours during the study period are shown in parentheses.

Year	Season	Open Spillbays (h)								Total Hours in Study
		9	12	14	15	17	20	21	22	
2011	Spring	341 (39%)	342 (40%)	297 (34%)	191 (22%)	56 (6%)	12 (1%)	4 (0.5%)	–	864
2012	Spring	–	269 (29%)	123 (13%)	114 (12%)	86 (9%)	79 (8%)	74 (8%)	61 (7%)	936
2012	Summer	–	133 (14%)	131 (14%)	119 (13%)	118 (13%)	26 (3%)	22 (2%)	16 (2%)	936

Table 2.6. TDA Operating Hours for Open Spillbays and Average Discharge for 2011 and 2012 for Spillbays Inside the Spill Wall (Spillbays 1–8) vs. Outside the Spill Wall (Spillbays 9–23)

Year	Season	Spillbays 1–8		Spillbays 9–23	
		Open (h)	Discharge (kcfs)	Open (h)	Discharge (kcfs)
2011	Spring	6,912	15.64	1,243	16.38
2012	Spring	7,488	15.89	806	6.33
2012	Summer	7,488	16.44	565	6.16

2.7 Statistical Analysis

There were two types of hypothesis tests performed when analyzing the data. The first hypothesis test was a standard t-test to determine if there was a difference between the passage survival rates of two variables. Every pairwise combination in a set of variables was tested. For the differences deemed statistically different the power of the test was calculated to help interpret the significance of the results. For the differences not found to be statistically different the probability of a Type II error was calculated assuming the point estimate is the true difference of the two variables. That is, using the sample sizes from the experiment, the likelihood of the test showing a statistical difference if the true difference is the same as the point estimate. For the purpose of follow up experiments, the sample size needed to reduce the probability of a Type II error to 20% was also calculated. It is important to note these probabilities depend on the point estimate to be an accurate portrayal of the true difference, which is not necessarily true. Finally, the 95% confidence interval was calculated for the difference of every pairwise combination in the set of variables. Confidence intervals can provide insight into the true difference between two variables regardless of the conclusions from the hypothesis test.

The second hypothesis test was used to provide additional evidence when comparing the survival rates of the spillbays of Bonneville spillway and only performed a handful of times. The test uses the point estimates derived from the pairwise differences in survival rates from a set of variables to determine if at least one member of the set has a different survival rate. If a variable X is statistically different than a subset of the variables Y = {Y1, Y2,…, Y¬n}, then this test can provide insight into the variables in Y that are not statistically different from X. Of the variables in Y that are not statistically different from X the test will show if there is at least one variable that is statistically different, but it will not be able to identify which variable it is or if there is more than one that is statistically different from X. The results from this test in and of themselves do not provide strong evidence, but in conjunction with statistically significant results from the standard t-test can help support evidence of trends occurring in the data. The following is a conceptual explanation of the hypothesis test; a more mathematical explanation can be found in Section 2.7.2. Consider comparing the survival rate of X with the survival rates of Y1, Y2, …, Yn. For each k, k=1, 2, …, n, define the point estimate of the difference in survival rates as θk (i.e., X-Yk= θk). If the true survival rates of X and Yk are equal then for each k the distribution of possible point estimates is normally distributed with a mean of 0. Due to the symmetry of the normal distribution, the probability of randomly selecting a positive point estimate is 0.5. If the true survival rates of X and Yk are equal for all k, then approximately half of the n point estimates, θ1, θ2, …, θn, should be positive. If the number of positive point estimates far exceeds or is far less than n/2 the original assumption that the survival rate of X is equal to the survival rate of Yk for all k is proven to be false. Hence, at least one of Y1, Y2, …, Yn has a different survival rate than X.

Pooling the data for all years the experiment was carried out can help identify trends hidden by smaller samples sizes. However, performing statistical analysis on only grouped years assumes each year is an accurate portrayal of the true survival rate (i.e., all samples are good samples). When grouping the years if a sample for a year is an outlier with respect to the true survival rate it has the potential to skew the results of the pooled years. In addition, pooling the years assumes either there are no other factors influencing the survival rate (e.g., unusual temperatures or predatory populations) or that those other factors are unchanging from year to year.

2.7.1 Important Confidence Intervals That Are Not Statistically Significant

There are two types of confidence intervals mentioned throughout this paper that alone do not provide statistically significant results, but in combination with statistically significant results can help provide insight into the survival trends. When confidence intervals approximate the true difference between two variables and do not provide statistically significant results the intervals contain both positive and negative numbers. The subset of the interval, which contains the negative numbers will be referred to as the negative part of the interval; and the subset of the interval, which contains the positive numbers will be referred to as the positive part of the interval.

The first of the two interval types are intervals where either the positive or negative part of the interval contains only survival rate differences that are biologically insignificant. The difference between the survival rates of two variables is defined as biologically insignificant if the absolute difference is less than 0.5%. If either the positive or negative part of a confidence interval contains only biologically insignificant differences then we can infer that the true difference in the survival rates in the two variables is either biologically insignificant or variable 1 has a higher/lower survival rate than variable 2. For example, the survival estimate for CH1 passing through BON spillbays 5 and 17 in 2010 have survival estimates of 99.61% and 95.15%, respectively. Using a t-distribution the 95% confidence interval for the true difference, spillbay 5 minus spillbay 17, is (-0.4%, 9.3%). From a statistical point of view, this confidence interval shows the survival rate of spillbay 5 is lower than, the same as, or higher than the survival rate than spillbay 17. From a biological point of view, the confidence interval shows either the difference between the survival rates of spillbay 5 and spillbay 17 is insignificant or spillbay 5 has a higher survival rate than spillbay 17. While not as informative as a statistically significant confidence interval, analyzing the appropriate confidence intervals from a biological perspective can increase the level of information gained from it.

The second type of confidence interval is not defined in the statistics literature and alone holds no statistical value. However, when combined with statistically relative results or used in groups similar logic used to create the second hypothesis test can be applied. These confidence intervals occur when either the negative or positive part is much larger than its counterpart. The size of each part is determined by the Student t-distribution used to create the confidence interval. If the positive part makes up more than 90% of the interval, then the confidence interval heavily favors the positive part. Similarly, if the negative part makes up more than 90% of the interval, then it the confidence interval heavily favors the negative part. An example of this occurs when comparing the survival estimates for the grouped spillbays 1–3 and the grouped spillbays 16–18 for the year 2011. The CH1 survival estimates for the grouped spillbays 1–3 and the grouped spillbays 16–18 for the year 2011 are 93.09% and 95.91%, respectively, and the 95% confidence interval for the difference, spillbays 1–3 minus spillbays 16–18, is (-6.6%, 0.9%). Using the t-distribution with degree of freedom 1486 (sample size of spillbays 1–3 plus sample size of spillbays 16–18 minus two) the size of the positive part of the interval 0.91 and the size of the negative part of the interval is 0.04. Hence the positive part makes up 95.35% of the interval and the negative part makes up 4.65% of the interval. For the year 2011, the confidence interval heavily favors the survival rate of the grouped spillbays 1–3 being higher than the survival rate of the grouped spillbays 16–18.

These two types of confidence intervals may provide additional guidance when identifying patterns in the survival rates that are made only partially clear through statistical testing. A group of such intervals could also provide weak evidence when no statistical significance is found, but this should not be done frequently as it increases risk of making an incorrect assessment.

2.7.2 Mathematical Description of the Second Hypothesis Test

Assume the true survival rates between X and Y_k, k=1,2,…,n, are equal. Therefore, based on the Central Limit Theorem, the sampling distribution of the difference X-Y_k for each k is approximately normal with mean 0 and standard deviation σ_k. Let θ_k be the point estimate of X-Y_k. Now define the random variable U_k as the k^{th} point estimate, θ_k, is positive, i.e.

$$U_k = \begin{cases} 1 & \theta_k > 0 \\ 0 & \theta_k < 0 \end{cases}.$$

By properties of a normal distribution, half of the distribution lies below the mean and half lies above the mean. Hence, the probability θ_k is positive is 0.5. In addition, U_k is a Bernoulli random variable with probability of success 0.5. Now define U as the total number of positive point estimates:

$$U = \sum_{k=1}^{n} U_k \ .$$

This gives U~Bin(n,0.5), since the sum of n Bernoulli random variables with probability of success "p" is a Binomial random variable. Therefore, for example, E(U)=0.5n and E(U/n)=0.5

- E(U): The expected number of positive point estimates is half of the total number of variables being compared to X.
- E(U/n): The expected proportion of positive point estimates is one half.

Now that we have defined the random variable for the number of positive point estimates if all variables possess the same survival rate, we may define the hypothesis test.
Under the assumption all survival rates are the same, the proportion of positive numbers is approximately half. Hence, the hypotheses are

$$\begin{aligned} H_0 &: p = 0.5 \\ H_1 &: p \neq 0.5 \end{aligned}.$$

Due to the small samples sizes the normal distribution will not provide a good approximation of the sampling distribution (U). Since the p-value is the probability of the observation or one more extreme is selected under the null hypothesis, the p-value will be defined using the binomial pdf. Let x be the number of positive point estimates of the n differences. Therefore, the p-value is given by

$$p-value = \begin{cases} 2P(U \le x) = 2 \cdot \sum_{k=0}^{x} \frac{n!}{(n-k)!k!} \cdot (0.5)^k (1-0.5)^{n-k} & \text{if } \frac{x}{n} \le 0.5 \\ 2P(U \ge x) = 2 \cdot \sum_{k=x}^{n} \frac{n!}{(n-k)!k!} \cdot (0.5)^k (1-0.5)^{n-k} & \text{if } \frac{x}{n} > 0.5 \end{cases}.$$

If the p-value is smaller than α=0.001 then the null hypothesis will be rejected. A smaller α was chosen to help offset the small sample size. If the null hypothesis is rejected it implies that at least one of the variables Y_k, k=1, 2,…, n has a survival rate that is different than the survival rate of X. This test can also be done by adding the number of negative point estimates.

3.0 Results—Bonneville Dam Powerhouse 1

The turbine operating ranges (Q1, Q2, Q3, Q4, BOR, and ABOP) for Bonneville Dam Powerhouse 1 (B1), as described under Methods (Section 2.0), are further detailed in Appendix A. CH1, STH, and CH0 passage detection and survival rates for B1 in the specified operating ranges are described in the following sections. In addition, fish passage survival estimates for the operating ranges are provided in Appendices B, D, and F.

3.1 Yearling Chinook Salmon (CH1) at B1

3.1.1 CH1 Passage Survival Rates at B1 by Operating Condition

The distribution of CH1 detected passing through B1 turbines by turbine operating conditions during the survival studies conducted in 2010, 2011, and 2012 are shown in Figure 3.1. The detected CH1 were clustered within certain operating ranges (head-discharge combinations) because of fish behavior, river flow, spillway discharge, and resulting turbine operations (Figure 3.1).

Estimated survival rates for CH1 passing through B1 and the number of detected fish used in the survival estimates for turbine operation ranges Q1 through ABOP are shown in Figure 3.2 and Table 3.1 (Appendix B, Table B.1). Among the six treatment operations, approximately 42% of the fish passed when operations were within Q4, the upper quartile of the 1% of peak operating efficiency range.

Passage survival estimates for CH1 were significantly lower (both $P < 0.0042$, power > 82%) for Q4 compared to Q1 and Q2 (Table 3-2). Survival estimates were not significantly different between Q3, Q4, BOR, and ABOP (using the $P < 0.05$ and power > 80% criteria). The 95% confidence interval interpretations are presented in Table 3-2. Based on the statistical test outcomes and the 95% confidence intervals, the survival rate for treatment Q1 and Q2 are greater than the survival rates of treatments Q3, Q4 and ABOP. In addition, for CH1, the confidence intervals strongly favor BOR having a lower survival rate than Q1 and Q2. For CH1, Q1–Q2 was significantly greater than Q3–Q4 ($p = 0.001$, power = 97%) (Table 3.2; Appendix B, Table B.2).

When survival estimates were grouped into treatments LL to UL, LL to BOP, BOR, and ABOP, there was not a significant difference (all $P > 0.05$) in survival rates between any of the groups (Figure 3.3; Appendix B, Table B.3).

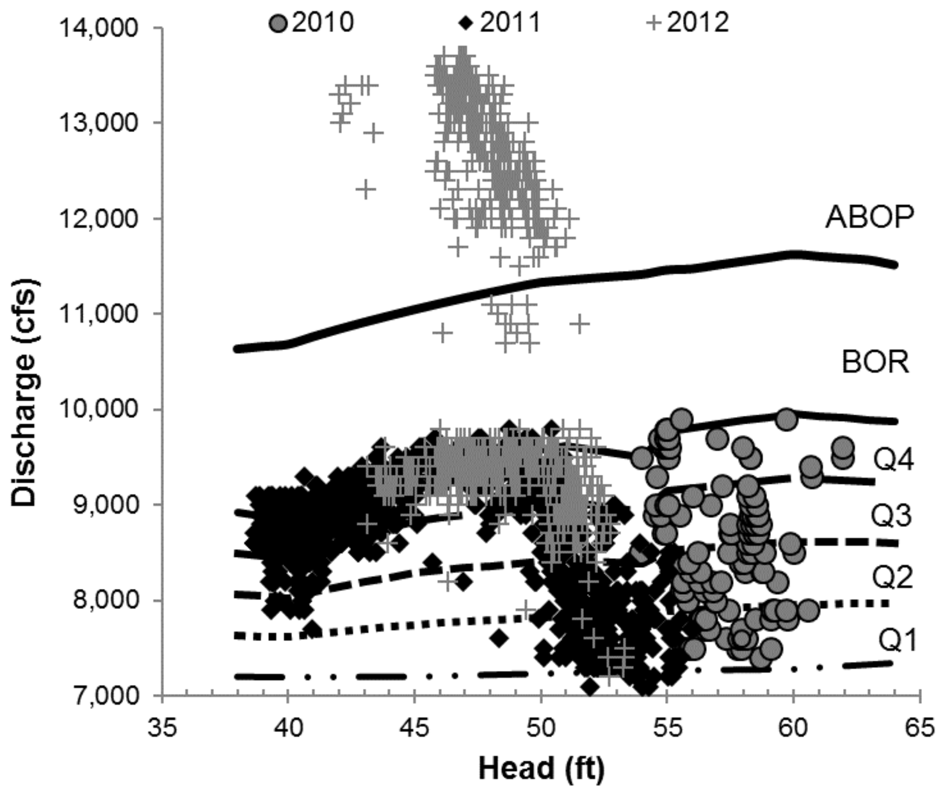

Figure 3.1. Turbine Operating Conditions for CH1 Detected Passing at B1 by Study Year. Each point represents the operating condition when an individual CH1 was detected passing through a turbine.

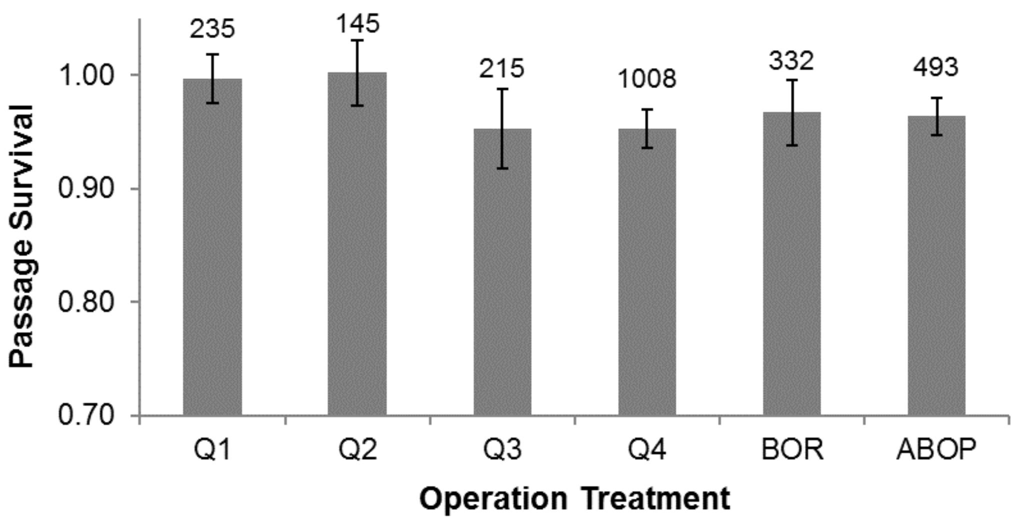

Figure 3.2. CH1 Survival Estimates with 95% Confidence Interval through B1 Turbines by Operation Treatment. Sample sizes are shown above the treatments.

Table 3.1. CH1 Survival Estimates and Passage Proportions at B1 by Treatment Group

Operation Treatment	Survival Estimate	Passage Proportion (%)
Q1	0.9971	9.7
Q2	1.0023	6.0
Q3	0.9530	8.9
Q4	0.9534	41.5
BOR	0.9672	13.7
ABOP	0.9640	20.3
LL–UL	0.9644	–
LL–BOP	0.9648	–

Table 3.2. P-values for T-tests Comparing Survival Estimates between Operation Levels for CH1 at B1 for All Test Years Combined. Survival estimates that are significantly different (P < 0.05 and power > 80%) are bolded. "*" indicate that the P < 0.05 with a power < 80%. Type II Error represents the probability of a Type II error assuming the point estimate is the true difference of the two variables. N 80% Power represents the sample size needed to reduce probability of a Type II error to 20%. CI LB and CI UB represent the confidence intervals for the lower and upper bounds, respectively.

Treatment	P-value	Power (%)	Type II Error (%)	N-80% Power	Point Estimate (%)	CI LB (%)	CI UB (%)
Q1 *vs.* Q2	0.7772	–	94	17439	-0.52	-4.13	3.09
Q1 *vs.* Q3	0.0371*	55	–	–	4.41	0.26	8.56
Q1 *vs.* Q4	**0.0018**	**88**	–	–	4.37	1.63	7.11
Q1 *vs.* BOR	0.104	–	63	883	2.99	-0.62	6.60
Q1 *vs.* ABOP	0.0175*	66	–	–	3.31	0.58	6.04
Q2 *vs.* Q3	0.0346*	56	–	–	4.93	0.36	9.50
Q2 *vs.* Q4	**0.0042**	**82**	–	–	4.89	1.55	8.23
Q2 *vs.* BOR	0.092	–	61	660	3.51	-0.57	7.59
Q2 *vs.* ABOP	0.0244*	61	–	–	3.83	0.50	7.16
Q3 *vs.* Q4	0.984	–	95	7085690	-0.04†	-3.95	3.87
Q3 *vs.* BOR	0.5414	–	91	5524	-1.42	-5.99	3.15
Q3 *vs.* ABOP	0.5807	–	91	6849	-1.10	-5.01	2.81
Q4 *vs.* BOR	0.4179	–	87	6039	-1.38	-4.72	1.96
Q4 *vs.* ABOP	0.3808	–	86	7706	-1.06	-3.43	1.31
BOR *vs.* ABOP	0.8506	–	95	82487	0.32†	-3.01	3.65
Q1–Q2 *vs.* Q3–Q4	**0.0001**	**97**	–	–	4.56	2.27	6.85

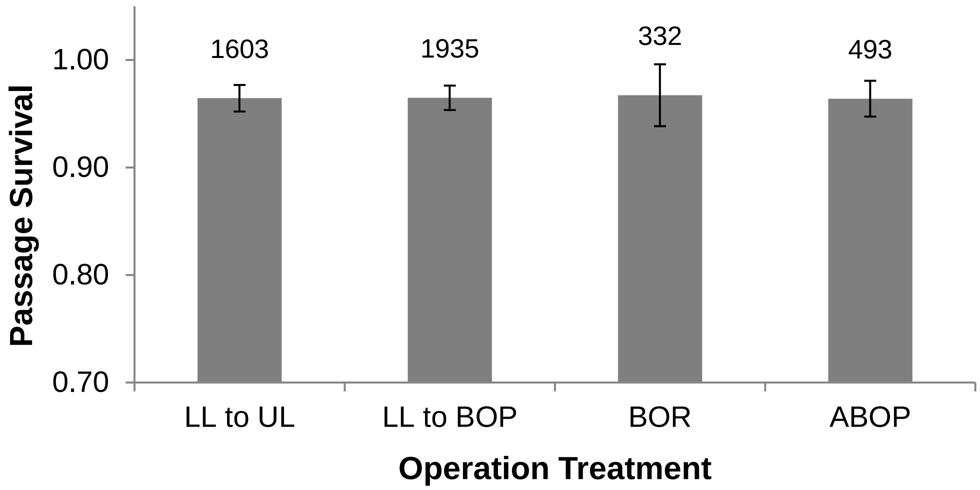

Figure 3.3. CH1 Survival Estimates with 95% Confidence Interval through B1 Turbines by Grouped Operation Treatment. Sample sizes are shown above the corresponding grouped survival estimate.

3.1.2 CH1 Passage Survival Rates at B1 by Tailrace Elevation

Each CH1 detected passing a turbine at B1 was placed into a 1 m tailrace elevation bin that corresponded to the tailrace elevation (MSL) when the fish passed into a turbine (Appendix D, Table D.1). The proportion of CH1 passing through B1 turbines was highest when the tailrace elevation was within the 8 m tailwater elevation bin (35.2%), followed by the 9 m (28.9%), 7 m (25.4%), 6 m (6.7%), and 5 m (3.8%) tailwater elevation bins.

The mean survival estimates for 5 m (0.9868, SE 0.0260) and 6 m bins (1.0052, SE 0.0152) were higher, though not statistically significant (using the $P < 0.05$, power > 80% criteria), than those of the 7 m, 8 m and 9 m bins (Figure 3.4; Appendix D, Table D.2) even with the lowest operating hours percentage compared to the other tailrace elevation bins, except for 5 m bin (Figure 3.4; Appendix D, Table D.2). If one employs a less restrictive P-value and power criteria ($P < 0.05$, power < 80%), 95% confidence intervals and point estimates, there is evidence to support that the 6 m tailrace elevation has a higher survival rate than 7 m, 8 m, and 9 m tailrace elevations (Table 3.3).

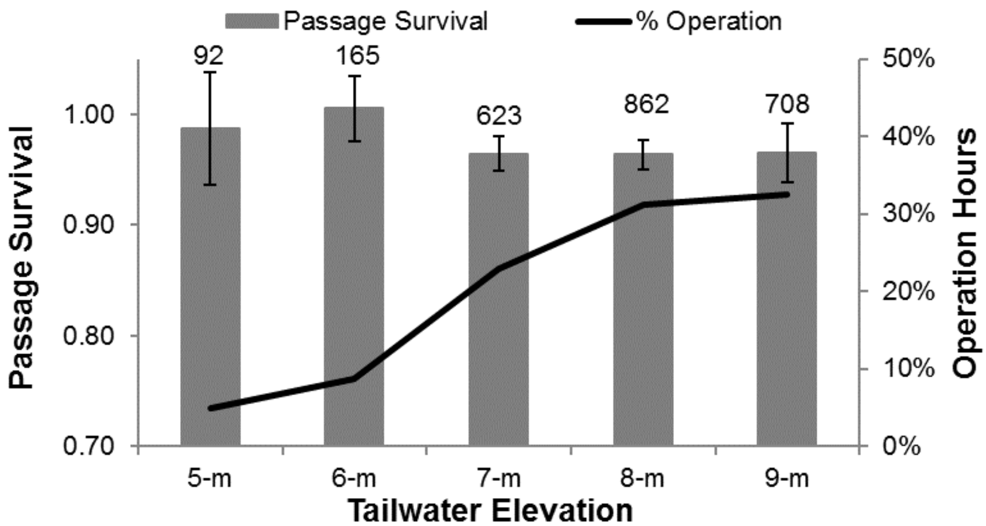

Figure 3.4. CH1 Survival Estimates Passing Turbines at B1 with 95% Confidence Interval and Percent Hours of Operation (Black Line) by Tailrace Elevation Bins. Sample sizes are shown above the estimates.

Table 3.3. P-values for T-tests Comparing Survival Estimates between Tailrace Elevations for CH1 at B1 for All Test Years Combined. Survival estimates that are significantly different (P < 0.05 and power > 80%) are bolded. "*" indicate that the P < 0.05 with a power < 80%. Type II Error represents the probability of a Type II error assuming the point estimate is the true difference of the two variables. N 80% Power represents the sample size needed to reduce the probability of a Type II error to 20%. CI LB and CI UB represent the confidence intervals for the lower and upper bounds, respectively.

Elevations	P-value	Power (%)	Type II Error (%)	N 80% Power	Point Est (%)	CI LB (%)	CI UB (%)
5 m *vs.* 6 m	0.5418	–	91	2344	-1.84	-7.77	4.09
5 m *vs.* 7 m	0.4084	–	87	1587	2.25	-3.09	7.59
5 m *vs.* 8 m	0.3857	–	86	1462	2.33	-2.94	7.60
5 m *vs.* 9 m	0.4605	–	89	3193	2.16	-3.58	7.90
6 m *vs.* 7 m	0.0175*	66	–	–	4.09	0.72	7.46
6 m *vs.* 8 m	0.0122*	71	–	–	4.17	0.91	7.43
6 m *vs.* 9 m	0.0487*	50	–	–	4.00	0.02	7.98
7 m *vs.* 8 m	0.9389	–	95	964807	0.08	-1.97	2.13
7 m *vs.* 9 m	0.954	–	95	1620608	-0.09	-3.15	2.97
8 m *vs.* 9 m	0.9097	–	95	450918	-0.17	-3.11	2.77

3.1.3 CH1 Tailrace Egress Time at B1

The median tailrace egress time for CH1 decreased with increasing turbine discharge (Table 3.4). The mean tailrace egress time and the range of egress times varied greatly within and between turbine operating conditions.

There was no significant difference (all P > 0.05) detected (based on hypothesis testing, P > 0.05, power < 80%) between operation treatments and mean egress times (Table 3.5; Appendix F, Table F.1). While there was not a statistical difference, there is weak evidence to suggest that CH1 passing within the Q1 and BOR operating ranges have a longer tailrace egress time than Q2, Q3, and Q4; and Q3 passed CH1 have shorter tailrace egress times than BOR and ABOP passed CH1.

Table 3.4. CH1 Tailrace Egress Times for CH1 at B1 by Turbine Operating Treatment

Operation Treatment	Median (h)	Mean (h)	Min (h)	Max (h)	SE	N
Q1	0.46	6.40	0.27	280.27	2.10	234
Q2	0.44	3.36	0.28	102.24	1.15	136
Q3	0.38	2.43	0.23	110.46	0.82	189
Q4	0.37	3.55	0.24	273.35	0.57	860
BOR	0.37	5.90	0.24	281.36	1.67	286
ABOP	0.30	4.23	0.21	200.41	0.70	485

Table 3.5. BON B1 Tailrace Egress Time for Operation Treatment by Individual Operation Treatment for 2010-2012 for CH1. Survival estimates that are significantly different (P < 0.05 and power > 80%) are bolded. "*" indicate that the P < 0.05 with a power < 80%. Type II Error represents the probability of a Type II error assuming the point estimate is the true difference of the two variables. N 80% Power represents the sample size needed to reduce the probability of a Type II error to 20%. CI LB and CI UB represent the confidence intervals for the lower and upper bounds, respectively.

Elevations	P-value	Power	Type II Error (%)	N 80% Power	Point Est (%)	CI LB (%)	CI UB (%)
Q1 *vs.* Q2	0.205	–	76	1035	3.04	-1.7	7.7
Q1 *vs.* Q3	0.079	–	58	580	3.97	-0.5	8.4
Q1 *vs.* Q4	0.1906	–	74	1270	2.85	-1.4	7.1
Q1 *vs.* BOR	0.8522	–	95	57658	0.5	-4.8	5.8
Q1 *vs.* ABOP	0.3273	–	84	2122	2.17	-2.2	6.5
Q2 *vs.* Q3	0.5107	–	90	2803	0.93	-1.8	3.7
Q2 *vs.* Q4	0.8823	–	95	100052	-0.19	-2.7	2.3
Q2 *vs.* BOR	0.211	–	76	1195	-2.54	-6.5	1.4
Q2 *vs.* ABOP	0.5184	–	90	4344	-0.87	-3.5	1.8
Q3 *vs.* Q4	0.2623	–	80	2549	-1.12	-3.1	0.8
Q3 *vs.* BOR	0.0628	–	54	606	-3.47	-7.1	0.2
Q3 *vs.* ABOP	0.0955	–	62	887	-1.8	-3.9	0.3
Q4 *vs.* BOP	0.1832	–	74	1534	-2.35	-5.8	1.1
Q4 *vs.* ABOP	0.4514	–	88	8790	-0.68	-2.5	1.1
BOR *vs.* ABOP	0.3567	–	85	2922	1.67	-1.9	5.2

3.2 Juvenile Steelhead (STH) at B1

3.2.1 STH Passage Survival Rates at B1 by Operating Condition

The distributions of STH detected passing through B1 turbines by turbine operating conditions during the survival studies conducted in 2010, 2011, and 2012 are shown in Figure 3.5. The detected STH were clustered within certain operating ranges (head-discharge combinations) because of fish behavior, river flow, spillway discharge, and resulting turbine operations (Figure 3.5).

B1 STH passage survival estimates for turbine operating ranges Q1 through ABOP and the number of detected fish in samples used to compute survival estimates are shown in Table 3.6. Among the six turbine operation treatments, the highest survival estimate was for operating range Q1, the lower quartile of the 1% of peak efficiency operating range. STH passage survival rate was lowest for the Q3 operating range, followed by that for passage with discharges within the Q2 operating range. STH survival rates ranged from 0.9328 to 0.9477 for the three operating conditions above the upper limit of 1% of peak efficiency (Figure 3.6; Table 3.6; Appendix B, Table B.1). More than 44% of STH passed through turbines operating in the upper quartile of the 1% of peak efficiency operating range (Q4, N = 1199).

Passage survival rates for Q1 were significantly higher (P = 0.0006, power = 93%) than survival rates for STH passing Q4 (Table 3.7). The confidence intervals strongly favors Q1 as having a significantly greater survival rate than Q2, Q3, Q4 and ABOP. In addition, the confidence intervals strongly favors BOP having a higher survival rate than Q3 and a lower survival rate than Q1. While the point estimates for Q2 were mostly negative (i.e., Q2 had a lower survival rate than the other treatments), the confidence intervals were wide and only slightly favored the negative numbers (Table 3.7).

Survival rates for combined Q1–Q2 treatments were greater than for Q3–Q4 combined, but were not significantly greater (using the $P < 0.05$ and power > 80% criteria) than survival rates above the 1% peak operating efficiency range (BOR *vs*. ABOP) (Table 3.7; Appendix B, Table B.2). The confidence intervals favors Q1–Q2 as having a significantly greater survival rate than Q3–Q4.

STH survival rate was slightly higher, but not significantly, at BOR than ABOP and when ranges were grouped LL to UL and LL to BOP (all $P > 0.05$) (Figure 3.7; Appendix B, Table B.3).

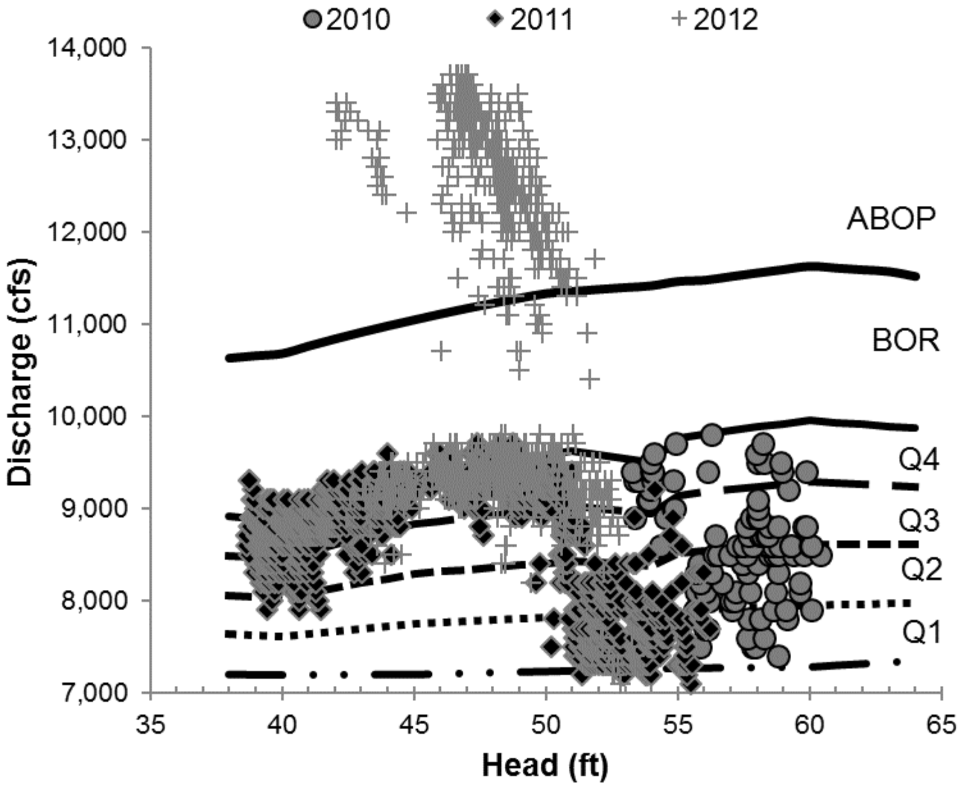

Figure 3.5. Turbine Operating Conditions for STH Detected Passing at B1 by Study Year. Each point represents the operating condition when an individual STH passed through a turbine.

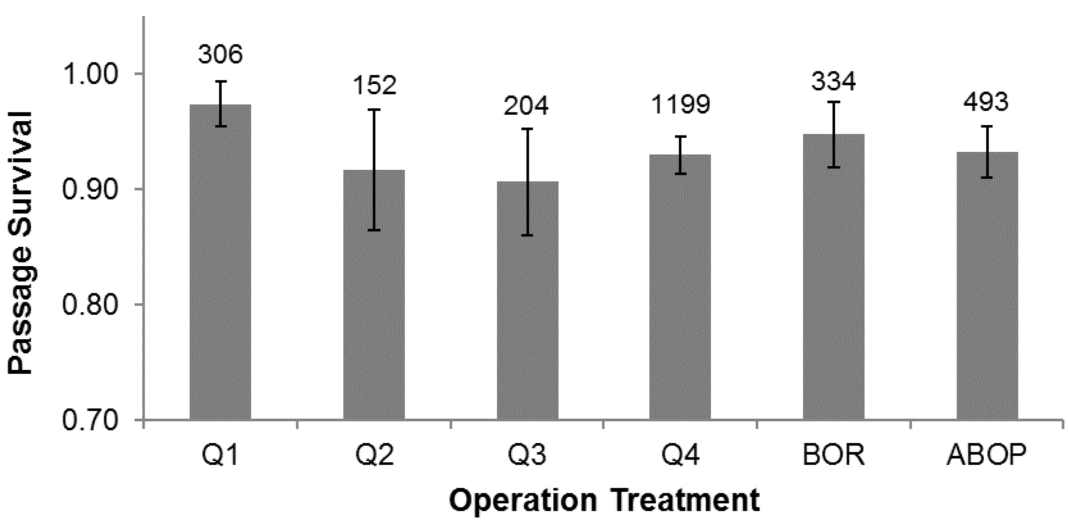

Figure 3.6. Survival Estimates with 95% Confidence Interval for STH through B1 Turbines by Operation Treatment. Sample sizes are shown above the corresponding treatment.

Table 3.6. Survival Estimates and Passage Proportions for STH at B1 by Operating Treatment Group

Operation Treatment	Survival Estimate	Passage Proportion (%)
Q1	0.9740	11.4
Q2	0.9173	5.7
Q3	0.9064	7.6
Q4	0.9300	44.6
BOR	0.9477	12.4
ABOP	0.9328	18.3
LL_UL	0.9335	–
LL_BOP	0.9357	–

Table 3.7. P-values for T-tests Comparing Survival Estimates between Operation Levels for STH at B1 for All Test Years Combined. Survival estimates that are significantly different (P < 0.05 and power > 80%) are bolded. "*" indicate that the P < 0.05 with a power < 80%. Type II Error represents the probability of a Type II error assuming the point estimate is the true difference of the two variables. N 80% Power represents the sample size needed to reduce the probability of a Type II error to 20%. CI LB and CI UB represent the confidence intervals for the lower and upper bounds, respectively.

Treatment	P-value	Power (%)	Type II Error (%)	N-80% Power	Point Estimate (%)	CI LB (%)	CI UB (%)
Q1 *vs.* Q2	0.0468*	51	–	–	5.67	0.08	11.26
Q1 *vs.* Q3	0.008*	76	–	–	6.76	1.78	11.74
Q1 *vs.* Q4	**0.0006**	**93**	–	–	4.40	1.88	6.92
Q1 *vs.* BOR	0.1297	–	67	1112	2.63	-0.77	6.03
Q1 *vs.* ABOP	0.0063*	78	–	–	4.12	1.17	7.07
Q2 *vs.* Q3	0.759	–	94	14619	1.09	-5.89	8.07
Q2 *vs.* Q4	0.6497	–	93	9307	-1.27	-6.76	4.22
Q2 *vs.* BOR	0.316	–	83	1507	-3.04	-8.99	2.91
Q2 *vs.* ABOP	0.5936	–	92	5651	-1.55	-7.25	4.15
Q3 *vs.* Q4	0.342	–	84	2742	-2.36	-7.23	2.51
Q3 *vs.* BOR	0.1327	–	68	832	-4.13	-9.52	1.26
Q3 *vs.* ABOP	0.3108	–	83	1986	-2.64	-7.75	2.47
Q4 *vs.* BOR	0.2846	–	81	3786	-1.77	-5.01	1.47
Q4 *vs.* ABOP	0.8426	–	95	147006	-0.28	-3.05	2.49
BOR *vs.* ABOP	0.4155	–	87	4691	1.49	-2.10	5.08
Q1–Q2 *vs.* Q3–Q4	0.0388*	54	–	–	2.80	0.14	5.46

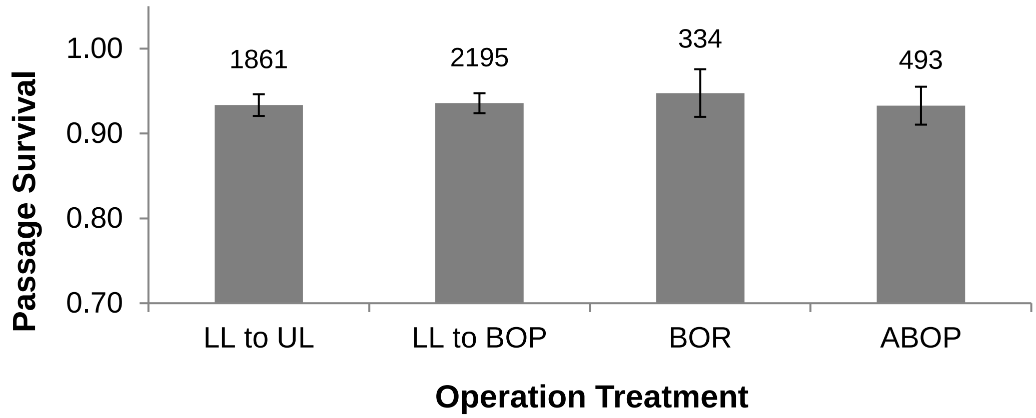

Figure 3.7. Survival Estimates with 95% Confidence Interval for STH Passing through B1 Turbines by Grouped Operation Treatment. Sample sizes are shown above the corresponding grouped survival estimate.

3.2.2 STH Passage Survival Rates at B1 by Tailwater Elevation

STH detected passing turbines at B1 were assigned to 1 m tailrace elevation bins that contained the tailrace elevation relative to MSL at the time they passed into a turbine (Appendix D, Table D.1). The survival estimate for STH in the 5 m bin was lower (0.8605, SE 0.0446) than that for fish in any of the other tailwater elevation bins (6 m, 7 m, 8 m, and 9 m), though the survival estimates were not statistically significant (all $P > 0.0586$) (Figure 3.8, Table 3.8, Appendix D, Table D.2). The 5 m elevation has a lower survival rate than other elevation bins. However, the survival rate for 5 m elevation is not statistically different than survival rates for the other elevation bins due to the wide confidence interval.

The limited powerhouse operating time when tailrace elevations were low affected the number of STH detected passing into turbines for tailrace elevations in the 5 m bin. STH passage proportion through B1 turbines was highest for the 8 m tailwater elevation bin (33.8%), followed by the 9 m (28.7%), 7 m (25.8%), 6 m (8.6%), and 5 m (3.1%) tailwater elevation bins.

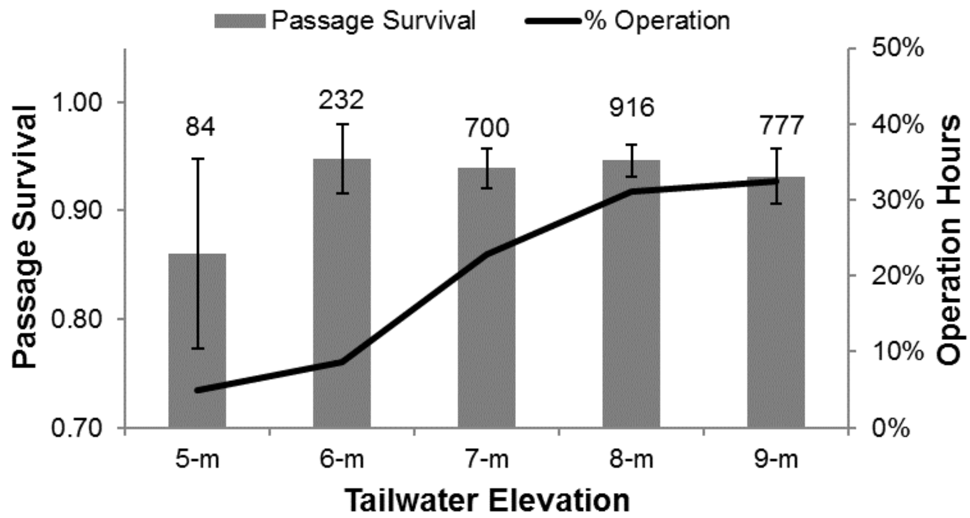

Figure 3.8. Survival Estimates for STH Passing Turbines at B1 with 95% Confidence Interval with Percent Hours of Turbine Operation (Black Line) by Tailrace Elevation. Sample sizes are shown above the estimates.

Table 3.8. P-values for T-tests Comparing Survival Estimates between Operation Levels for STH at B1 for All Test Years Combined. Survival estimates that are significantly different ($P < 0.05$ and power > 80%) are bolded. "*" indicate that the $P < 0.05$ with a power < 80%. Type II Error represents the probability of a Type II error assuming the point estimate is the true difference of the two variables. N 80% Power represents the sample size needed to reduce the probability of a Type II error to 20%. CI LB and CI UB represent the confidence intervals for the lower and upper bounds, respectively.

Elevation Bins	P-value	Power	Type II Error (%)	N 80% Power	Point Est (%)	CI LB (%)	CI UB (%)
5 m *vs*. 6 m	0.0659	–	55	235	-8.75	-18.08	0.58
5 m *vs*. 7 m	0.0843	–	59	288	-7.87	-16.81	1.07
5 m *vs*. 8 m	0.0586	–	53	238	-8.57	-17.45	0.31
5 m *vs*. 9 m	0.125	–	67	459	-7.13	-16.24	1.98
6 m *vs*. 7 m	0.6352	–	92	12126	0.88	-2.76	4.52
6 m *vs*. 8 m	0.9197	–	95	277719	0.18	-3.32	3.68
6 m *vs*. 9 m	0.4325	–	88	5677	1.62	-2.43	5.67
7 m *vs*. 8 m	0.5597	–	91	18212	-0.70	-3.05	1.65
7 m *vs*. 9 m	0.6405	–	92	27061	0.74	-2.37	3.85
8 m *vs*. 9 m	0.3379	–	84	6958	1.44	-1.51	4.39

3.2.3 STH Tailrace Egress Time at B1

The median tailrace egress time for STH trend was shorter with increasing turbine discharge (Table 3.9; Appendix F, Table F.2). The mean tailrace egress time and range of egress times varied greatly between turbine operating conditions.

Even with the variation, Q4 and BOR had significantly greater mean egress times than for Q1 and Q3 (all P < 0.002, power > 96%) (Table 3.10). The confidence intervals (and less restrictive hypothesis testing [P < 0.05, power < 80%]) strongly favor BOR having a greater egress time than Q2, Q4, and ABOP, while ABOP had a greater mean egress time than Q1, Q2, and Q3.

Table 3.9. Egress Times for STH at B1 by Turbine Operating Treatment

Operation Treatment	Median (h)	Mean (h)	Min (h)	Max (h)	SE	N
Q1	0.60	8.51	0.25	254.90	1.69	301
Q2	0.57	9.84	0.25	589.93	4.57	146
Q3	0.63	7.75	0.26	225.21	2.10	146
Q4	0.52	17.14	0.24	419.08	1.39	1013
BOR	0.58	23.96	0.25	404.61	3.49	282
ABOP	0.42	15.11	0.20	415.51	2.21	476

Table 3.10. BON B1 Tailrace Egress Time for Operation Treatment by Individual Operation Treatment for 2010–2012 for STH. Survival estimates that are significantly different (P < 0.05 and power > 80%) are bolded. "*" indicate that the P < 0.05 with a power < 80%. Type II Error represents the probability of a Type II error assuming the point estimate is the true difference of the two variables. N 80% Power represents the sample size needed to reduce the probability of a Type II error to 20%. CI LB and CI UB represent the confidence intervals for the lower and upper bounds, respectively.

Elevations	P-value	Power (%)	Type II Error (%)	N 80% Power	Point Est (%)	CI LB (%)	CI UB (%)
Q1 *vs.* Q2	0.785	–	94	17421	-1.33	-10.9	8.2
Q1 *vs.* Q3	0.7781	–	94	20522	0.76	-4.5	6.1
Q1 *vs.* Q4	**0.0001**	**98**	–	–	-8.63	-12.9	-4.3
Q1 *vs.* BOR	**0.0001**	**98**	–	–	-15.45	-23.1	-7.8
Q1 *vs.* ABOP	0.0179	66	–	–	-6.6	-12.1	-1.1
Q2 *vs.* Q3	0.678	–	93	6681	2.09	-7.8	12.0
Q2 *vs.* Q4	0.1267	–	67	739	-7.3	-16.7	2.1
Q2 *vs.* BOR	0.0145*	69	–	–	-14.12	-25.4	-2.8
Q2 *vs.* ABOP	0.2996	–	82	1524	-5.27	-15.2	4.7
Q3 *vs.* Q4	**0.0002**	**96**	–	–	-9.39	-14.3	-4.4
Q3 *vs.* BOR	**0.0001**	**98**	–	–	-16.21	-24.2	-8.2
Q3 *vs.* ABOP	0.0161*	67	–	–	-7.36	-13.3	-1.4
Q4 *vs.* BOP	0.0697	–	56	912	-6.82	-14.2	0.5
Q4 *vs.* ABOP	0.437	–	88	8167	2.03	-3.1	7.2
BOR *vs.* ABOP	0.0325*	57	–	–	8.85	0.7	17.0

3.3 Subyearling Chinook Salmon (CH0) at B1

3.3.1 CH0 Passage Survival Rates at B1 by Operating Condition

During the survival studies conducted in 2010 and 2012 at B1, detected CH0 were distributed across the entire 1% of peak efficiency turbine operating range. However, CH0 were clustered at certain operation levels, because of river discharge and the turbine operations needed to respond to meet power production needs and river discharge volumes (Figure 3.9). Turbines were seldom operated outside of the upper limit of the 1% of peak efficiency operating range in summer, and, when they were, the limit was only exceeded by several hundred cubic feet per second.

Survival estimates for B1 CH0 for operation ranges Q1 through BOR, and the sample size for the estimates, are shown in Figure 3.10 and Table 3.11 (Appendix B, Table B.1). Turbines at B1 were not operated up to BOP in either the 2010 or 2012 summer seasons, because river flows were not high enough to require turbine operation outside of the 1% of peak efficiency operating range. CH0 survival estimates were highest for operating range Q3, followed by Q4 and BOR. Lowest survival estimates were found when turbines were operating at Q1 and Q2, the lower half of the 1% of peak efficiency operating range.

The CH0 survival estimates were not significantly different between operation ranges (all $P > 0.1302$; Table 3.12). Based on the confidence intervals, though, there is a potential that Q3 has a higher survival rate than Q2, Q4, and BOR. More than 60% of the CH0 detected passed when turbines were operating in the Q4 operating range and only about 5% of fish were detected when turbines were running in the Q1 and Q2 operating ranges (Figure 3.10, Appendix B, Table B.2).

There was no significant different using either hypothesis testing or confidence intervals when comparing the group ranges of Q1–Q2 to Q3–Q4. With the current samples sizes, if the true survival rate of sub-yearling Chinook salmon passing through B1 with treatments Q1–Q2 is 3.2% lower than the true survival rate of sub-yearling Chinook salmon passing through B1 with treatments Q3–Q4, then the probability of detecting a statistical difference is 22%. To increase the probability of detecting a statistical difference to 80%, a greater sample size is needed ($N = 909$).

The differences in the survival estimates for grouped treatments (LL to UL, LL to BOP, BOR, and ABOP), were less than 0.002, which was not significantly different (all $P > 0.05$) (Figure 3.11, Appendix B, Table B.3). Overall, the results for CH0 are mixed and have larger confidence intervals.

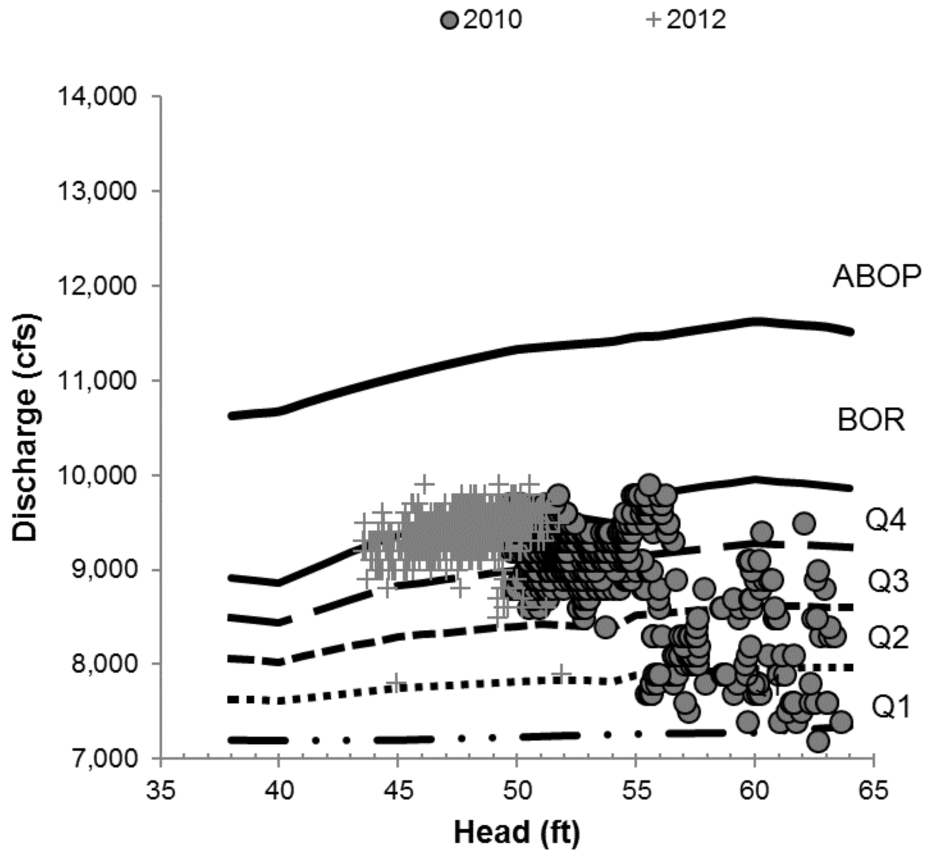

Figure 3.9. Turbine Operating Conditions for CH0 Detected Passing at B1 by Study Year. Each point represents the operating condition when an individual CH0 passed through a turbine.

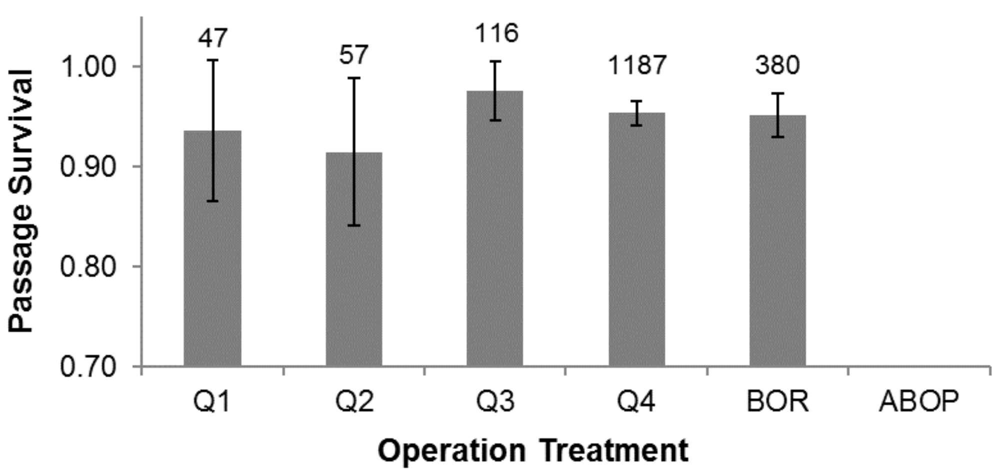

Figure 3.10. Survival Estimates with 95% Confidence Interval for CH0 Passing through B1 Turbines by Operation Treatment. Sample sizes are shown above the corresponding treatment.

Table 3.11. Survival Estimates and Passage Proportions for CH0 at B1 by Operation Treatment Group

Operation Treatment	Survival Estimate	Passage Proportion (%)
Q1	0.9362	2.6
Q2	0.9145	3.2
Q3	0.9760	6.5
Q4	0.9537	66.4
BOR	0.9515	21.3
LL-UL	0.9534	–
LL-BOP	0.9530	–

Table 3.12. P-values for T-tests Comparing Survival Estimates between Operation Levels for CH0 at B1 for All Test Years Combined. Survival estimates that are significantly different (P < 0.05 and power > 80%) are bolded. "*" indicate that the P < 0.05 with a power < 80%. Type II Error represents the probability of a Type II error assuming the point estimate is the true difference of the two variables. N 80% Power represents the sample size needed to reduce the probability of a Type II error to 20%. CI LB and CI UB represent the confidence intervals for the lower and upper bounds, respectively.

Treatment	P-value	Power	Type II Error (%)	N-80% Power	CI LB (%)	CI UB (%)
Q1 *vs.* Q2	0.6764	–	93	2388	2.17	-8.11
Q1 *vs.* Q3	0.3051	–	83	430	-3.98	-11.62
Q1 *vs.* Q4	0.6295	–	92	2786	-1.75	-8.87
Q1 *vs.* BOP	0.6828	–	93	3624	-1.53	-8.88
Q1 *vs.* ABOP	–	–	–	–	–	–
Q2 *vs.* Q3	0.1302	–	67	224	-6.15	-14.13
Q2 *vs.* Q4	0.3043	–	82	661	-3.92	-11.40
Q2 *vs.* BOP	0.3462	–	84	739	-3.70	-11.41
Q2 *vs.* ABOP	–	–	–	–	–	–
Q3 *vs.* Q4	0.1693	–	72	1176	2.23	-0.95
Q3 *vs.* BOP	0.1893	–	74	964	2.45	-1.21
Q3 *vs.* ABOP		–	–	–	–	–
Q4 *vs.* BOP	0.8646	–	95	156340	0.22	-2.31
Q4 *vs.* ABOP	–	–	–	–	–	–
BOP *vs.* ABOP	–	–	–	–	–	–
Q1–Q2 *vs.* Q3–Q4	0.234	–	78	909	-3.20	-8.47

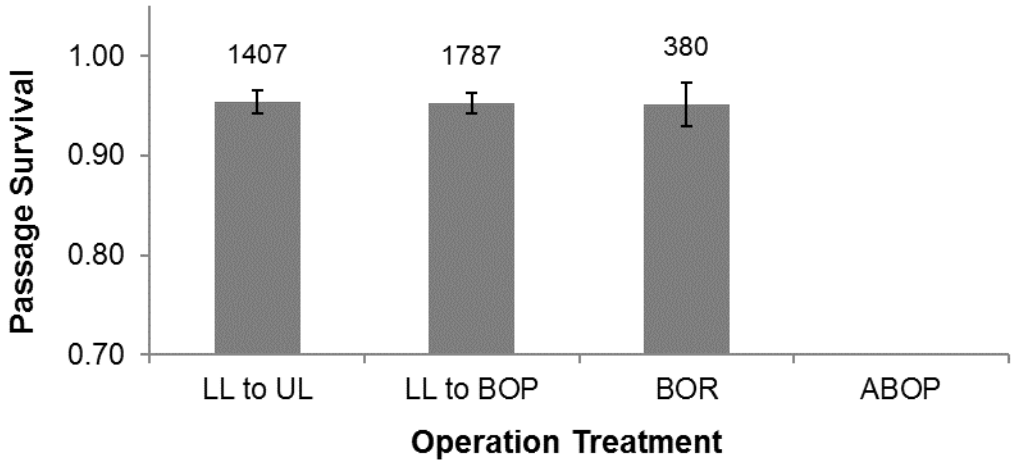

Figure 3.11. Survival Estimates with 95% Confidence Interval for CH0 Passing through B1 Turbines by Grouped Operation Treatment. Sample sizes are shown above the corresponding grouped survival estimate.

3.3.2 CH0 Passage Survival Rates at B1 by Tailwater Elevation

CH0 detected passing turbines at B1 were assigned to 1 m tailrace elevation bins, depending upon the tailrace elevation relative to MSL at the time they passed (Appendix D, Table D.2). Turbine operating times were lowest when tailwater elevations were in the ranges of the 5 m, 6 m, and 9 m tailwater elevation bins (Figure 3.12; Appendix D, Table D.1). More CH0 passed through B1 turbines when the tailrace elevations were within the 7 m (31.7%) and 8 m (45.5%) bins than during tailwater elevations contained within 9 m (9.6%), 6 m (7.4%), and 5 m (5.8%) bins (Figure 3.12).

The survival estimate (0.8939, SE 0.0305) for CH0 that passed when the tailwater was low (5 m bin) was lower than those for fish that passed at higher tailwater elevations. CH0 survival rate was highest for passage during tailwater elevations in the 6 m bin (0.9811, SE 0.0132), followed by 7 m bin (0.9604, SE 0.0088), 8 m bin (0.9517, SE 0.0077), and 9 m bin (0.9483, SE 0.0170) (Figure 3.12; Appendix D, Table D.2).

Turbine passage survival rates for CH0 did not statistically differ between the tailwater bins (Table 3.13, using $P < 0.05$, power > 80% criteria). Based on a less restrictive hypothesis test criteria ($P < 0.05$, power < 80%) and confidence interval test, there is evidence to support 5 m tailwater elevation is favored to have a lower survival rate than the elevations 6 m, 7 m, 8 m, and 9 m. Similarly, 6 m is favored to have a higher survival rate than an elevation of 7 m, 8 m, and 9 m for CH0.

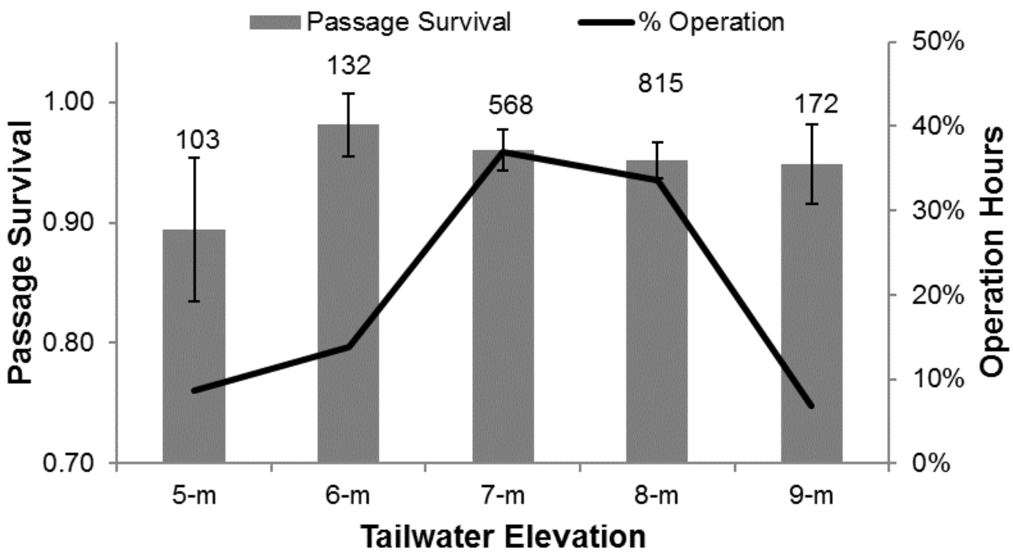

Figure 3.12. Survival Estimates for CH0 Passing through Turbines at B1 with 95% Confidence Interval with Percent Hours of Operation (Black Line) by Tailrace Elevation. Sample sizes are shown above the estimates.

Table 3.13. P-values for T-tests Comparing Survival Estimates between Tailrace Elevations for CH0 at B1 for All Test Years Combined. Survival estimates that are significantly different (P < 0.05 and Power > 80%) are bolded. "*" indicate that the P < 0.05 with a power < 80%. Type II Error represents the probability of a Type II error assuming the point estimate is the true difference of the two variables. N 80% Power represents the sample size needed to reduce the probability of a Type II error to 20%. CI LB and CI UB represent the confidence intervals for the lower and upper bounds, respectively.

Bins	P-value	Power (%)	Type II Error (%)	N 80% Power	Point Est (%)	CI LB (%)	CI UB (%)
5 m vs. 6 m	0.0093*	74	–	–	-8.72	-15.27	-2.17
5 m vs. 7 m	0.0366*	55	–	–	-6.65	-12.88	-0.42
5 m *vs.* 8 m	0.0665	–	55	340	-5.78	-11.95	0.39
5 m *vs.* 9 m	0.1204	–	66	389	-5.44	-12.31	1.43
6 m *vs.* 7 m	0.1924	–	74	1231	2.07	-1.04	5.18
6 m *vs.* 8 m	0.0547	–	52	649	2.94	-0.06	5.94
6 m *vs.* 9 m	0.1286	–	67	534	3.28	-0.96	7.52
7 m *vs.* 8 m	0.457	–	88	9586	0.87	-1.42	3.16
7 m *vs.* 9 m	0.5275	–	90	5037	1.21	-2.55	4.97
8 m *vs.* 9 m	0.8555	–	95	66691	0.34	-3.32	4.00

3.3.3 CH0 Tailrace Egress Time at B1

CH0 median tailrace egress time generally decreased with increasing operation condition from low to high discharge (Table 3.14; Appendix F, Table F.3). There was little variation in median egress time for fish passing during Q3, Q4, and BOR operating conditions. The mean and range of tailrace egress times varied greatly between turbine operating conditions.

The tailrace egress time for BOR is significantly greater than the tailrace egress time for Q2 and Q3, and Q4 is significantly greater than Q2 (all P < 0.0033, power > 84%) (Table 3.15). The confidence intervals and less restrictive hypothesis test (P < 0.05, power < 80%) strongly favors BOP as having a greater tailrace egress time than Q1. Overall, there is evidence to suggest the operation treatments Q4 and BOP have greater mean tailrace egress times compared to the other operation treatments.

Table 3.14. Egress Times at B1 for CH0 by Turbine Operating Treatment

Operation Treatment	Median (h)	Mean (h)	Min (h)	Max (h)	SE	N
Q1	0.46	2.17	0.29	68.26	1.45	47
Q2	0.44	1.22	0.32	31.24	0.56	56
Q3	0.39	1.67	0.25	44.93	0.53	116
Q4	0.40	3.81	0.24	622.50	0.68	1148
BOR	0.40	4.33	0.27	127.56	0.68	363

Table 3.15. BON B1 Tailrace Egress Time for Operation Treatment by Individual Operation Treatment for 2010-2012 for CH0. Survival estimates that are significantly different (P < 0.05 and power > 80%) are bolded. "*" indicate that the P < 0.05 with a power < 80%. Type II Error represents the probability of a Type II error assuming the point estimate is the true difference of the two variables. N 80% Power represents the sample size needed to reduce the probability of a Type II error to 20%. CI LB and CI UB represent the confidence intervals for the lower and upper bounds, respectively.

Elevations	P-value	Power (%)	Type II Error (%)	N 80% Power	Point Est (%)	CI LB (%)	CI UB (%)
Q1 *vs.* Q2	0.5425	–	91	1032	0.95	-2.1	4.0
Q1 *vs.* Q3	0.7465	–	94	4176	0.5	-2.5	3.5
Q4 *vs.* BOR	0.5888	–	92	20307	-0.52	-2.4	1.4
Q1 *vs.* BOR	0.1782	–	73	451	-2.16	-5.3	1.0
Q2 *vs.* Q3	0.5602	–	91	1967	-0.45	-2.0	1.1
Q3 *vs.* Q4	0.0132*	70	–	–	-2.14	-3.8	-0.4
Q2 *vs.* BOR	**0.0005**	**94**	–	–	-3.11	-4.8	-1.4
Q2 *vs.* Q4	**0.0033**	**84**	–	–	-2.59	-4.3	-0.9
Q3 *vs.* BOR	**0.0022**	**87**	–	–	-2.66	-4.4	-1.0
Q1 *vs.* Q4	0.306	–	82	1841	-1.64	-4.8	1.5

4.0 Results—Bonneville Dam Powerhouse 2

The method used to partition the range of turbine operations for B2 within 1% of peak efficiency into the operations quartiles Q1, Q2, Q3, and Q4 is described in Methods (Section 2.0) and additional details are provided in Appendix A (Table A.2 and Table A.3.). Turbine passage survival estimates and other statistics describing passage of CH1, STH, and CH0 through turbines at B2 within turbine operation quartiles are presented in the following sections and are available in Appendix B. Data for passage of tagged juvenile salmonids through B2 turbines from years 2008–2012 were used for the analyses. Results in Sections 4.1 through 4.3 are for periods when STSs were deployed in the turbine intakes. Section 4.4 compares survival rates with and without STSs deployed in the turbine intakes. Additional data for this section can be found in Appendices D and F.

4.1 Yearling Chinook Salmon (CH1) at B2

4.1.1 CH1 Passage Survival Rates at B2 by Operating Condition

During the survival studies conducted from 2008 through 2012 for CH1, turbines at B2 were operated over the 1% of peak efficiency operating range. CH1 were clustered within certain turbine operating ranges within years of the study because of the turbine operations used in response to operation criteria designated in the Fish Passage Plan, power production needs and the differences in river discharge between years (Figure 4.1).

Survival estimates for B2 CH1 detected passing turbines within each of the four operating range quartiles, and the number of detected fish (sample size) used for survival estimates during the spring 2008–2012 studies are shown in Figure 4.2 and Table 4.1. The survival estimates among the quartiles (i.e., Q1 to Q4), differed by less than 0.0075. Survival estimates ranged from 0.9501 for Q3 to 0.9575 for Q2.

There were no significant differences between the survival estimates between any of the quartiles (all $P > 0.6927$) (Table 4.2; Appendix B, Table B.4). None of the examined operations were found to have strong trends using the confidence interval criteria. A large number of point estimates for CH1 were found to be biologically insignificant and contained mixed results. Splitting the data by years may have provided better insight into potential operation effects. However, increases in sample sizes (est. 17,200–559,000) would be needed to address the question statistically.

The proportion of fish detections (sample size) within the quartiles was skewed to the lower half of the 1% operating range with 64.4% of the fish passing B2 in the Q1–Q2 quartiles (Figure 4.3; Appendix B, Table B.4). Similar to survival estimates for individual operating quartiles, the difference in survival estimates between the lower and upper halves of the 1% of peak efficiency operating range was only 0.0018. The turbine passage survival estimate for Q1–Q2 was 0.9556 (SE 0.0063) and that for Q3–Q4 was 0.9538 (SE 0.0090). The turbine passage survival estimates were not significantly different ($P > 0.8699$, Table 4.2) between the lower half (Q1–Q2) and upper half (Q3–Q4) of the 1% operating range (Appendix B, Table B.5). In order to assess this question statistically, a much greater sample size would be needed ($N = 272,844$).

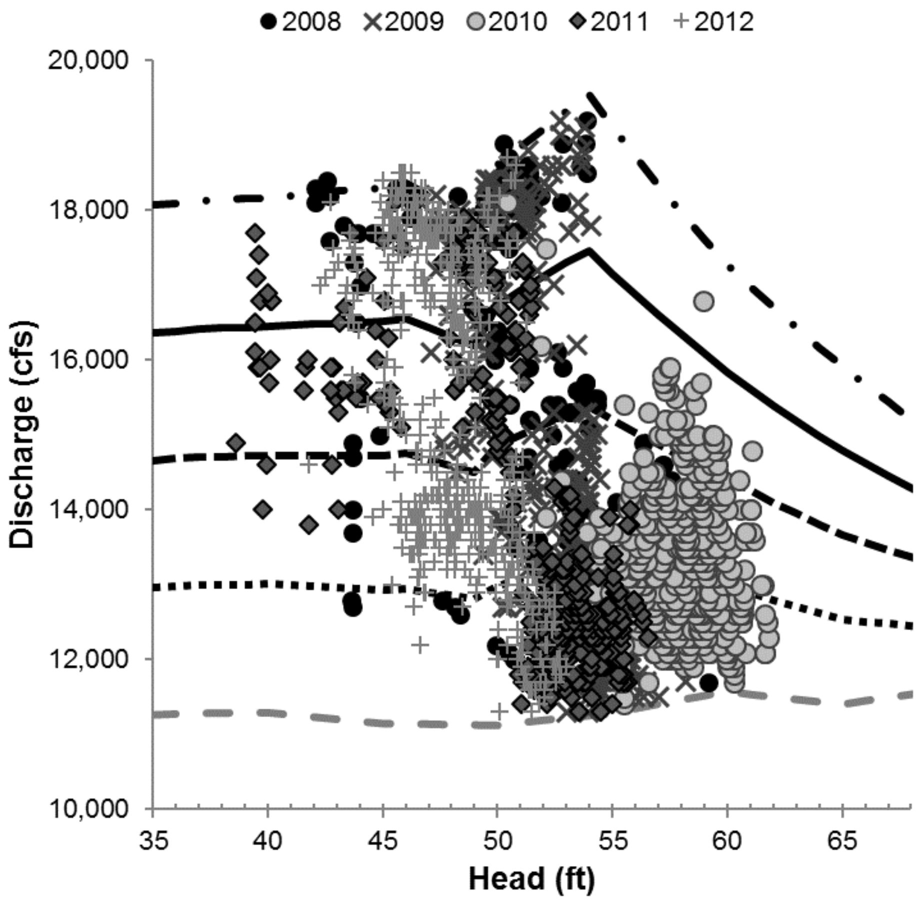

Figure 4.1. Turbine Operating Conditions for CH1 Detected Passing through Turbines at B2 by Study Year. Each point represents the operating condition when an individual CH1 passed through a turbine.

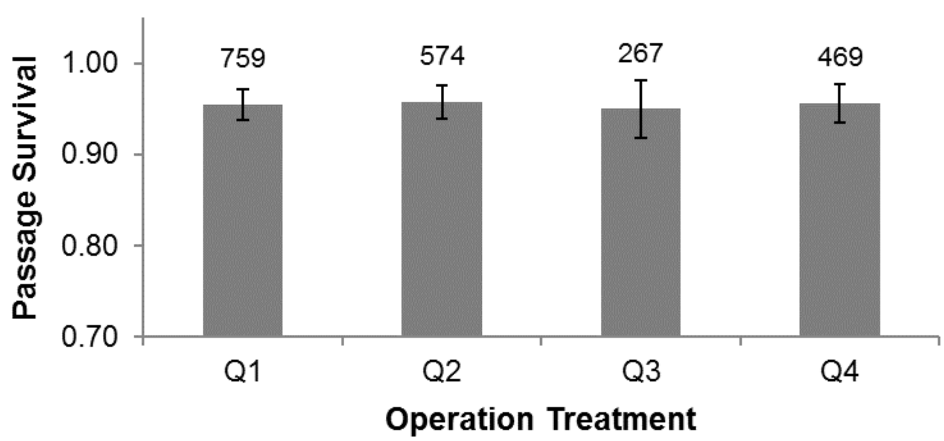

Figure 4.2. Survival Estimates with 95% Confidence Interval for CH1 Passing through B2 Turbines by Operation Treatment. Sample sizes are shown above the corresponding treatment.

Table 4.1. CH1 Survival Estimates and Passage Proportions at B2 by Operation Treatment

Operation Treatment	Survival Estimate	Passage Proportion (%)
Q1	0.9545	36.7
Q2	0.9575	27.7
Q3	0.9501	12.9
Q4	0.9563	22.7

Table 4.2. P-values for T-tests Comparing Survival Estimates between Operation Levels for CH1 at B2 for All Test Years Combined. Survival estimates that are significantly different ($P < 0.05$ and power > 80%) are bolded. "*" indicate that the $P < 0.05$ with a power < 80%. Type II Error represents the probability of a Type II error assuming the point estimate is the true difference of the two variables. N 80% Power represents the sample size needed to reduce the probability of a Type II error to 20%. CI LB and CI UB represent the confidence intervals for the lower and upper bounds, respectively.

Treatment	P-value	Power	Type II Error (%)	N 80% Power	Point Est (%)	CI LB (%)	CI UB (%)
Q1 *vs.* Q2	0.8128	–	94	92606	-0.30	-2.78	2.18
Q1 *vs.* Q3	0.8118	–	94	52150	0.44	-3.19	4.07
Q1 *vs.* Q4	0.8962	–	95	269676	-0.18	-2.89	2.53
Q2 *vs.* Q3	0.6927	–	93	17172	0.74	-2.93	4.41
Q2 *vs.* Q4	0.9322	–	95	558530	0.12	-2.65	2.89
Q3 *vs.* Q4	0.7506	–	94	25517	-0.62	-4.45	3.21
Q1–Q2 *vs.* Q3–Q4	0.8699	–	95	272844	0.18	-1.97	2.33

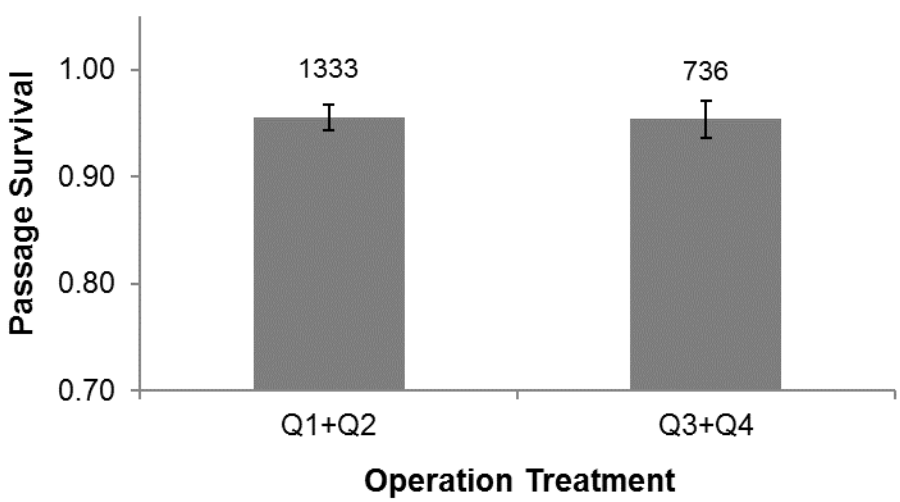

Figure 4.3. Survival Estimates with 95% Confidence Interval for CH1 Passing through B2 Turbines within the Lower and Upper Halves of the 1% of Peak Efficiency Operating Range. Sample sizes are shown above the corresponding treatment.

4.1.2 CH1 Passage Survival Rates at B2 by Tailwater Elevation

CH1 detected passing turbines at B2 were assigned to 1 m tailrace elevation bins relative to MSL that contained the tailrace elevation when they passed into a turbine (Figure 4.4). The proportion of CH1 passing through B2 was highest when tailwater was within the 6 m (24.9%) and 8 m (23.9%) tailwater elevation bins (Figure 4.4; Appendix D, Table D.3).

Survival estimates were lowest for CH1 that passed when tailwater was within the 9 m tailrace bin (0.9167, SE 0.0222). The survival estimates for the 5 m, 6 m, 7 m, and 8 m bins were within a 0.0088 range (5 m [0.9515, SE 0.0120]; 6 m [0.9510, SE 0.0106]; 7 m [0.9577, SE 0.0102]; and 8 m [0.9598, 0.0091]). Survival estimates were not significantly different between tailwater elevations (all $P > 0.0728$) (Table 4.3). For Ch1, the confidence intervals favor an elevation 9 m having a lower survival rate than 7 m and 8 m, but were not statistically different from 6 m.

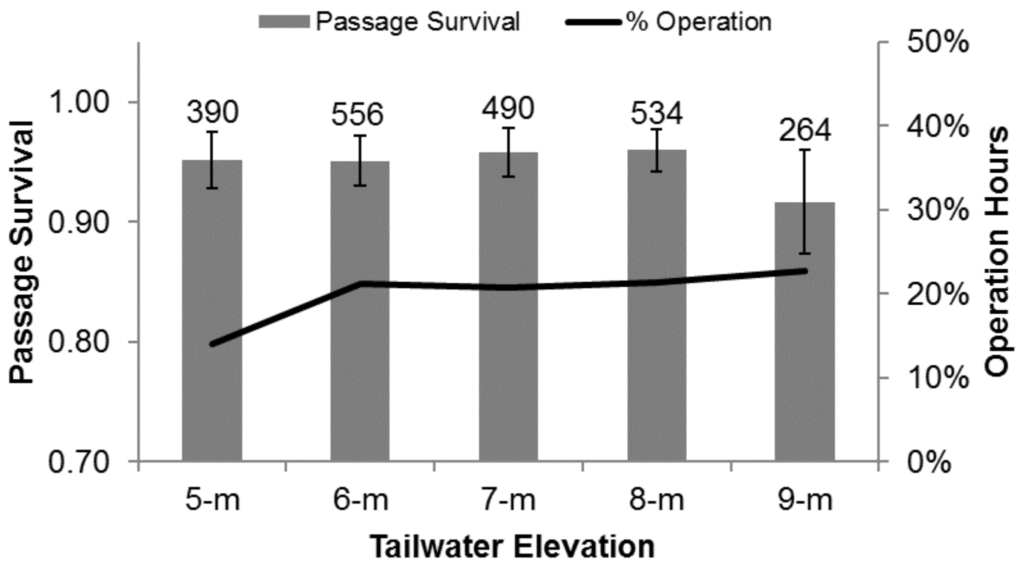

Figure 4.4. Survival Estimates for CH1 Passing through Turbines at B2 with 95% Confidence Intervals with Percent Hours of Operation (Black Line) by Tailrace Elevation. Sample sizes are shown above the estimates.

Table 4.3. P-values for T-tests Comparing Survival Estimates between Tailrace Elevations for CH1 at B2 for All Test Years Combined. Survival estimates that are significantly different (P < 0.05 and power > 80%) are bolded. "*" indicate that the P < 0.05 with a power < 80%. Type II Error represents the probability of a Type II error assuming the point estimate is the true difference of the two variables. N 80% Power represents the sample size needed to reduce the probability of a Type II error to 20%. CI LB and CI UB represent the confidence intervals for the lower and upper bounds, respectively.

Bins	P-value	Power	Type II Error (%)	N 80% Power	Point Est (%)	CI LB (%)	CI UB (%)
5 m vs. 6 m	0.9751	–	95	3732226	0.05	-3.09	3.19
5 m vs.7 m	0.6939	–	93	21925	-0.62	-3.71	2.47
5 m *vs.* 8 m	0.5817	–	91	11461	-0.83	-3.79	2.13
5 m *vs.* 9 m	0.1684	–	72	1211	3.48	-1.48	8.44
6 m *vs.* 7 m	0.6489	–	93	19874	-0.67	-3.56	2.22
6 m *vs.* 8 m	0.5289	–	90	10834	-0.88	-3.62	1.86
6 m *vs.* 9 m	0.1636	–	71	1288	3.43	-1.40	8.26
7 m *vs.* 8 m	0.8779	–	95	169761	-0.21	-2.89	2.47
7 m *vs.* 9 m	0.0937	–	61	848	4.10	-0.70	8.90
8 m *vs.* 9 m	0.0728	–	57	739	4.31	-0.40	9.02

4.1.3 CH1 Tailrace Egress Time at B2

The median tailrace egress time for CH1 decreased with increasing turbine operating condition from low to high discharge (Table 4.4; Appendix F, Table F.1). The mean and range of egress times varied greatly within and between the turbine operation quartiles.

Passage survival estimates were significantly greater in the Q2 treatment when compared to the Q4 (P = 0.0018, power = 88%; Table 4.5). Based on the confidence intervals, the Q1 treatment is strongly favored to have a lower tailrace egress time than Q2 and Q3. In addition, the Q3 treatment has a greater tailrace egress time than Q4.

Table 4.4. Tailrace Egress Time at B2 Relative to Turbine Operating Treatment during CH1 Passage

Operation Treatment	Median (h)	Min (h)	Max (h)	Mean (h)	SE	N
Q1	0.65	0.28	18.53	0.77	0.04	514
Q2	0.65	0.25	15.53	0.86	0.06	350
Q3	0.61	0.29	8.61	0.92	0.12	111
Q4	0.55	0.25	3.41	0.65	0.03	141

Table 4.5. P-values for T-tests Comparing Survival Estimates between Egress Time Relative to Turbine Operations for CH1 at B2 for All Test Years Combined. Survival estimates that are significantly different (P < 0.05 and power > 80%) are bolded. "*" indicate that the P < 0.05 with a power < 80%. Type II Error represents the probability of a Type II error assuming the point estimate is the true difference of the two variables. N 80% Power represents the sample size needed to reduce the probability of a Type II error to 20%. CI LB and CI UB represent the confidence intervals for the lower and upper bounds, respectively.

Treatment	P-value	Power (%)	Type II Error (%)	N 80% Power	Point Est (%)	CI LB (%)	CI UB (%)
Q1 *vs.* Q2	0.2123	–	76	2023	-0.09	-0.2	0.1
Q1 *vs.* Q3	0.2361	–	78	848	-0.15	-0.4	0.1
Q1 *vs.* Q4	0.0167*	67	–	–	0.12	0.0	0.2
Q1 *vs.* OG	0.5474	–	91	248	-0.35	-1.5	0.8
Q2 *vs.* Q3	0.6549	–	93	6259	-0.06	-0.3	0.2
Q2 *vs.* Q4	**0.0018**	**88**	–	–	**0.21**	**0.1**	**0.3**
Q2 *vs.* OG	0.6559	–	93	501	-0.26	-1.4	0.9
Q3 *vs.* Q4	0.03*	58	–	–	0.27	0.0	0.5
Q3 *vs.* OG	0.7362	–	94	923	-0.2	-1.4	1.0
Q4 *vs.* OG	0.4197	–	87	114	-0.47	-1.6	0.7

4.2 Juvenile Steelhead (STH) at B2

4.2.1 STH Passage Survival Rates at B2 by Operating Condition

During the survival studies conducted from 2008 through 2012, passage of STH through B2 turbines was distributed across the turbine 1% of peak efficiency operating range. STH were clustered within certain operating ranges within years of the study because of the way turbines were operated between years used in response to operation criteria designated in the Fish Passage Plan, to meet power production needs and to accommodate the change in river discharge between years (Figure 4.5). Turbine passage survival estimates for STH and corresponding samples sizes during the spring 2008–2012 studies by turbine operation quartile are shown in Figure 4.6.

For all tested years combined, the survival rate of STH passing through B2 with treatment Q1 is between 1.1% and 8.8% lower (Table 4.6) than the survival rate of STH passing through B2 with treatment Q2, though not significantly lower (using the P < 0.05, and power > 80% criteria) (Figure 4.6, Figure 4.7; Appendix B, Table B.4). To increase the probability of detecting a statistical difference to 80%, the sample size needed is up to 15,991 STH.

Similarly, the turbine passage survival rate was not significantly different (P = 0.8995) for STH passing B2 turbines in the lower half (Q1–Q2) (0.9128, SE 0.0101) and upper half (Q3–Q4) (0.9152, SE 0.0161) of the 1% of peak efficiency operating range (Figure 4.7). Almost 75% of STH passed in the lower half of the 1% operating range (Q1–Q2) (Table 4.7; Appendix B, Table B.5). With the current sample sizes, if the true survival rate of STH passing through B2 with treatments Q1–Q2 is -0.24% lower than the true survival rate of STH passing through B2 with treatments Q3–Q4, then the probability of detecting a true statistical difference is 5%. To increase the probability of detecting a statistical difference to 80%, the sample size needed is 250,773 STH.

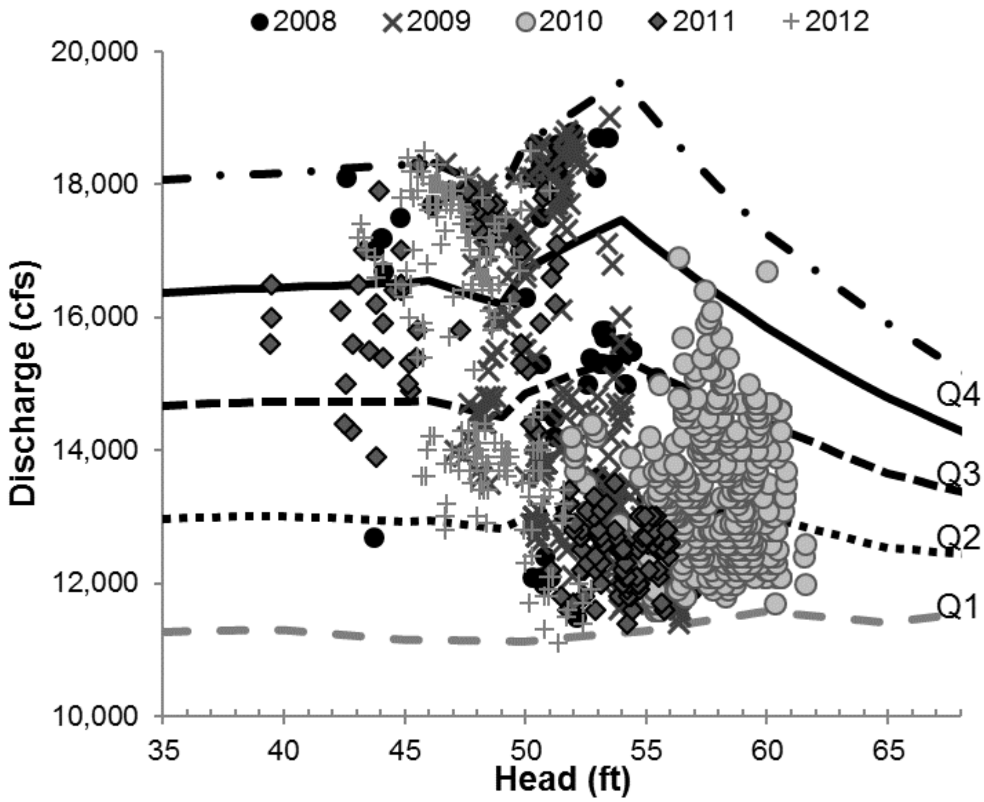

Figure 4.5. Turbine Operating Conditions for STH Detected Passing through Turbines at B2 by Study Year. Each point represents the operating condition when an individual STH passed through a turbine.

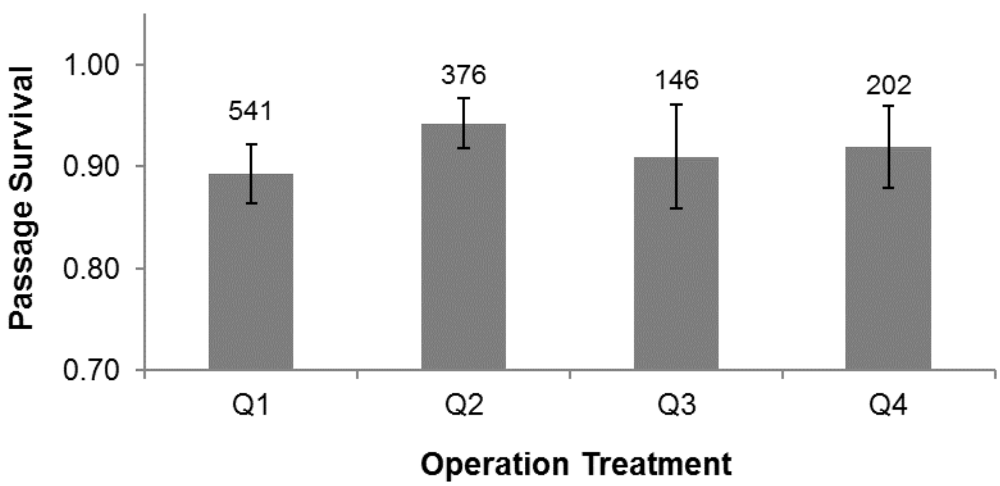

Figure 4.6. STH Survival Estimates through B2 Turbines with 95% Confidence Interval by Operation Treatment. Sample sizes are shown above the corresponding bar.

Table 4.6. STH Survival Estimates and Passage Proportions at B2 by Operation Treatment Group

Operation Treatment	Survival Estimate	Passage Proportion (%)
Q1	0.8932	42.8
Q2	0.9427	29.7
Q3	0.9097	11.5
Q4	0.9192	16.0

Table 4.7. P-values for T-tests Comparing Survival Estimates between Operation Levels for STH at B2 for All Test Years Combined. Survival estimates that are significantly different ($P < 0.05$ and power > 80%) are bolded. "*" indicate that the $P < 0.05$ with a power < 80%. Type II Error represents the probability of a Type II error assuming the point estimate is the true difference of the two variables. N 80% Power represents the sample size needed to reduce the probability of a Type II error to 20%. CI LB and CI UB represent the confidence intervals for the lower and upper bounds, respectively.

Treatment	P-value	Power (%)	Type II Error (%)	N 80% Power	Point Est (%)	CI LB (%)	CI UB (%)
Q1 *vs.* Q2	0.011*	72	–	–	-4.95	-8.76	-1.14
Q1 *vs.* Q3	0.5791	–	91	6166	-1.65	-7.49	4.19
Q1 *vs.* Q4	0.3019	–	82	2331	-2.60	-7.54	2.34
Q2 *vs.* Q3	0.2539	–	79	1155	3.30	-2.38	8.98
Q2 *vs.* Q4	0.3313	–	84	2090	2.35	-2.40	7.10
Q3 *vs.* Q4	0.7738	–	94	15991	-0.95	-7.45	5.55
Q1–Q2 *vs.* Q3–Q4	0.8995	–	95	250773	-0.24	-3.97	3.49

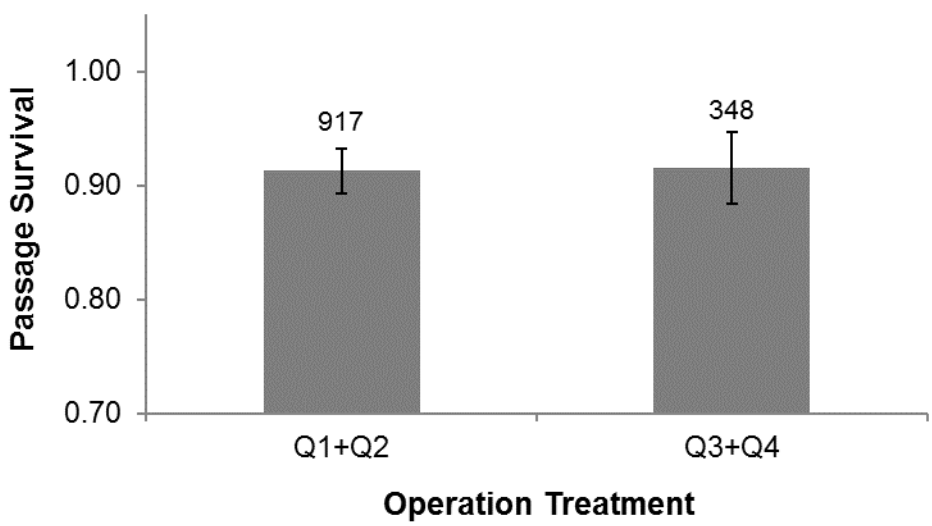

Figure 4.7. STH Survival Estimates with 95% Confidence Interval through the B2 Turbines within the Lower Half and the Upper Half of the 1% of Peak Efficiency Operating Range. Sample sizes are shown above the bars.

4.2.2 STH Passage Survival Rates at B2 by Tailwater Elevation

STH detected passing turbines at B2 were assigned to 1 m tailrace elevation bins relative to MSL that corresponded to the tailrace elevation when the fish passed into turbines. Passage survival estimates and hours of turbine operation for each quartile are shown in Figure 4.8 (Appendix D, Table D.3).

The proportion of STH passing through B2 turbines varied by bin (5 m [30.2%], 6 m [27.5%], 7 m [18.2%], 8 m [16.2%], and 9 m [7.9%]) (Appendix D, Table D.3). The highest survival rate was observed for fish that passed when tailwater elevation was in the 7 m bin (0.9846, SE 0.0105). The survival rate of STH for all other bins were similar, ranging from 0.8953 (SE 0.0217) for the 8 m bin to 0.9144 (SE 0.0322) for the 9 m bin (Figure 4.8).

The survival rate of STH passing in the 7 m tailwater elevation bin was significantly greater than for STH passing in the 5 m, 6 m, and 8 m bins ($P < 0.0002$, power > 96%; Table 4.8). Based on the less restrictive hypothesis test criteria ($P < 0.05$, power < 80%) and confidence intervals, the 7 m tailwater elevation bin is favored to have a greater survival rate than the 9 m bin.

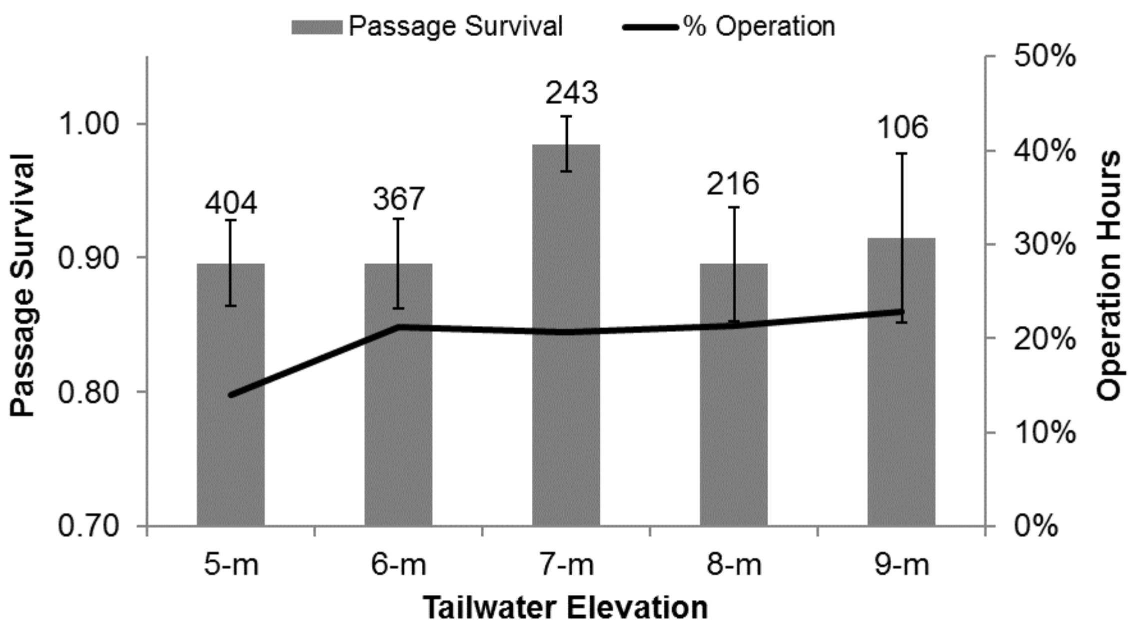

Figure 4.8. Survival Estimates with 95% Confidence Interval for STH with Percent B2 Hours of Turbine Operation by Tailwater Elevation. Sample sizes are shown above the bars.

Table 4.8. P-values for T-tests Comparing Survival Estimates between Tailrace Elevations for STH at B2 for All Test Years Combined. Survival estimates that are significantly different (P < 0.05 and power > 80% are bolded. "*" indicate that the P < 0.05 with a power < 80%. Type II Error represents the probability of a Type II error assuming the point estimate is the true difference of the two variables. N 80% Power represents the sample size needed to reduce the probability of a Type II error to 20%. CI LB and CI UB represent the confidence intervals for the lower and upper bounds, respectively.

Bins	P-value	Power (%)	Type II Error (%)	N 80% Power	Point Est (%)	CI LB (%)	CI UB (%)
5 m *vs.* 6 m	0.983	–	95	6675558	0.05	-4.56	4.66
5 m *vs.*7 m	**<0.0001**	**100**	–	–	-8.86	-12.65	-5.07
5 m *vs.* 8 m	0.9794	–	95	3338100	0.07	-5.25	5.39
5 m *vs.* 9 m	0.6099	–	92	5026	-1.84	-8.92	5.24
6 m *vs.* 7 m	**<0.0001**	**99**	–	–	-8.91	-12.83	-4.99
6 m *vs.* 8 m	0.9942	–	95	40907288	0.02	-5.39	5.43
6 m *vs.* 9 m	0.604	–	92	4766	-1.89	-9.05	5.27
7 m *vs.* 8 m	**0.0002**	**96**	–	–	8.93	4.19	13.67
7 m *vs.* 9 m	0.0389*	54	–	–	7.02	0.36	13.68
8 m *vs.* 9 m	0.6231	–	92	4581	-1.91	-9.55	5.73

4.2.3 STH Tailrace Egress Time at B2

B2 STH tailrace egress time by quartile is shown in Table 4.9 (Appendix F, Table F.2). The median egress time has a slight decreasing trend from Q1 to the other quartiles with increasing turbine discharge. The highest median egress time was 0.72 h for the Q1 operating condition, but the median Q3 egress time was least (0.68 h) (Table 4.9). Minimum egress times were similar between quartiles, while maximum and mean egress times varied.

There were no statistical differences (all P > 0.1176) found when comparing the tailrace egress time at B2 relative to turbine operations for all years combined (Table 4.10; Appendix F, Table F.2). For STH, the confidence intervals favored Q4 having a shorter tailrace egress time than Q1 and Q2.

Table 4.9. Tailrace Egress Time at B2 Relative to Turbine Operating Treatment during STH Passage

Operation Treatment	Median (h)	Min (h)	Max (h)	Mean (h)	SE	N
Q1	0.72	0.26	48.20	1.16	0.16	381
Q2	0.71	0.22	24.13	1.16	0.14	257
Q3	0.68	0.21	70.55	1.67	0.89	79
Q4	0.71	0.22	5.19	0.89	0.10	57

Table 4.10. P-values for T-tests Comparing Survival Estimates between Egress Time Relative to Turbine Operations for STH at B2 for All Test Years Combined. Survival estimates that are significantly different (P < 0.05 and power > 80%) are bolded. "*" indicate that the P < 0.05 with a power < 80%. Type II Error represents the probability of a Type II error assuming the point estimate is the true difference of the two variables. N 80% Power represents the sample size needed to reduce the probability of a Type II error to 20%. CI LB and CI UB represent the confidence intervals for the lower and upper bounds, respectively.

Treatments	P-value	Power (%)	Type II Error (%)	N 80% Power	Point Est (%)	CI LB (%)	CI UB (%)
Q1 *vs.* Q2	1	–	95	65535	0	-0.4	0.4
Q1 *vs.* Q3	0.573	–	91	2192	-0.51	-2.3	1.3
Q1 *vs.* Q4	0.1531	–	70	1117	0.27	-0.1	0.6
Q2 *vs.* Q3	0.5717	–	91	2053	-0.51	-2.3	1.3
Q2 *vs.* Q4	0.1176	–	65	608	0.27	-0.1	0.6
Q3 *vs.* Q4	0.3854	–	86	827	0.78	-1.0	2.6

4.3 Subyearling Chinook Salmon (CH0) at B2

4.3.1 CH0 Passage Survival Rates at B2 by Operating Condition

During the survival studies conducted at B2 in the summers of 2008, 2009, 2010, and 2012, the passage of CH0 through turbines was distributed across all quartiles in the 1% of peak efficiency range of turbine operations. Studies were not conducted during summer 2011 because of high river discharge. Detected CH0 were consistently clustered within certain operating ranges within years of the study, reflecting the difference in turbine operations between years that occurred in response to operation criteria designated in the Fish Passage Plan, power production needs and differences in river discharge between years (Figure 4.9, Figure 4.10, and Table 4.11; Appendix B, Table B.4 and Table B.5).

CH0 turbine passage survival rates were not significantly different between quartiles (all P > 0.051) (Table 4.12; Appendix B, Table B.4). Unlike CH1 and STH, a higher proportion of CH0 were detected in the Q4 operating range bin (55.0%) mainly due to higher than average flows during summer 2012. Turbine passage proportions for the other quartiles ranged from 11.3% for Q1 to 19.0% for Q2 (Figure 4.10; Appendix B, Table B.4). Based on the confidence intervals, Q4 is favored to have a higher survival rate than Q2 and Q3; and Q1 a higher survival rate than Q2. The difference between Q2 and Q4 provided a p-value of 0.051 (power = 50%), which is close to the rejection threshold for the p-value even for the less restrictive hypothesis criteria (p < 0.05, power < 80%). The 95% confidence interval provides that the survival rate with treatment Q2 is between 5% lower and 0.01% higher than the survival rate of Q4. To better examine the statistical relationships between operation treatments (at an 80% power), sample sizes would need to increase no less than 1,411 up to 63,969 CH0 passing through B2.

Turbine passage survival estimates for the lower (Q1–Q2) and upper (Q3–Q4) half of the 1% operating range, 0.9397 (SE 0.0086) and 0.9527 (SE 0.0052) respectively, were not significantly different (P < 0.1959) (Table 4.12, Figure 4.11). With the current sample sizes, if the true survival rate of CH0 passing through B2 with treatments Q1–Q2 is -1.30% lower than the true survival rate of CH0 passing through B2 with treatments Q3–Q4, then the probability of detecting a true statistical difference is 25%. To increase the probability of detecting a statistical difference to 80%, the sample size needed is 5044 CH0.

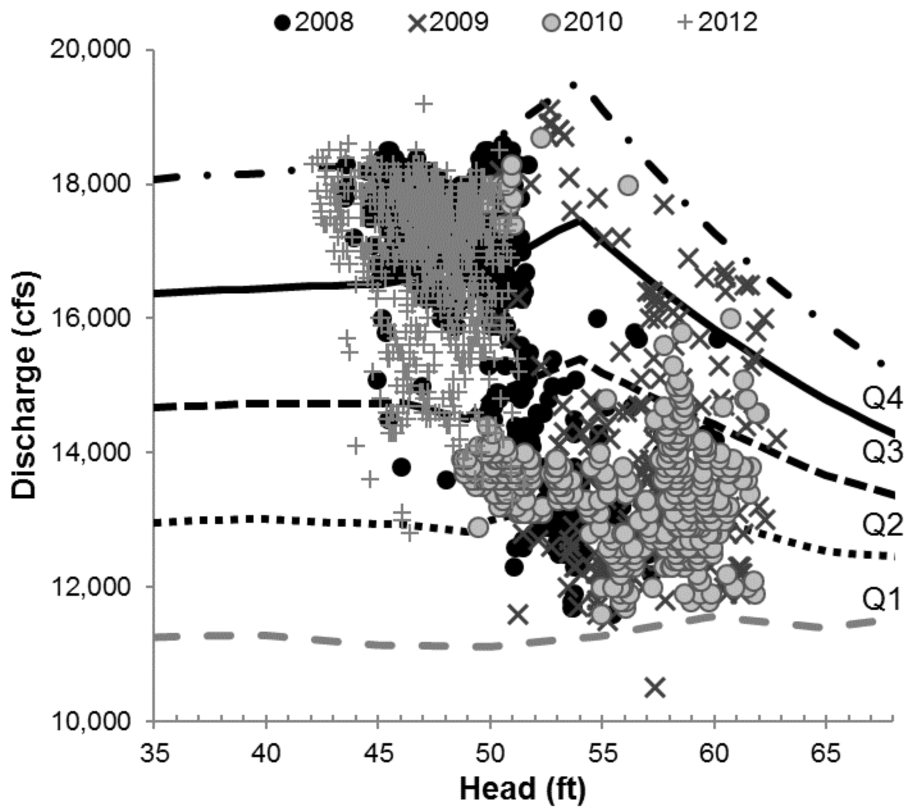

Figure 4.9. Turbine Operating Conditions for CH0 Detected Passing through Turbines at B2 by Study Year. Each point represents the operating condition when an individual CH0 passed through a turbine.

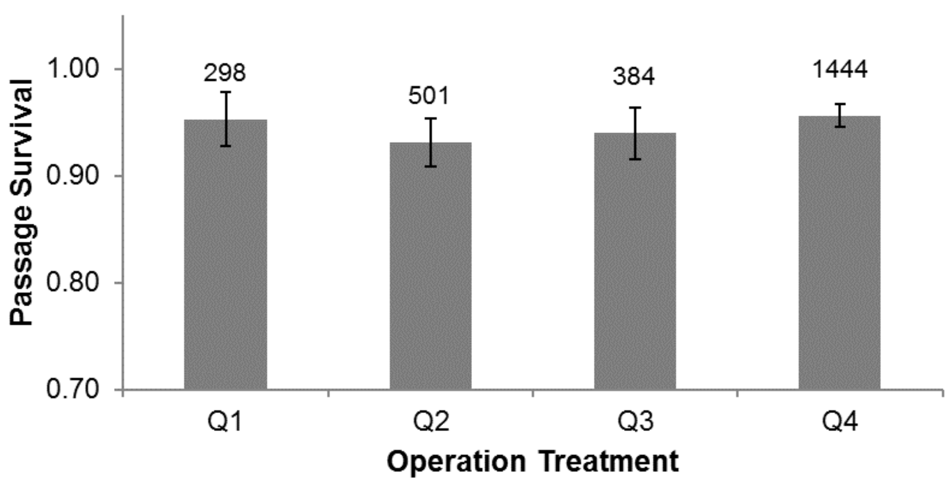

Figure 4.10. CH0 Survival Estimates through B2 Turbines with 95% Confidence Interval by Operation Treatment. Sample sizes are shown above the corresponding bar.

Table 4.11. CH0 Survival Estimates and Passage Proportions at B2 by Operation Treatment Group

Operation Treatment	Survival Estimate	Passage Proportion (%)
Q1	0.9528	11.3
Q2	0.9314	19.1
Q3	0.9397	14.6
Q4	0.9562	55.0

Table 4.12. P-values for T-tests Comparing Survival Estimates between Operation Levels for CH0 at B2 for All Test Years Combined. Survival estimates that are significantly different (P < 0.05 and power < 80%) are bolded. "*" indicate that the P < 0.05 with a power < 80%. Type II Error represents the probability of a Type II error assuming the point estimate is the true difference of the two variables. N 80% Power represents the sample size needed to reduce the probability of a Type II error to 20%. CI LB and CI UB represent the confidence intervals for the lower and upper bounds, respectively.

Treatment	P-value	Power (%)	Type II Error (%)	N 80% Power	Point Est (%)	CI LB (%)	CI UB (%)
Q1 *vs.* Q2	0.2122	–	76	1958	2.14	-1.22	5.50
Q1 *vs.* Q3	0.4625	–	89	4948	1.31	-2.19	4.81
Q1 *vs.* Q4	0.8078	–	94	63969	-0.34	-3.08	2.40
Q2 *vs.* Q3	0.6223	–	92	14177	-0.83	-4.14	2.48
Q2 *vs.* Q4	0.051	–	50	1411	-2.48	-4.97	0.01
Q3 *vs.* Q4	0.2254	–	77	3011	-1.65	-4.32	1.02
Q1–Q2 *vs.* Q3–Q4	0.1959	–	75	5044	-1.30	-3.27	0.67

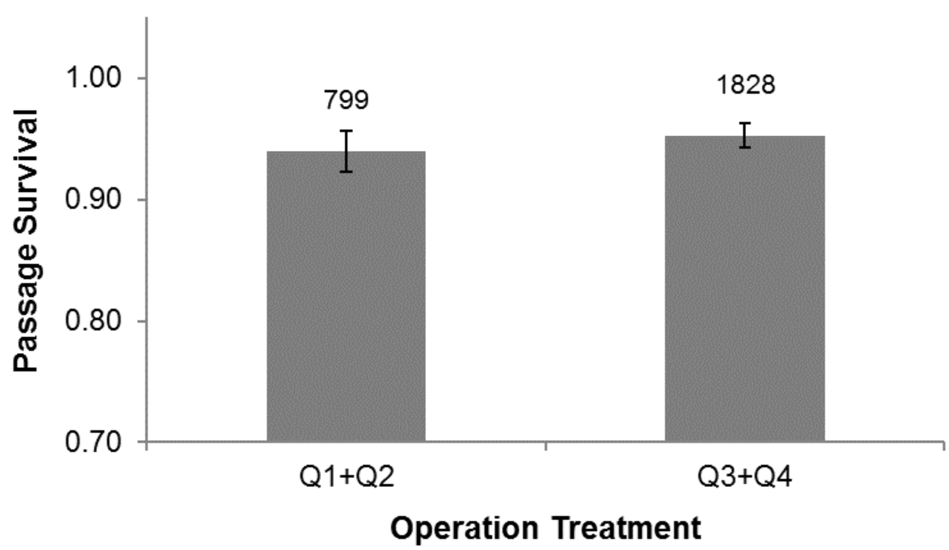

Figure 4.11. Survival Estimates with 95% Confidence Interval for CH0 Passing through B2 Turbines within the Lower and Upper Halves of the 1% of Peak Efficiency Operating Range. Sample sizes are shown above the bars.

4.3.2 CH0 Passage Survival Rates at B2 by Tailwater Elevation

CH0 detected passing turbines at B2 were assigned to 1 m tailrace elevation bins relative to MSL corresponding to the tailrace elevation when the fish passed into turbines. CH0 turbine passage survival estimates and the hours of turbine operation for each bin are shown in Figure 4.12 (Appendix D, Table D.3). The highest passage survival rate was observed for CH0 that passed when tailwater elevation was within the 9 m bin (0.9663, SE 0.0104) and lowest survival estimate was observed when tailwater was low, within 5 m bin (0.9102, SE 0.0158).

The number of turbine operation hours was higher when tailwater elevation was within the 5 m and 8 m tailwater elevation bins and lower for tailwater elevations in 6 m, 7 m, and 9 m bins. The proportion of CH0 passing B2 turbines varied by tailwater elevation bin (5 m [12.5%], 6 m [10.4%], 7 m [14.7%], 8 m [50.8%], and 9 m [11.6%]).

Based on confidence intervals, survival estimates increased with increasing tailwater elevation, which is the survival rate was greater for the 8 m and 9 m bin than for the 5 m bin (Table 4.13). There was no significant difference between any of the other bins ($P > 0.0747$, based on the $P > 0.05$, power > 80% criteria) (Figure 4.12, Table 4.13; Appendix D, Table D.3). Using the less restrictive hypotheses testing and confidence intervals, survival estimates for the 5 m bin was less than the survival estimates for the 8 m and 9 m bins. There is also evidence indicating that the elevation of 9 m has a greater survival rate than that of elevations 6 m, 7 m, and 8 m.

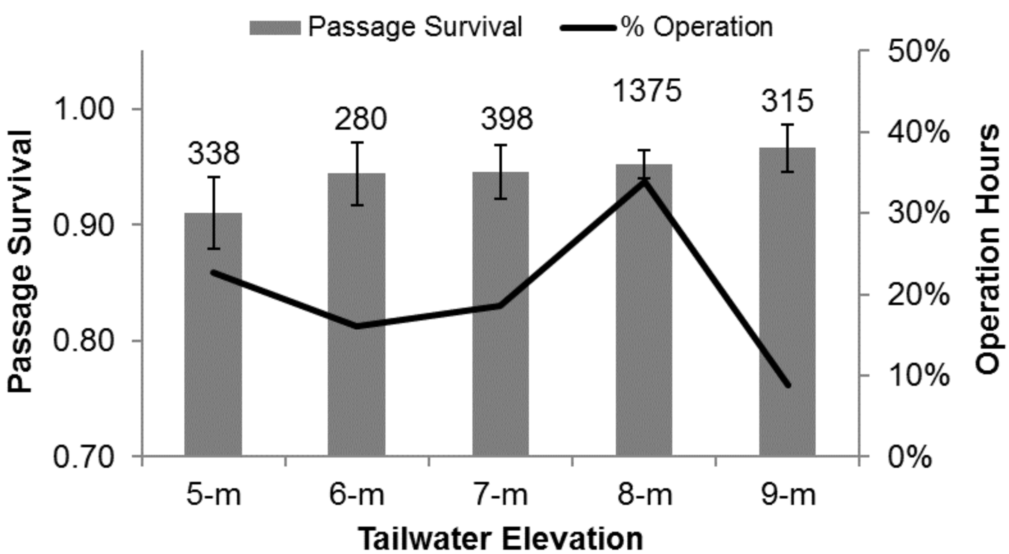

Figure 4.12. Survival Estimates with 95% Confidence Interval for CH0 at B2 with Percent Hours of Turbine Operation by Tailwater Elevation Bin. Sample sizes are shown above the bars.

Table 4.13. P-values for T-tests Comparing Survival Estimates between Tailrace Elevations for CH0 at B2 for All Test Years Combined. Survival estimates that are significantly different (P < 0.05 and power > 80% are bolded. "*" indicate that the P < 0.05 with a power < 80%. Type II Error represents the probability of a Type II error assuming the point estimate is the true difference of the two variables. N 80% Power represents the sample size needed to reduce the probability of a Type II error to 20%. CI LB and CI UB represent the confidence intervals for the lower and upper bounds, respectively**.**

Elevations	P-value	Power (%)	Type II Error (%)	N 80% Power	Point Est (%)	CI LB (%)	CI UB (%)
5 m *vs.* 6 m	0.1088	–	64	955	-3.38	-7.51	0.75
5 m *vs.* 7 m	0.0747	–	57	888	-3.52	-7.39	0.35
5 m *vs.* 8 m	0.013*	70	–	–	-4.20	-7.51	-0.89
5 m *vs.* 9 m	0.0031*	84	–	–	-5.61	-9.32	-1.90
6 m *vs.* 7 m	0.9388	–	95	439830	-0.14	-3.72	3.44
6 m *vs.* 8 m	0.5882	–	92	12108	-0.82	-3.79	2.15
6 m *vs.* 9 m	0.1994	–	75	1397	-2.23	-5.64	1.18
7 m *vs.* 8 m	0.6075	–	92	17829	-0.68	-3.28	1.92
7 m *vs.* 9 m	0.1844	–	74	1613	-2.09	-5.18	1.00
8 m *vs.* 9 m	0.2404	–	78	3304	-1.41	-3.76	0.94

4.3.3 CH0 Tailrace Egress Time at B2

The tailrace egress time for B2 CH0 by turbine operation quartile is shown in Table 4.14 (Appendix F, Table F.3). The median egress time decreased from Q1 to Q4 with increasing turbine discharge. The mean and range of egress times varied within and between turbine operation quartiles with a large mean difference between Q3 and the other quartiles.

However, there were no statistical differences (all P > 0.05) found when comparing the tailrace egress time at B2 relative to turbine operations for all years combined (Table 4.15). The confidence intervals favor Q4 having a shorter egress time than Q2.

Table 4.14. Tailrace Egress Time at B2 Relative to Turbine Operating Treatment during CH0 Passage

Operation Treatment	Median (h)	Min (h)	Max (h)	Mean (h)	SE	N
Q1	0.73	0.29	6.15	0.83	0.06	111
Q2	0.71	0.22	8.03	0.85	0.05	272
Q3	0.67	0.21	530.52	2.82	2.01	263
Q4	0.64	0.19	13.90	0.78	0.03	911

Table 4.15. P-values for T-tests Comparing Survival Estimates between Egress Time Relative to Turbine Operations for CH0 at B2 for All Test Years Combined. Survival estimates that are significantly different (P < 0.05 and power > 80%) are bolded. "*" indicate that the P < 0.05 with a power < 80%. Type II Error represents the probability of a Type II error assuming the point estimate is the true difference of the two variables. N 80% Power represents the sample size needed to reduce the probability of a Type II error to 20%. CI LB and CI UB represent the confidence intervals for the lower and upper bounds, respectively.

Treatments	P-value	Power (%)	Type II Error (%)	N 80% Power	Point Est (%)	CI LB (%)	CI UB (%)
Q1 *vs.* Q2	0.798	–	94	21294	-0.02	-0.2	0.1
Q1 *vs.* Q3	0.323	–	83	2118	-1.99	-5.9	2.0
Q1 *vs.* Q4	0.4562	–	88	3837	0.05	-0.1	0.2
Q2 *vs.* Q3	0.3276	–	84	2159	-1.97	-5.9	2.0
Q2 *vs.* Q4	0.2302	–	78	2407	0.07	0.0	0.2
Q3 *vs.* Q4	0.3104	–	83	2009	2.04	-1.9	6.0

4.4 CH1 and STH Turbine Passage Survival Rates at B2 with and without Submerged Traveling Screens

Data were available for the spring out-migration periods in 2008 and 2011 to investigate the turbine passage survival of CH1 and STH at B2 with and without STSs in turbine intakes. Figure 4.13 shows the distribution of CH1 and STH within discharge quartiles of the 1% of peak efficiency and of B2 turbines operating without STSs. The majority of juvenile salmonids observed passed at discharge levels in the upper quarter of the 1% of peak efficiency discharge range (Q4) due to the high discharge, necessitating removal of the STSs.

The distribution of CH1 and STH within 1% of peak efficiency for B2 turbines with STSs installed in turbine intakes is shown in Figure 4.14. During the period of time that B2 turbines were operating with screens installed in 2008 and 2011, B2 turbines were operating almost exclusively in the upper half of the 1% of peak efficiency discharge range due to high river discharge.

In 2008, CH1 passing through turbines at B2 without STSs showed a distinctively lower turbine passage survival rate than those that passed through turbines with STSs installed. In 2011, the turbine passage survival rates for CH1 were similar for fish that passed through B2 turbines with and without STSs in the turbine intakes (Figure 4.15). The survival rate differences for CH1 in 2008 are large, but due to the large confidence intervals for the survival estimates and small sample sizes, hypothesis testing was not conducted.

In both 2008 and 2011, STH showed lower turbine passage survival rates for passage through B2 turbines when STSs were installed in turbine intakes than when they were not installed (Figure 4.16). For STH, the differences in the survival rates and the confidence intervals are large, hypothesis testing was not conducted.

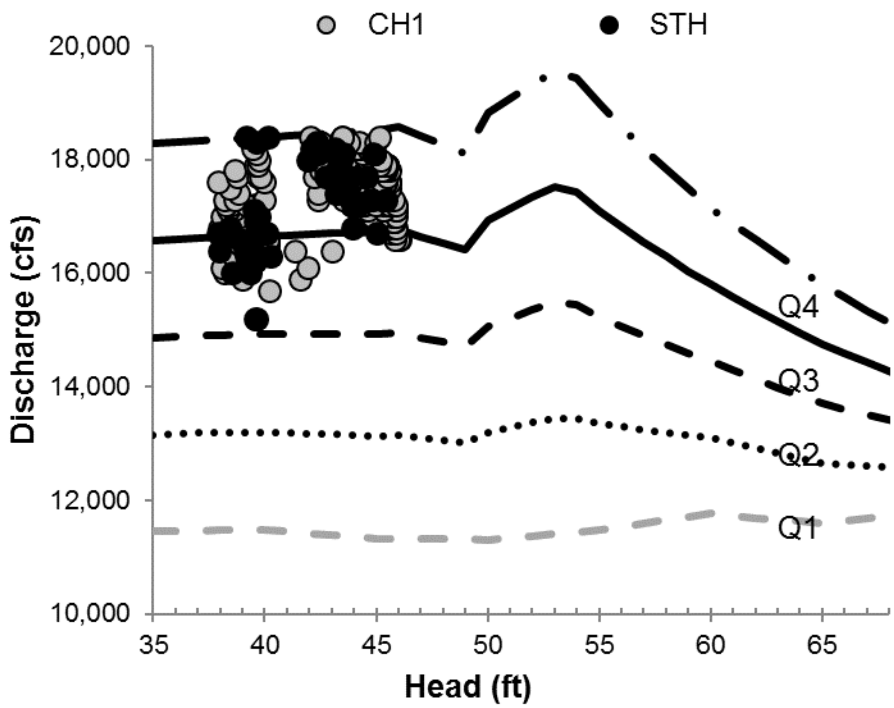

Figure 4.13. The Distribution of CH1 and STH within the 1% of Peak Efficiency Range for B2 Turbines without STSs

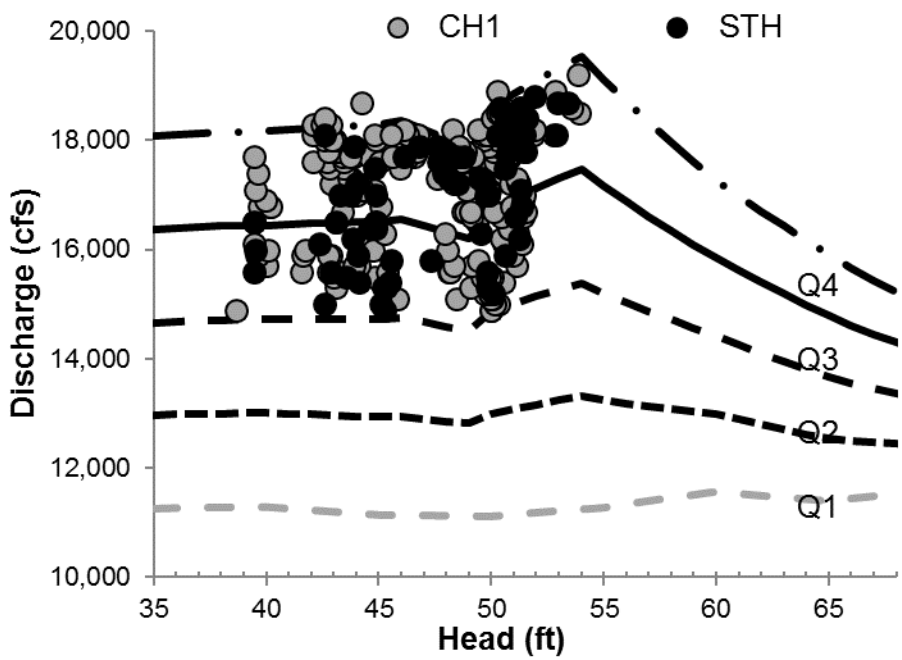

Figure 4.14. The Distribution of CH1 and STH within the 1% of Peak Efficiency Range for B2 Turbines with STSs Installed

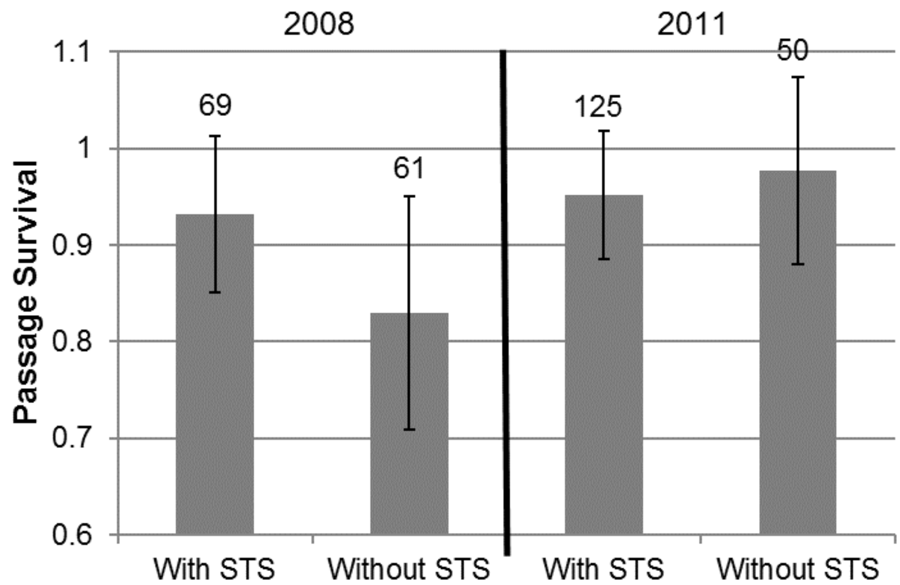

Figure 4.15. Turbine Passage Survival Rate Estimates with 95% Confidence Interval for CH1 that Passed through Turbines at B2 with and without STSs in 2008 and 2011

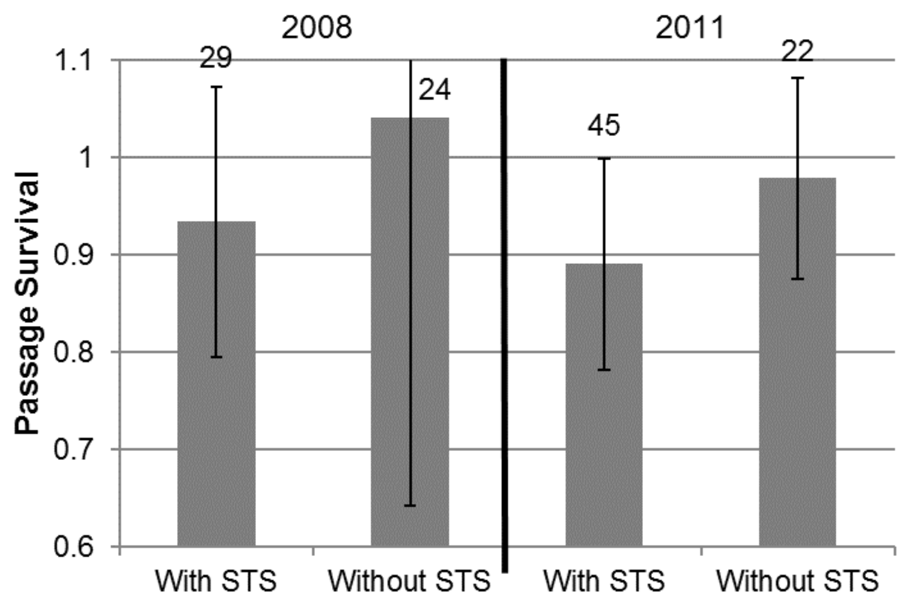

Figure 4.16. Turbine Passage Survival Rate Estimates with 95% Confidence Interval for STH that Passed through Turbines at B2 with and without STSs in 2008 and 2011

5.0 Results—Bonneville Dam Spillway

The methods used to partition the spillbays and discharge rates for the BON spillway are described in Methods (Section 2.0). Spillway passage survival estimates and other statistics describing passage of CH1, STH, and CH0 through the spillway at BON are presented in the following sections and are also available in Appendix C. In addition, Appendix C, has additional statistical analyses not addressed in the results because they provided little additional information. Data for passage of tagged juvenile salmonids through the BON spillway for years 2008 and 2010–2012 were used for the analyses.

5.1 Yearling Chinook Salmon (CH1) at BON Spillway

5.1.1 CH1 Passage Survival Rates at BON by Spillbay

Before examining each individual spillbay, possible variations between years were considered. First, there was no significant difference (all $P > 0.1607$) found between individual years (2008 vs. 2010 vs. 2011 vs. 2012), though the confidence intervals favored 2008 having a higher survival rate than 2010 (Table 5.1; Appendix C, Table C.1). The 2011 survival rates were compared to all other years as well to identify if the high flows during the second half of the spring season affected survival. There was no significant difference ($P = 0.4226$) in survival rates of 2011 compared to the combined 2008, 2010, and 2012 (Table 5.2; Appendix C, Table C.2).

To better determine if there were survival differences, especially in the region of spillbays 8–12 where structural damage was evident, spillway passage survival estimates for CH1 for all study years were combined (2008, 2010, 2011, and 2012) as shown in Figure 5.1, Figure 5.2, Table 5.3, and Appendix C.

CH1 spill passage survival rates averaged over all spillbays and all years was 0.936. Estimates of CH1 passage survival through spillbays 5, 6, 10, 14, 16, and 18 were > 0.95, while those for spillbays 3, 9, and 13 were < 0.92 (Figure 5.1, Table 5.3). There was a trend for more CH1 to pass through spillbays 1–3, followed by spillbays 4–7, than other spillbays. The number and proportion of CH1 passage through individual spillbays is shown in Figure 5.1, and Table 5.3, respectively (Appendix C, Table C.3 and Table C.5).

When survival estimates for CH1 were compared between years for individual spillbays, a significant difference ($P = 0.0048$, power = 81%) was found where survival was higher in 2008 than in 2010 for spillbay 3 (using the $P < 0.05$, power > 80% criteria) (Table 5.4). Using the confidence intervals and a less restrictive power condition ($P < 0.05$, power < 80%), Bay 3 in 2008 had a higher survival rate than 2010, 2011, and 2012; Bay 5 in 2008 had a lower survival rate than 2010; Bays 6 and 9 in 2011 had a lower survival rate than 2012; Bay 13 in 2010 had a lower survival rate than 2012; and Bay 16 in 2011 had a higher survival rate than 2010 and 2012 (Table 5.4). The full table (P-value, power, type II error, N 80%, point estimates and confidence intervals) can be found in Appendix C, Table C.11.

Additionally, for spillbays 2 and 4 the confidence intervals (no hypothesis test included) favor 2008 having higher survival rates than in 2010 and 2012; Bay 2, had higher survival rates in 2011 than in 2010 and 2012. For spillbay 3, the confidence interval favors 2010 having a higher survival rate than in 2011.

For spillbay 5, the confidence intervals favor 2008 having lower survival rates, and 2010 having higher survival rates than in 2011 and 2012. For Bay 9, the confidence interval favors 2008 having a higher survival rate than in 2011. For spillbay 10, the confidence interval favors 2010 having a lower survival rate than in 2012. For spillbay 11, the confidence intervals favor 2008 having lower survival rates than in 2010, 2011, and 2012. For spillbay 12, the confidence intervals favor 2011 having lower survival rates than in 2008 and 2010. For spillbay 13, the confidence interval favors 2011 having a lower survival rate than in 2012. Lastly, for spillbay 17, the confidence interval strongly favors 2008 having a lower survival rate than in 2010 and 2012.

Table 5.1. BON Spillway Survival Estimates for Spillway Passage by Grouped Spillway Passage and Individual Years

Year	Spillbays for CH1						
	P-value	Power (%)	Type II Error (%)	N 80% Power	Point Est (%)	CI LB (%)	CI UB (%)
2008 *vs.* 2010	0.1607		71	6351	1.72	-0.68	4.12
2008 *vs.* 2011	0.51		90	35648	0.79	-1.56	3.14
2008 *vs.* 2012	0.3684		85	16114	1.03	-1.21	3.27
2010 *vs.* 2011	0.3158		83	18840	-0.93	-2.75	0.89
2010 *vs.* 2012	0.4203		87	23400	-0.69	-2.37	0.99
2011 *vs.* 2012	0.7689		94	253520	0.24	-1.36	1.84

Table 5.2. BON Spillway Survival Estimates for Spillway Passage in 2011 Compared to all Other Years

P-value	Power (%)	Type II Error (%)	N 80% Power	Point Est (%)	CI LB (%)	CI UB (%)
0.4226		80	46307	0.59	-0.85	2.03

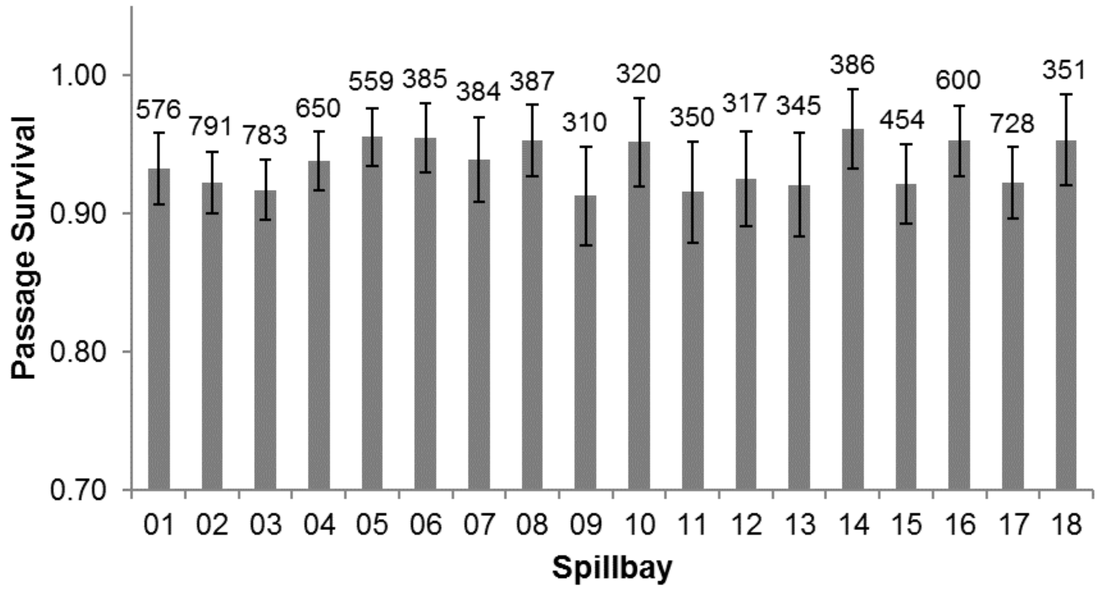

Figure 5.1. Survival Estimates with 95% Confidence Interval for CH1 by Spillbay at BON. Sample sizes are shown above the bars.

Table 5.3. Survival Estimates and Passage Proportions for CH1 by Spillbay at BON

Spillbay	Survival Estimate	Passage Proportion (%)
1	0.9326	6.6
2	0.9224	9.1
3	0.9172	9.0
4	0.9377	7.5
5	0.9553	6.4
6	0.9550	4.4
7	0.9390	4.4
8	0.9527	4.5
9	0.9127	3.6
10	0.9518	3.7
11	0.9156	4.0
12	0.9253	3.7
13	0.9207	4.0
14	0.9612	4.5
15	0.9216	5.2
16	0.9525	6.9
17	0.9225	8.4
18	0.9532	4.1

Table 5.4. P-values for T-tests Comparing Survival Estimates between Years for Individual Spillbays for CH1 at the BON Spillway. Survival estimates that are significantly different (P < 0.05 and power > 80%) are bolded; P-values italicized with a "*" indicate a P < 0.05 and power < 80%. The full table (P-value, power, type II error, N 80%, point estimates and confidence intervals can be found in Appendix C, Table C.11.

	2008/2010	2008/2011	2008/2012	2010/2011	2010/2012	2011/2012
Bay 1	0.950	0.712	0.912	0.730	0.847	0.594
Bay 2	0.081	0.581	0.087	0.196	0.927	0.212
Bay 3	**0.005**	*0.039**	*0.014**	0.154	0.355	0.516
Bay 4	0.205	0.279	0.071	0.786	0.744	0.493
Bay 5	*0.017**	0.218	0.139	0.195	0.098	0.914
Bay 6	0.611	0.408	0.298	0.147	0.632	*0.020**
Bay 7	0.705	0.417	0.664	0.310	0.900	0.339
Bay 8	0.524	0.298	0.316	0.541	0.606	0.816
Bay 9	0.431	0.131	0.663	0.269	0.454	*0.024**
Bay 10	0.398	0.918	0.907	0.358	0.195	0.996
Bay 11	0.160	0.150	0.151	0.973	0.934	0.903
Bay 12	0.515	0.153	0.243	0.149	0.313	0.654
Bay 13	0.391	0.642	0.568	0.562	*0.020**	0.058
Bay 14	0.567	0.944	0.417	0.434	0.791	0.274
Bay 15	0.505	0.244	0.628	0.568	0.795	0.360
Bay 16	0.342	0.502	0.347	*0.036**	0.974	*0.033**
Bay 17	0.154	0.292	0.224	0.575	0.779	0.795
Bay 18	0.860	0.821	0.470	0.627	0.289	0.478

5.1.2 CH1 Spillway Passage Survival Rates at BON by Spillway Group

The spillway survival of CH1 was estimated for the five groups of adjacent spillbays shown in Figure 5.2 and Appendix C, Table C.4 and C.8. BON spillbays were divided into five groups, because of structural differences between some spillbays. Spillbays 1–3 and 16–18 have deep-flow deflectors (7 ft above MSL), while all other spillbays have shallow-flow deflectors (14 ft above MSL). The spillbays with shallow-flow deflectors were divided into three groups, because it was suspected that the middle spillbays (8–12) may have increased erosion on the spill chute and in the stilling basin and tailrace, or rock deposition in the tailrace. The highest survival rate for CH1 was observed for spillbays 4–7 (0.9462, SE 0.0061) and the lowest for spillbays 1–3 (0.9229, SE 0.0068) (Figure 5.2).

Based on hypotheses testing, survival rates were lower across the spillbay group 1–3 than the adjacent group of spillbays 4–7, but were not significantly different (all P > 0.1065) between any groups of spillbays for combined years (Table 5.5). Based on confidence intervals and a less restrictive hypothesis testing criteria, spillbays 1–3 had a lower survival rate than spillbays 4–7 (P = 0.0108, power = 72%) (Appendix C, Table C.17).

When broken out by individual years, survival was lower for CH1 passage at spillbays 1–3, than spillbays 4–7 and spillbays 8–12 in 2010 and 2012 (Table 5.6), based on the confidence intervals and a less restrictive power criteria ($P < 0.05$, power < 80%). During survival studies from 2008, and 2010 to 2012, the highest proportion of CH1 passed through spillbays 1–3 (24.8%) and the lowest through spillbays 13–15 (13.7%) (Appendix C, Table C.4 and Table C.8). For spillbays 1–3, the confidence intervals favored 2010 having a lower survival rate than in 2011; and spillbays 16–18, the confidence intervals favored 2011 having a higher survival rate than in 2012. There was a significant difference in survival for spillbays 1–3 between 2008 and 2010, and for spillbays 1–3 between 2008 and 2012 when using relaxed power criteria. A difference was not seen between other bay grouping between years (Appendix C, Table C.14). Within year differences were not seen, unless the power criteria was relaxed (Appendix C, Table C.20).

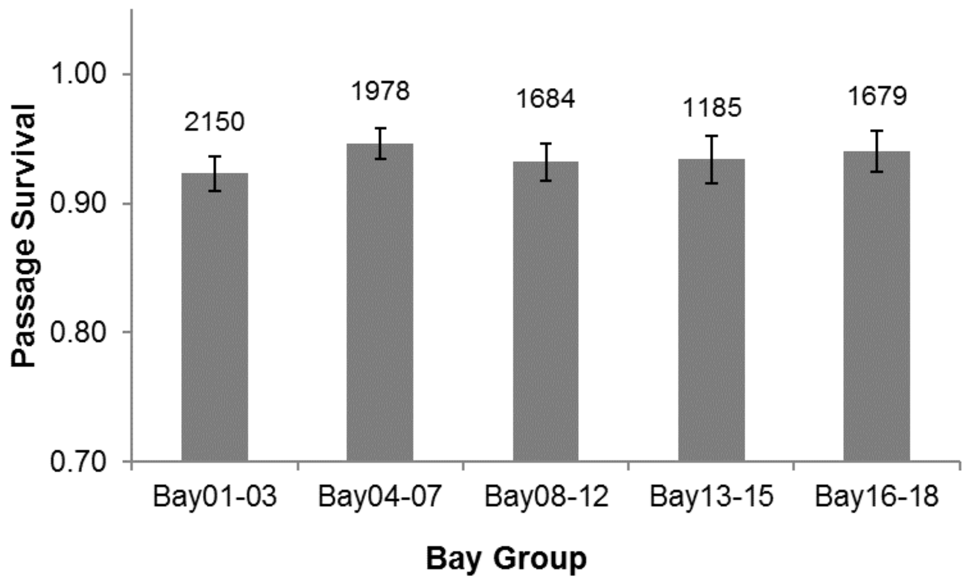

Figure 5.2. Survival Estimates with 95% Confidence Interval for CH1 by Spillbay Groups at BON. Sample sizes are shown above the bars.

Table 5.5. P-values for T-tests Comparing Survival Estimates between Grouped Spillbays for CH1 at the BON Spillway. Survival estimates that are significantly different (P < 0.05 and power > 80%) are bolded. P-values italicized with a "*" indicate a P < 0.05 and power < 80%. Type II Error represents the probability of a Type II error assuming the point estimate is the true difference of the two variables. N 80% Power represents the sample size needed to reduce the probability of a Type II error to 20%. CI LB and CI UB represent the confidence intervals for the lower and upper bounds, respectively.

Spillbays	P-value	Power (%)	Type II Error (%)	N 80% Power	Point Est (%)	CI LB (%)	CI UB (%)
1 to 3 *vs.* 4 to 7	*0.0108**	*72*	≥ 290 kcfs	–	*-2.33*	*-4.12*	*-0.54*
1 to 3 *vs.* 8 to 12	0.3741	–	86	18822	-0.90	-2.88	1.08
1 to 3 *vs.* 13 to 15	0.3408	–	84	13202	-1.09	-3.33	1.15
1 to 3 *vs.* 16 to 18	0.1065	–	64	5636	-1.72	-3.81	0.37
4 to 7 *vs.* 8 to 12	0.1392	–	68	6465	1.43	-0.47	3.33
4 to 7 *vs.* 13 to 15	0.2614	–	80	8883	1.24	-0.92	3.40
4 to 7 *vs.* 16 to 18	0.5506	–	91	39360	0.61	-1.39	2.61
8 to 12 *vs.* 13 to 15	0.8728	–	95	424310	-0.19	-2.52	2.14
8 to 12 *vs.* 16 to 18	0.4606	–	89	24250	-0.82	-3.00	1.36
13 to 15 *vs.* 16 to 18	0.6093	–	92	42189	-0.63	-3.05	1.79

Table 5.6. P-values for T-tests Comparing Survival Estimates between Grouped Spillbays by Year for CH1 at the BON Spillway. Survival estimates that are significantly different (P < 0.05 and power > 80%) are bolded. P-values italicized with a "*" indicate a P < 0.05 with power < 80%. The full table (P-value, power, type II error, N 80%, point estimates and confidence intervals can be found in Appendix C, Table C.20.

Spillbay Groups	2008	2010	2011	2012
1-3 *vs.* 4-7	0.266	*0.014**	0.371	*0.021**
1-3 *vs.* 8-12	0.729	*0.047**	0.757	*0.022**
1-3 *vs.* 13-15	0.29	0.489	0.5	0.142
1-3 *vs.* 16-18	0.232	0.066	0.138	0.404
4-7 *vs.* 8-12	0.602	0.653	0.272	0.904
4-7 *vs.* 13-15	0.852	0.192	0.915	0.698
4-7 *vs.* 16-18	0.767	0.635	0.525	0.272
8-12 *vs.* 13-15	0.548	0.349	0.374	0.643
8-12 *vs.* 16-18	0.484	0.961	0.104	0.252
13-15 *vs.* 16-18	0.932	0.388	0.505	0.558

5.1.3 CH1 Spillway Passage Survival Rates at BON by Discharge

Spillway passage data for CH1 were grouped into 10 kcfs discharge bins and analyzed to evaluate the response of CH1 survival rates to spill discharge level (Figure 5.3, Table 5.7; Appendix D, Table D.5 and

Table D.6). The highest proportion of CH1 passed at spill levels contained in the 100 kcfs bin. The 100 kcfs bin also had the most hours of operation as specified in the FPP.

There was not a distinguishing trend in survival rates across spill levels (Table 5.8, Appendix C, Table C.23). There was a marked decrease in survival estimates at flows ≥ 290 kcfs (0.8563, SE 0.0431) that was (based on hypothesis testing [250 vs. ≥ 290 kcfs had a P = 0.0032, power = 84%] and confidence intervals [110–130, 150, 170, 200, 220, and 280 vs. ≥ 290 kcfs ranged between P = 0.0113–0.318 and power = 72%–57%]) than most other spill volumes (Table 5.8, Appendix C, Table C.23).

There was a higher survival rate at flows near 250 kcfs than ≤ 90–100, 120, 140, 160, 180–190, 210 and ≥ 290 kcfs based on hypothesis testing [250 vs. 100, 140 kcfs had a P = 0.0032 and 0.004, power = 84% and 82%, respectively] and confidence intervals.

The confidence intervals strongly favor the discharge bin 210 kcfs having a lower survival rate than the discharge bins 130, 150, 170, 210, and 280 kcfs.

Interestingly, the discharge bin 100 kcfs and 140 kcfs had lower survival rates than the discharge bins 120, 130, 150, 170, 220, 250 and 280 (based on hypothesis testing [all P =0.0077–0.0479, power =51%–76%] and confidence intervals (Table 5.7 and Table 5.8).

The confidence intervals favor the discharge bin ≤90 kcfs having a lower survival rate than the discharge bins 130, 150, 170, 220, and 280 kcfs.

In general, CH1 survival estimates where higher at 250 kcfs than for lower spill volumes, and survival rates for the ≥ 290 kcfs spill volume were lower than all other 10 kcfs discharge bins.

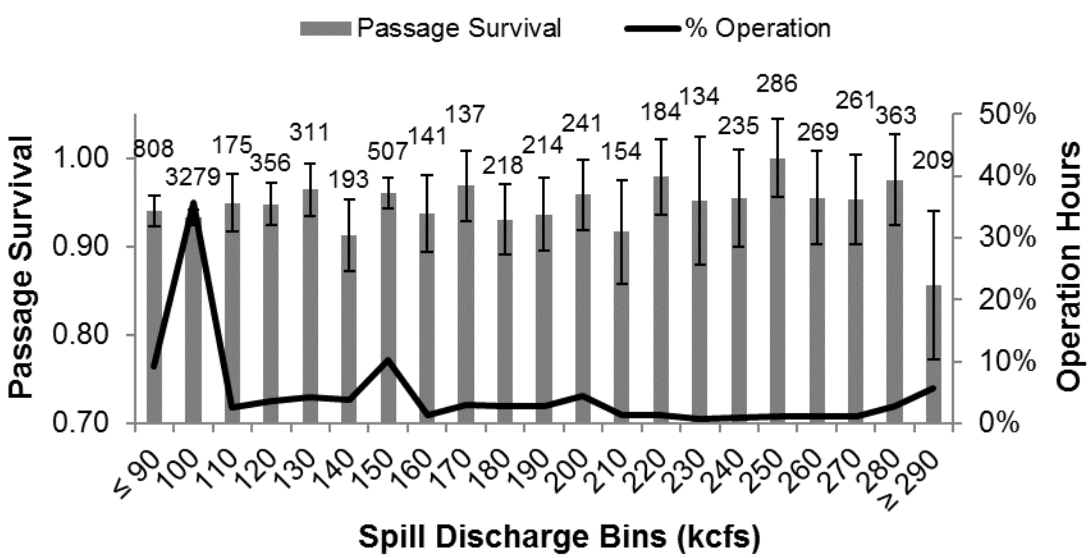

Figure 5.3. Survival Estimates with 95% Confidence Interval for CH1 Passing through the BON Spillway by 10 kcfs Spill Discharge Bins with Percent Spillway Operation. Sample sizes are shown above the bars.

Table 5.7. Median Spillway Tailrace Egress Time and Survival Estimates for CH1 at BON by 10 kcfs Discharge Intervals

Discharge (10 kcfs Bins)	Survival Estimate	Median Egress Time (h)
70	---[a]	0.53
80	---[a]	0.51
90	0.9404	0.46
100	0.9330	0.41
110	0.9491	0.39
120	0.9481	0.37
130	0.9643	0.35
140	0.9127	0.34
150	0.9603	0.32
160	0.9372	0.31
170	0.9685	0.30
180	0.9308	0.30
190	0.9365	0.30
200	0.9588	0.28
210	0.9165	0.26
220	0.9793	0.26
230	0.9515	0.26
240	0.9541	0.27
250	1.0002	0.28
260	0.9553	0.27
270	0.9530	0.27
280	0.9752	0.28
290	0.8563	0.26
300	---[b]	0.28

(a) Survival estimates were calculated for the 70, 80, and 90 kcfs bins combined.
(b) Survival estimates were calculated for the 290 and 300 kcfs bins combined.

Table 5.8. T-tests Comparing Survival Estimates between Spillway Discharge Volumes for CH1 at BON spillway for All Test Years Combined. Significantly different discharge volumes (P < 0.05 and power > 80%) are identified with an 'X'. "p" indicates a P < 0.05 and power < 80%. The full table (P-value, power, type II error, N 80%, point estimates and confidence intervals) can be found in Appendix C, Table C.12.

Bins	2008, 2010 and 2012 for CH1																			
1 \ 2	≤90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280
100																				
110																				
120																				
130		p																		
140					p															
150		p				p														
160																				
170																				
180																				
190																				
200																				
210																				
220		p				p														
230																				
240																				
250	p	X		p		X		p		p	p		p							
260																				
270																				
280																				
≥290			p				p		p			p		p			X			p

5.1.4 Spillway Passage Survival Rates of CH1 at BON by Tailwater Elevation

CH1 spillway passage survival rates were examined for the potential influence of tailwater elevation (Figure 5.4; Appendix D, Table D.4). The proportion of spillway operations that occurred during spring when tailwater elevations were in the range of the 8 m and 9 m tailwater elevation bins was relatively more frequent than those when tailwater elevations were in the range of 7 m and lower. CH1 passage proportion varied among the tailwater elevation bin groups (5 m [13.8%], 6 m [19.3%], 7 m [17.5%], 8 m [21.7%], and 9 m [27.6%]) and coincided with operation hours (Figure 5.4; Appendix D, Table D.1).

Higher survival estimates were observed for discharges in the range of the 6 m (0.9535, SE 0.0070) and 9 m bins (0.9542, SE 0.0094) based on hypothesis testing and confidence intervals (Table 5.9).

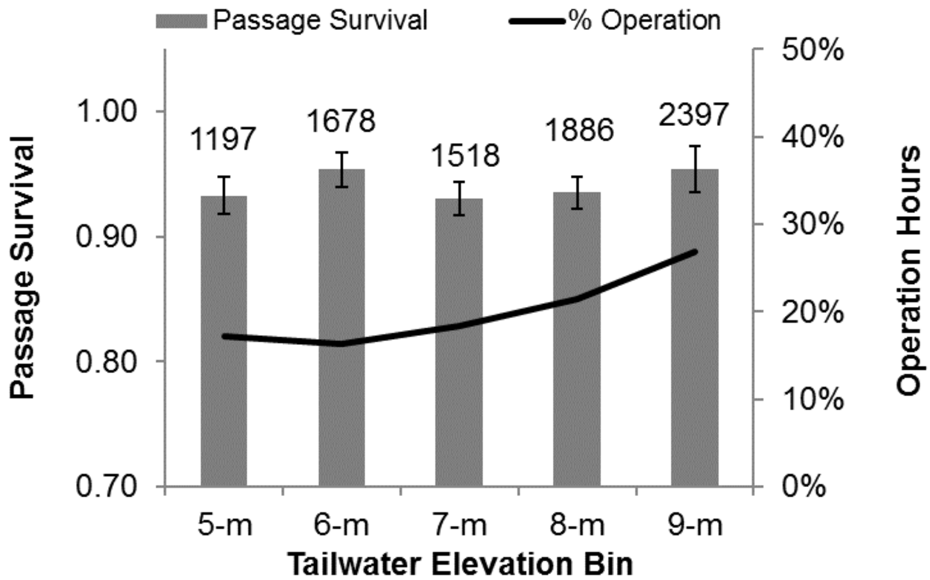

Figure 5.4. Survival Estimates with 95% Confidence Intervals for CH1 at BON by Spillway Tailwater Elevation Bins with Percent Spill Operation. Sample sizes are shown above the bars.

Table 5.9. P-values for T-tests Comparing Survival Estimates between Tailrace Elevations for CH1 at BON spillway for All Test Years Combined. Survival estimates that are significantly different (P < 0.05 and power > 80%) are bolded. Type II Error represents the probability of a Type II error assuming the point estimate is the true difference of the two variables. N 80% Power represents the sample size needed to reduce the probability of a Type II error to 20%. CI LB and CI UB represent the confidence intervals for the lower and upper bounds, respectively.

Elevation Bins	P-value	Power (%)	Type II Error (%)	N 80% Power	Point Est (%)	CI LB (%)	CI UB (%)
5 m *vs.* 6 m	*0.0452*	*52*	–	–	*-2.07*	*-4.10*	*-0.04*
5 m *vs.* 7 m	0.7988	–	94	161891	0.26	-1.74	2.26
5 m *vs.* 8 m	0.8158	–	94	213783	-0.23	-2.17	1.71
5 m *vs.* 9 m	0.0768	–	58	4818	-2.14	-4.51	0.23
6 m *vs.* 7 m	*0.017*	*67*	–	–	*2.33*	*0.42*	*4.24*
6 m *vs.* 8 m	0.0508	–	50	3644	1.84	-0.01	3.69
6 m *vs.* 9 m	0.9524	–	95	4711919	-0.07	-2.37	2.23
7 m *vs.* 8 m	0.5971	–	92	47444	-0.49	-2.31	1.33
7 m *vs.* 9 m	*0.0386*	*54*	–	–	*-2.40*	*-4.67*	*-0.13*
8 m *vs.* 9 m	0.0915	–	61	6171	-1.91	-4.13	0.31

5.1.5 CH1 Spillway Tailrace Egress Time at BON

Tailrace egress time for CH1 was examined by grouping egress data into 10 kcfs discharge bins; details for grouping are provided in Appendix F (Table F.4). Median values for egress time grouped into 10 kcfs spill discharge bins are shown in Table 5.7. There was a consistent decline in egress time with increase spillway discharge to about 200 kcfs, at which point egress time leveled off. The largest sample size in the 10 kcfs discharge groups (N = 2,571) was for the 100 kcfs spill discharge bin; median egress time was 0.41 h. The median egress times for fish passing at discharges contained within the range of the 190 to 230 kcfs discharge bins (N = 204) was about 0.27 h. The median egress time for discharges within the 70 to 180 kcfs bins was about 0.38 h; median egress time was 0.27 h for discharges within the 240 to 300 kcfs bins (Appendix F, Table F.4).

The ≤ 70, 90–100, 120–160 kcfs bins had longer tailrace egress time (based on hypothesis testing and confidence intervals) than other compared discharge bins (see Table 5.10 for exact comparisons; Appendix C, Table C.29). Conversely, the confidence intervals strongly favor the discharge bin 290 kcfs having a shorter tailrace egress time than discharge bins ≤70, 90, 100, 110, 120, 130, 140, 150, 160, 180, and 200. kcfs. The full table (P-value, power, type II error, N 80%, point estimates and confidence intervals) can be found in Appendix C, Table C.29.

Table 5.10. T-tests Comparing Survival Estimates between Spillway Discharge Volumes for CH1 at BON spillway for All Test Years Combined. Significantly different discharge volumes (P < 0.05 and power > 80%) are identified with an 'X'. "p" indicates a P < 0.05 and power < 80%. The full table (P-value, power, type II error, N 80%, point estimates and confidence intervals) can be found in Appendix C, Table C.29.

Bins	CH1																						
	≤70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290
80																							
90																							
100																							
110																							
120	p		X	X																			
130	X		X	X		p																	
140	X		X	X		X																	
150	X		X	X		X	X	X															
160	X		X	X		X	X	X	X														
170																							
180	X		X	X		X	X	X	X	X													
190	X																						
200	X		X	X		X	p																
210	X		X	X		X	X	X	p	p													
220																							
230	X		X	X		X	X	p															
240	X		X	X																			
250	X																						
260	X		X	X		X	X	X	X	X													
270	X		X	X		X	X	X	X														
280	X		X	X		X	X	X	X	X													
290	X		X	X	p	X	X	X	X	X		p		p									
≥300	X		X	X		X	p	p															

5.2 Juvenile Steelhead (STH) at BON Spillway

5.2.1 STH Spillway Passage Survival Rates by Spillbay

Before examining each individual spillbay and grouped spillbays, possible variations between years were considered. First, there was no significant difference (all P > 0.1192) found between individual years (2008 vs. 2010 vs. 2011 vs. 2012) (Table 5.11; Appendix C, Table C.1). The 2011 survival rates were compared to all other years as well to identify if the high flows during the late spring season affected survival. There was no significant difference (P = 0.1047) in survival rates for 2011 compared to the combined 2008, 2010, and 2012 (Table 5.12; Appendix C, Table C.2).

To better determine if there were survival differences, especially in the region of spillbays 8–12, where structural damage was evident, spillway passage survival estimates for STH for all study years were then combined (2008, 2010, 2011, and 2012) as shown in Figure 5.5, Figure 5.6, Table 5.12, and Appendix C.

STH spill passage survival rates averaged over all spillbays and all years was 0.942. There was a trend for relatively higher survival of STH passing through spillbays 4, 11, 12, 13, 15, and 18 (all > 0.95), while survival estimates for spillbays 3, 5, 6, and 9 were relatively lower (all < 0.93) (Table 5.13, Appendix C, Table C.6). As with CH1, STH tended to pass through spillbays near the ends of the spillway, with fewer passing spillbays near the center of the spillway. Numbers and proportions of STH passing through individual spillbays are shown in Figure 5.5 and Table 5.13 (Appendix C, Table C.3 and Table C.6).

When survival estimates for STH were compared between years for individual spillbays, a significant difference (P = 0.0052, power = 80%) was found where survival was lower in 2010 than in 2011 for spillbay 3 (using the P < 0.05, power > 80% criteria) (Table 5.14; Appendix C, Table C.12).

Using the confidence intervals and a less restrictive power condition (P < 0.05, power < 80%), Bay 3 in 2011 had a higher survival rate than 2012 (P = 0.039, power = 54%), Bay 5 in 2012 had a lower survival rate than 2010 and 2011 (P < 0.0485, Power < 59%) (Table 5.13). The full table (P-value, power, type II error, N 80%, point estimates and confidence intervals) can be found in Appendix C, Table C.12.

Table 5.11. BON Spillway Survival Estimates for Spillway Passage by Grouped Spillway Passage and Individual Years

Year	Spillbays for STH						
	P-value	Power (%)	Type II Error (%)	N 80% Power	Point Est (%)	CI LB (%)	CI UB (%)
2008 *vs.* 2010	0.7478		94	108814	-0.42	-2.98	2.14
2008 *vs.* 2011	0.3223		83	14591	-1.16	-3.46	1.14
2008 *vs.* 2012	0.9796		95	19311199	0.03	-2.27	2.33
2010 *vs.* 2011	0.4394		88	25207	-0.74	-2.62	1.14
2010 *vs.* 2012	0.6382		92	57032	0.45	-1.43	2.33
2011 *vs.* 2012	0.1192		66	8468	1.19	-0.31	2.69

Table 5.12. BON Spillway Survival Estimates for Spillway Passage by 2011 compared to all other years

P-value	Power (%)	Type II Error (%)	N 80% Power	Point Est (%)	CI LB (%)	CI UB (%)
0.1047		60	11358	1.11	-0.23	2.45

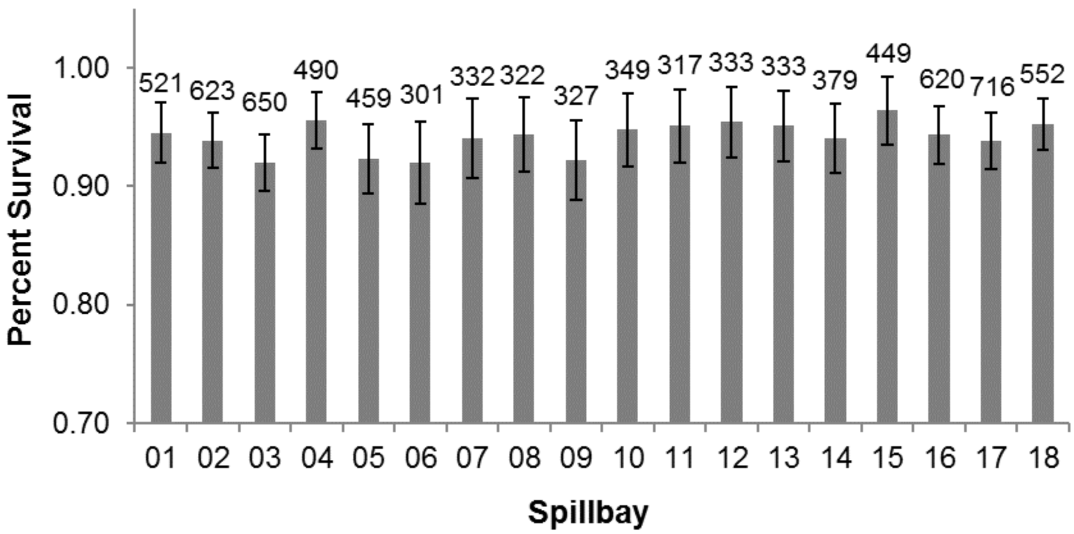

Figure 5.5. Spillway Passage Survival Estimates with 95% Confidence Intervals for STH at BON by Spillbay. Sample sizes are shown above the bars.

Table 5.13. Spillway Survival Estimates and Passage Proportions for STH at BON by Spillbay

Spillbay	Survival Estimate	Passage Proportion (%)
1	0.9451	6.5
2	0.9386	7.7
3	0.9203	8.1
4	0.9558	6.1
5	0.9232	5.7
6	0.9198	3.7
7	0.9408	4.1
8	0.9438	4.0
9	0.9225	4.1
10	0.9477	4.3
11	0.9510	3.9
12	0.9541	4.1
13	0.9511	4.1
14	0.9405	4.7
15	0.9639	5.6
16	0.9434	7.7
17	0.9382	8.9
18	0.9528	6.8

Table 5.14. P-values for T-tests Comparing Survival Estimates between Years for Individual Spillbays for STH at the BON Spillway. Survival estimates that are significantly different (P < 0.05 and power > 80% are bolded; "*" indicate a P < 0.05 with power < 80%). The full table (P-value, power, type II error, N 80%, point estimates and confidence intervals can be found in Appendix C, Table C.12.

Spillbays	2008/2010	2008/2011	2008/2012	2010/2011	2010/2012	2011/2012
Bay 1	0.062	0.210	0.404	0.294	0.168	0.610
Bay 2	0.995	0.677	0.814	0.668	0.799	0.479
Bay 3	0.312	0.208	0.998	**0.005**	0.187	*0.039**
Bay 4	0.907	0.808	0.931	0.687	0.802	0.787
Bay 5	0.248	0.196	0.654	0.895	*0.049**	*0.029**
Bay 6	0.598	0.751	0.860	0.311	0.604	0.475
Bay 7	0.983	0.985	0.795	0.996	0.813	0.762
Bay 8	0.482	0.729	0.700	0.228	0.653	0.320
Bay 9	0.133	0.386	0.321	0.239	0.286	0.838
Bay 10	0.363	0.953	0.356	0.143	0.939	0.100
Bay 11	0.573	0.787	0.947	0.608	0.358	0.674
Bay 12	0.772	0.713	0.538	0.928	0.211	0.137
Bay 13	0.494	0.330	0.749	0.810	0.565	0.288
Bay 14	0.387	0.060	0.118	0.255	0.460	0.580
Bay 15	0.785	0.997	0.484	0.743	0.332	0.332
Bay 16	0.317	0.881	0.668	0.193	0.342	0.586
Bay 17	0.801	0.506	0.321	0.258	0.172	0.580
Bay 18	0.219	0.421	0.411	0.279	0.295	0.960

5.2.2 STH Spillway Passage Survival Rates at BON by Spillbay Group

STH passing the spillway at BON were grouped for estimating survival rates by adjacent spillbays as shown in Figure 5.6 and Appendix C, Table C.4 and Table C.9. Spillbays were divided into five groups because spillbays 1–3 and 16–18 have deep-flow deflectors (7 ft above MSL) and all other spillbays have shallow-flow deflectors (14 ft above MSL). The spillbays with shallow-flow deflectors were divided into three groups because it was suspected that the middle spillbays (8–12) may have increased erosion on the spill chute, in the stilling basin or tailrace, or rock deposition in the tailrace.

The highest survival rate was estimated for STH passing through spillbay group 13–15 (0.9525, SE 0.0087) and the lowest survival rate was estimated for those passing through spillbay group 1–3 (0.9340, SE 0.0071). During survival studies from 2008 to 2012 (excluding 2009), the fewest STH passed through spillbays 13–15 (14.4%); passage proportions through the remaining spillbay groups were similar: spillbay group 1–3 (22.2%), spillbay group 4–7 (19.6%), spillbay group 8–12 (20.4%), and spillbay group 16–18 (23.4%) (Appendix C, Table C.4 and Table C.9). There were no significant differences in STH survival estimates between spillbay groups for years combined or individual years (using the P < 0.05, power > 80% criteria) (Table 5.15). In 2010, the confidence intervals favor spillbay group 1–3 having a lower survival rate than bay groups 8–12 and 16–18. In 2012, the confidence intervals favor bay group 13–15 having a higher survival rate than bay groups 1–3 and 4–7 (Appendix C, Table C.15, Table C.18, and Table C.21).

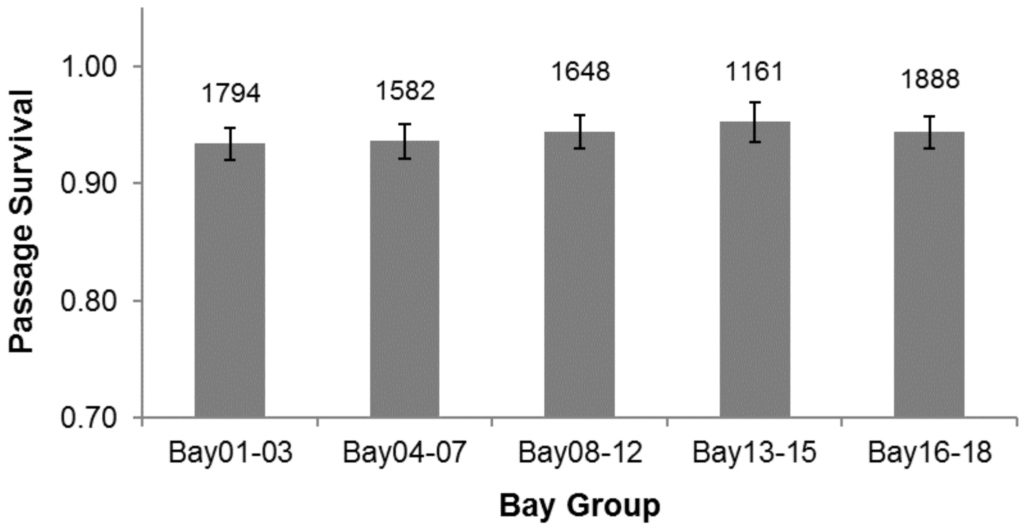

Figure 5.6. Spillway Passage Survival Estimates with 95% Confidence Intervals for STH at BON by Spillbay Group. Sample sizes are shown above the bars.

Table 5.15. P-values for T-tests Comparing Survival Estimates between Grouped Spillbays for STH at the BON Spillway. Survival estimates that are significantly different (P < 0.05 and power > 80% are bolded. Type II Error represents the probability of a Type II error assuming the point estimate is the true difference of the two variables. N 80% Power represents the sample size needed to reduce the probability of a Type II error to 20%. CI LB and CI UB represent the confidence intervals for the lower and upper bounds, respectively.

Spillbay Groups	2008	2010	2011	2012
1-3 *vs.* 4-7	0.691	0.498	0.757	0.986
1-3 *vs.* 8-12	0.541	0.111	0.835	0.372
1-3 *vs.* 13-15	0.360	0.416	0.495	0.147
1-3 *vs.* 16-18	0.434	0.184	0.718	0.520
4-7 *vs.* 8-12	0.818	0.445	0.623	0.358
4-7 *vs.* 13-15	0.604	0.841	0.738	0.134
4-7 *vs.* 16-18	0.706	0.575	0.522	0.512
8-12 *vs.* 13-15	0.787	0.651	0.390	0.518
8-12 *vs.* 16-18	0.897	0.851	0.895	0.808
13-15 *vs.* 16-18	0.881	0.773	0.301	0.390

5.2.3 STH Spillway Passage Survival Rates at BON by Discharge

The survival rates of STH were estimated for passage in spill discharge divided into 10 kcfs bins, then analyzed to assess patterns in STH survival related to spill discharge rates (Figure 5.7 and Table 5.16; Appendix D, Table D.5 and Table D.6). There was a weak pattern in higher survival with increasing discharge up to 290 kcfs where survival declined drastically. The highest proportion of STH passed in spill discharges within the range of the 100 kcfs bin, which had the most hours of operation, following requirements for spillway operation in the BON FPP.

The results from the 10 kcfs discharge bin analysis, based on less restrictive hypotheses testing criteria (all $P < 0.048$, power > 50%) and confidence intervals (Table 5.17), indicated higher passage survival estimates for discharges in the 230 to 250 kcfs bins than for discharge bins between 90–140 kcfs (Figure 5.77); whereas lower survival estimates were found for passage in discharges ≥ 290 kcfs bins relative to lower discharge volumes ($P < 0.0477$, power > 51%) (Figure 5.7) (Table 5.17; Appendix C, Table C.24). The discharge bin 130 had a lower survival rate than 230, 240, 250, and 280 ($P < 0.0327$, power > 57%).

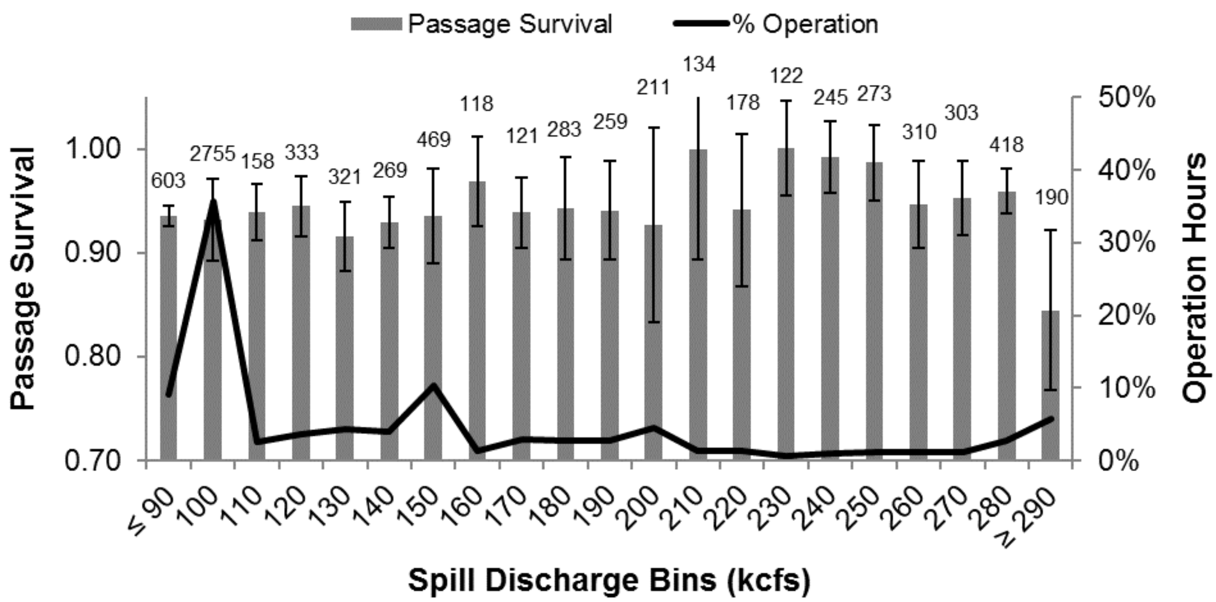

Figure 5.7. Spillway Passage Survival Estimates with 95% Confidence Intervals for STH at BON by 10 kcfs Spill Discharge Bins with Percent Spillway Operation. Sample sizes are shown above the bars.

Table 5.16. Median Spillway Tailrace Egress Time and Survival Estimates for STH at BON by 10 kcfs Discharge Intervals

Discharge (10 kcfs Bins)	Survival Estimate	Median Egress Time (h)
70	---[(a)]	0.47
80	---[(a)]	0.47
90	0.9559	0.43
100	0.9374	0.41
110	0.9317	0.38
120	0.9378	0.36
130	0.9446	0.35
140	0.9159	0.32
150	0.9302	0.31
160	0.9442	0.31
170	0.9848	0.31
180	0.9415	0.3
190	0.9643	0.29
200	0.9942	0.29
210	0.9800	0.25
220	0.9604	0.23
230	0.9607	0.31
240	1.0182	0.28
250	0.9906	0.29
260	0.9869	0.29
270	0.9463	0.31
280	0.9530	0.29
290	0.8448	0.29
300	---[(b)]	0.33

(a) Survival estimates were calculated for the 70, 80, and 90 kcfs bins combined.
(b) Survival estimates were calculated for the 290 and 300 kcfs bins combined.

Table 5.17. T-tests Comparing Survival Estimates between Spillway Discharge Volumes for STH at the BON spillway for All Test Years Combined. Significantly different discharge volumes (P < 0.05 and power > 80%) are identified with an 'X'. "p" indicates a P < 0.05 and power < 80%. The full table (P-value, power, type II error, N 80%, point estimates and confidence intervals) can be found in Appendix C, Table C.24.

Bins	2008, 2010 to 2012 for STH																			
1 \ 2	≤90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280
100																				
110																				
120																				
130																				
140																				
150																				
160																				
170																				
180																				
190																				
200																				
210																				
220																				
230	p	p	p	p	X	p	p		p											
240	X	p	p	p	X	X			p											
250	p	p	p		X	p														
260																				
270																				
280					P															
≥290	p	p	p	p		p	p	p	p	p	p		p		X	X	X	p	p	X

5.2.4 Spillway Passage Survival Rates by Tailwater Elevation

STH spillway survival rates were investigated to determine if spill passage survival is dependent upon tailwater elevation. STH spill passage survival was estimated for discharges that occurred within the five 1 m tailwater elevation groupings shown in Figure 5.8 (Appendix D, Table D.4). The survival estimates for STH passing when tailwater elevations were within the range of the bin groups ranged from 0.9308 (SE 0.0064) for the 8 m bin to 0.9538 (SE 0.0076) for the 6 m bin.

Survival estimates for STH that passed at the spillway when tailwater elevations were within the 6 m elevation bin were higher than for STH that passed in the 7 m and 8 m tailwater elevations (using a less restrictive criteria and confidence intervals) (P < 0.0302, power > 58%). Survival estimates were higher for STH passing when tailwater elevations were within the 9 m bin than for when passing in the 7 m and 8 m bins (P < 0.0332, power > 57%) (Table 5.18).

The proportion of time that the BON spillway was operating during spring was higher when tailwater was within the range of the 8 m and 9 m tailwater elevation bins than when tailwater was less than the 8 m bin. Passage proportions varied for discharges that occurred when tailwater was within the range of the various elevation bins (5 m [11.0%], 6 m [17.1%], 7 m [16.9%], 8 m [24.2%], and 9 m [30.8%]) and coincided with the operation hours at each tailwater elevation (Appendix D, Table D.1).

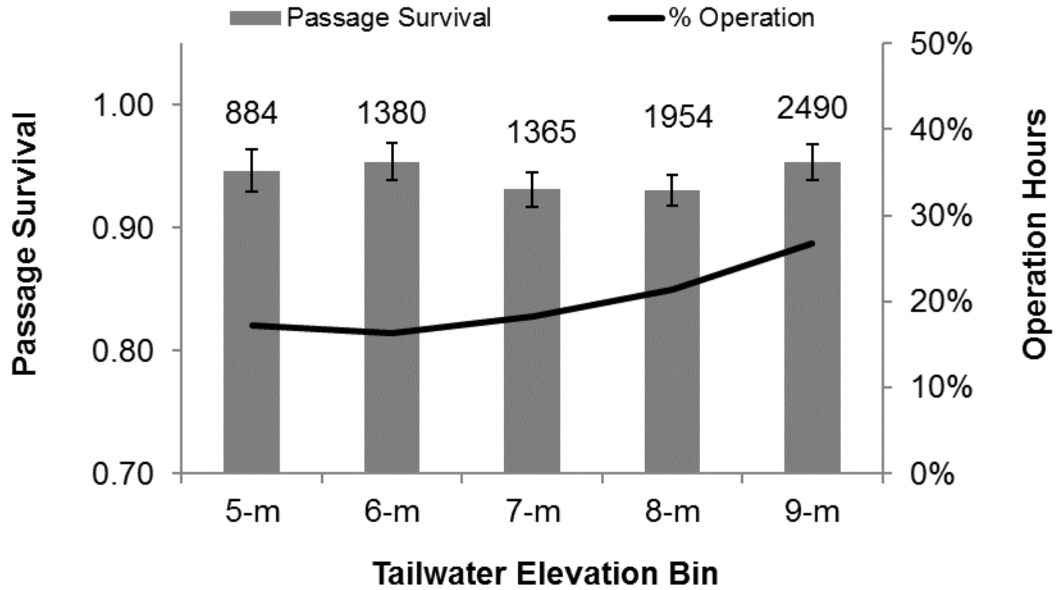

Figure 5.8. Spillway Passage Survival Estimates with 95% Confidence Intervals for STH at BON by Tailwater Elevation Bin with Percent Spillway Operation. Sample sizes are shown above the bars.

Table 5.18. P-values for T-tests Comparing Survival Estimates between Tailrace Elevations for STH at BON Spillway for All Test Years Combined. Survival estimates that are significantly different ($P < 0.05$ and power > 80%) are bolded. Type II Error represents the probability of a Type II error assuming the point estimate is the true difference of the two variables. N 80% Power represents the sample size needed to reduce the probability of a Type II error to 20%. CI LB and CI UB represent the confidence intervals for the lower and upper bounds, respectively.

Elevation Bins	P-value	Power (%)	Type II Error (%)	N 80% Power	Point Est (%)	CI LB (%)	CI UB (%)
5 m *vs.* 6 m	0.5305	–	90	21987	-0.72	-2.97	1.53
5 m *vs.* 7 m	0.1671	–	72	4452	1.55	-0.65	3.75
5 m *vs.* 8 m	0.1406	–	69	4576	1.58	-0.52	3.68
5 m *vs.* 9 m	0.5536	–	91	35532	-0.68	-2.93	1.57
6 m *vs.* 7 m	*0.0302*	*58*	–	–	*2.27*	*0.22*	*4.32*
6 m *vs.* 8 m	*0.0207*	*64*	–	–	*2.30*	*0.35*	*4.25*
6 m *vs.* 9 m	0.9703	–	95	10970966	0.04	-2.07	2.15
7 m *vs.* 8 m	0.9752	–	95	13158747	0.03	-1.86	1.92
7 m *vs.* 9 m	*0.0332*	*57*	–	–	*-2.23*	*-4.28*	*-0.18*
8 m *vs.* 9 m	*0.023*	*62*	–	–	*-2.26*	*-4.21*	*-0.31*

5.2.5 Spillway Tailrace Egress Time

Tailrace egress time for STH was examined using discharges grouped into 10 kcfs bins; details are provided in Appendix F (Table F.5). Median tailrace egress values for spill discharge grouped into 10 kcfs bins are shown in Table 5.19.

There was a consistent decline in egress time with increase spillway discharge to about 190 kcfs, at which point egress time leveled off. Following the FPP, which specifies spill discharge per bay, the largest sample size in the 10 kcfs discharge bins (N = 2,179) occurred for the 100 kcfs spill discharge; median egress time was 0.41 h. The average of the median egress times for spill discharges within the range of the 70 to 180 kcfs bins was 0.37 h; the average median egress time was 0.29 h for discharges within the range of the 190 to 300 kcfs bins (Appendix F, Table F.5). The full table (P-value, power, type II error, N 80%, point estimates and confidence intervals) can be found in Appendix C, Table C.30).

Based on confidence intervals, the discharge bin ≤ 70 kcfs has a longer tailrace egress time than 140, 210, 220, 240, 250, 260, 280, and 290 kcfs bins. Based on hypothesis testing, the discharge bin 80 kcfs had a significantly longer tailrace egress time (all $P < 0.0268$, all power > 60%) than 110, 120, 130, 140, 160, 180, 210, 220, 230, 240, 250, 260, 280, 290, and ≥300 kcfs bins. Based on confidence intervals, discharge bins 90 kcfs had longer tailrace egress time than 110, 120, 130, 140, 160, 180, 210, 220, 230, 240, 250, 260, 280, 290, and ≥ 300 kcfs bins. The discharge bin 110 kcfs had a longer tailrace egress time than the 140, 210, 220, 240, 250, 260, 280, and 290 kcfs bins. The discharge bin 120 and 150 kcfs had a longer tailrace egress time than 140, 160, 210, 220, 240, 250, 260, 280, 290, and ≥ 300 kcfs bins. The 130 kcfs discharge bin had a longer tailrace egress time than 140, 210, 220, 240, 250, 260, 280, and 290 kcfs discharge bins. The discharge bins 210 and 220 kcfs has a shorter tailrace egress time than ≤ 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, and 180 kcfs discharge bins. The 250 kcfs discharge bin had a shorter tailrace egress time than the ≤ 70, 80, 90, 110, 120, 130, 150, and 160 kcfs discharge bins.

Table 5.19. Statistically Significant Tailrace Egress Time Differences Between 10 kcfs Discharge Bins of BON for STH and All Test Years Combined. Significantly different discharge volumes (P < 0.05 and power > 80%) are identified with an ‘X’. “p” indicates a P < 0.05 and power < 80%. The full table (P-value, power, type II error, N 80%, point estimates and confidence intervals) can be found in Appendix C, Table C.30.

Bins	STH																						
	≤70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290
80																							
90																							
100																							
110		X	p																				
120		p																					
130		X	P																				
140	p	X	p		X	X	p																
150								p															
160		X	p			p			p														
170																							
180		p																					
190																							
200																							
210	p	X	p	p	X	X	X	p	X	p		p											
220	p	X	p	p	X	X	X	p	X	p		p											
230		X	p																				
240	p	X	p		X	X	p		X														
250	p	X	p		X	X	X		X	p													
260	p	X	p		X	X	p		p														
270																							
280	p	X	p		X	X	X		X														
290	p	X	p		p	X	p		p														
≥300		X	p			p			p														

5.3 Subyearling Chinook Salmon (CH0) at BON Spillway

5.3.1 CH0 Spillway Passage Survival Rates at BON by Spillbay

Before examining each individual spillbay and grouped spillbays, possible variations between years were considered. First, 2012 survival rates were significantly higher than in 2010 (P > 0.0001, power = 99%), and, the confidence intervals favored 2008 having a higher survival rate than 2010 (i.e. 2012 > 2008 > 2010) (Table 5.20; Appendix C, Table C.1).

To better determine if there were survival differences, especially in the region of spillbays 8–12, where structural damage was evident, spillway passage survival estimates for CH0 for all study years were then combined (2008, 2010, and 2012) as shown in Figure 5.9, Figure 5.10, and Table 5.21, and further detailed in Appendix C, Table C.13. Based on the hypothesis test criteria only spillbay 14 in 2012 had greater survival rates than in 2010. The confidence intervals indicated spillbay 5 in 2008 had a lower survival rate than in 2012, spillbays 13 and 18 in 2010 had a lower survival rate than 2012, and spillbay 14 in 2010 had a lower survival rate than 2008 (Table 5.22 and Appendix C, Table C.13).

Passage survival estimates across all spillbays averaged 0.95. There was not a definite trend in survival estimates across the spillway (Figure 5.9 and Table 5.21; Appendix C, Table C.7), as was the case for STH and CH1.

Spillbays 2 and 3 had the lowest passage survival rate (0.9286 and 0.9370, respectively), but spillbays at the other end of the spillway did not follow this lower survival trend, and spillbay 1 had one of the higher survival rates (0.9575, SE 0.0095). Spillbay 4 had the highest passage (N = 1,021) and also high survival (0.9596, SE 0.0063). There was no significant difference in survival rates between spillbays. The proportion of CH0 that passed through individual spillbays is shown in Table 5.21. (Appendix C, Table C.4).

Table 5.20. BON Spillway Survival Estimates for Spillway Passage by Grouped Spillway Passage and Individual Years

Year	Spillbays for CH0						
	P-value	Power (%)	Type II Error (%)	N 80% Power	Point Est (%)	CI LB (%)	CI UB (%)
2008 *vs.* 2010	0.0171	66			1.90	0.34	3.46
2008 *vs.* 2011							
2008 *vs.* 2012	0.0379	55			-1.20	-2.33	-0.07
2010 *vs.* 2011							
2010 *vs.* 2012	0	99			-3.10	-4.44	-1.76
2011 *vs.* 2012							

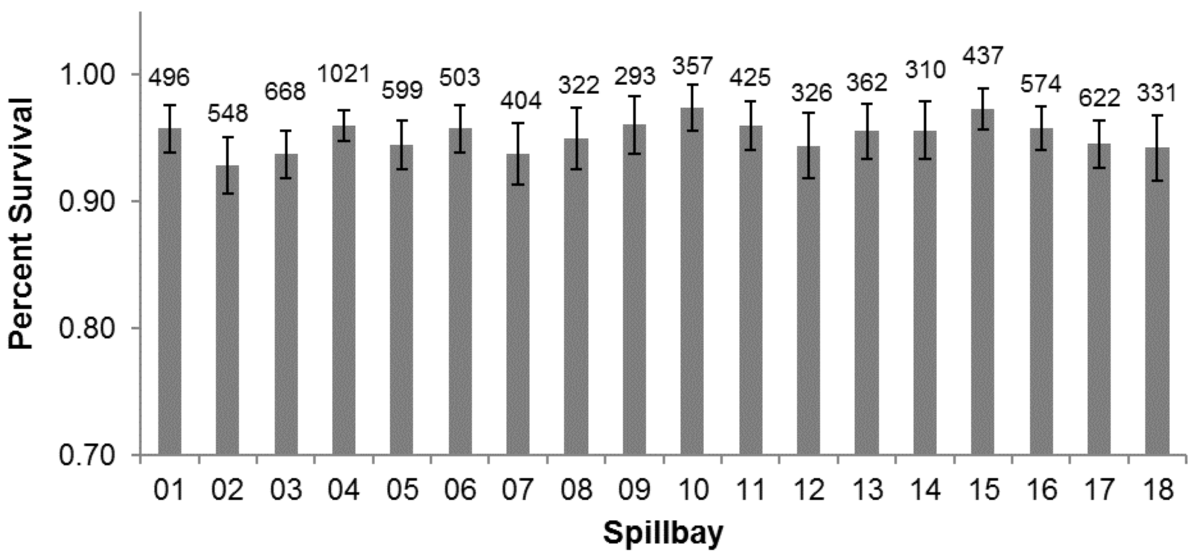

Figure 5.9. Spillway Passage Survival Estimates with 95% Confidence Intervals for CH0 at BON by Spillbay. Sample sizes are shown above the bars.

Table 5.21. Spillway Passage Survival Estimates and Passage Proportions for CH0 at BON by Spillbay

Spillbay	Survival Estimate	Passage Proportion (%)
1	0.9575	5.8
2	0.9286	6.4
3	0.9370	7.8
4	0.9596	11.9
5	0.9445	7.0
6	0.9573	5.9
7	0.9374	4.7
8	0.9494	3.8
9	0.9604	3.4
10	0.9739	4.2
11	0.9595	4.9
12	0.9438	3.8
13	0.9552	4.2
14	0.9560	3.6
15	0.9729	5.1
16	0.9578	6.7
17	0.9450	7.2
18	0.9422	3.9

Table 5.22. P-values for T-tests Comparing Survival Estimates between Years for Individual Spillbays for CH0 at the BON Spillway. Survival estimates that are significantly different (P < 0.05 and power > 80% are bolded; P-values italicized indicted a P < 0.05 with power < 80%). The full table (P-value, power, type II error, N 80%, point estimates and confidence intervals can be found in Appendix C, Table C.13.

Spillbays	2008/2010	2008/2012	2010/2012
Bay 1	0.811	0.924	0.864
Bay 2	0.104	0.228	0.571
Bay 3	0.695	0.442	0.148
Bay 4	0.539	0.588	0.238
Bay 5	0.152	*0.043**	0.718
Bay 6	0.743	0.051	0.112
Bay 7	0.774	0.330	0.457
Bay 8	0.504	0.270	0.085
Bay 9	0.076	0.243	0.269
Bay 10	0.825	0.808	0.619
Bay 11	0.535	0.182	0.164
Bay 12	0.584	0.433	0.960
Bay 13	0.058	0.684	*0.022**
Bay 14	*0.022**	0.632	**0.002**
Bay 15	0.539	0.328	0.135
Bay 16	0.142	0.664	0.228
Bay 17	0.833	0.891	0.920
Bay 18	0.109	0.609	*0.023**

5.3.2 CH0 Spillway Passage Survival Rates at BON by Spillbay Grouping

Similar to CH1 and STH, BON CH0 spillway survival rate was estimated for groups of adjacent spillbays (Figure 5.10 and Appendix C, Table C.4 and Table C.10). Spillbays were divided into five groups because spillbays 1–3 and 16–18 have deep-flow deflectors (7 ft above MSL); all other spillbays have shallow-flow deflectors (14 ft above MSL). The spillbays with shallow–flow deflectors were divided into three groups, because it was suspected that the middle spillbays (8–12) may have increased erosion or rock deposition in the tailrace.

The survival of CH0 passing through the end spillbays with the deep-flow deflectors was lower (< 0.95) than that for passage through the spillbays with shallow-flow deflectors, with survival through spillbays 1–3 being significantly lower (P < 0.05) than CH0 passing through spillbays 8-12 and 13-15 (Table 5.23). Significantly lower survival was detected at spillbays 1–3 in 2012 relative to spillbay groups 4–7, 8–12, and 13–15 (Table 5.24).

By year survival was also lower at spillbays 4–7 in 2008 than for spillbays 8–12 (Table 5.24). The highest survival was estimated for passage through spillbays 13–15 (0.9625, SE 0.0059) and the lowest survival rate was estimated for passage through spillbays 1–3 (0.9403, SE 0.0059). During survival studies from

2008, 2010, and 2012, most CH0 passed through spillbays 4–7 (29.4%); the fewest passed spillbays 13–15 (12.9%) (Figure 5.10; Appendix C, Table C.16, Table C.19 and Table C.22).

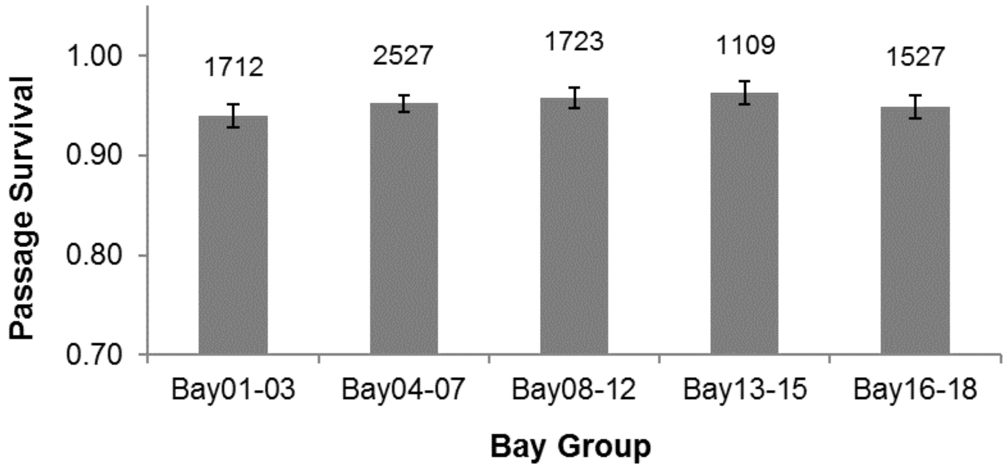

Figure 5.10. Spillway Passage Survival Estimates with 95% Confidence Intervals for CH0 at BON by Spillbay Group. Sample sizes are shown above the bars.

Table 5.23. P-values for T-tests Comparing Survival Estimates between Grouped Spillbays for CH0 at the BON Spillway. Survival estimates that are significantly different (P < 0.05) are bolded.

Bay Groups	2008, 2010 and 2011			
	1-3	4-7	8-12	13-15
4–7	0.112			
8–12	**0.025**	0.392		
13–15	**0.008**	0.154	0.535	
16–18	0.286	0.704	0.272	0.111

Table 5.24. P-values for T-tests Comparing Survival Estimates between Grouped Spillbays by year for CH0 at the BON Spillway. Survival estimates that are significantly different ($P < 0.05$) are bolded.

Spillbay Groups	2008	2010	2012
1–3 *vs.* 4–7	0.138	0.340	*0.049*
1–3 *vs.* 8–12	0.511	0.394	0.070
1–3 *vs.* 13–15	0.726	0.415	*0.012*
1–3 *vs.* 16–18	0.629	0.905	0.289
4–7 *vs.* 8–12	*0.034*	0.965	1.000
4–7 *vs.* 13–15	0.101	0.970	0.325
4–7 *vs.* 16–18	0.051	0.450	0.460
8–12 *vs.* 13–15	0.838	0.942	0.379
8–12 *vs.* 16–18	0.863	0.499	0.498
13–15 *vs.* 16–18	0.953	0.504	0.151

5.3.3 CH0 Spillway Passage Survival Rate at BON by Discharge

The survival rate of CH0 was estimated for passage in spill discharge binned by 10 kcfs intervals, then analyzed to identify differences in CH0 survival rates that might result from passage in higher or lower spill discharge (Figure 5.11 and Table 5.25; Appendix D, Table D.5 and D.6). Unlike CH1 and STH, CH0 spill discharges did not exceed 230 kcfs for the 10 kcfs bins. There was a correlation between spill and survival rates for CH0 ($R^2 = 0.70$, $P < 0.05$) (Figure 5.12), with increased survival rates at higher spill discharge. Survival estimates for the 10 kcfs discharge bins indicate CH0 passing in the 90 kcfs and 100 kcfs bins were significantly lower ($P < 0.05$) than survival estimates of CH0 passing in higher spill volumes (Table 5.26). This trend in lower survival rates at lower flows vs higher flows was observed over the entire range of spill volumes, but the correlation was not as strong at the higher spill volumes.

For the 10 kcfs bins, a higher proportion of CH0 passed with discharges within the ≤ 90 kcfs and 150 kcfs bins, 14.9% and 13.9%, respectively (Figure 5.11; Appendix C, Table C.25). Operation hours were greatest for spill discharges within the ≤ 90 and 100 kcfs bins, which is consistent with the FPP for 85 kcfs and 95 kcfs spill volumes during CH0 summer passage.

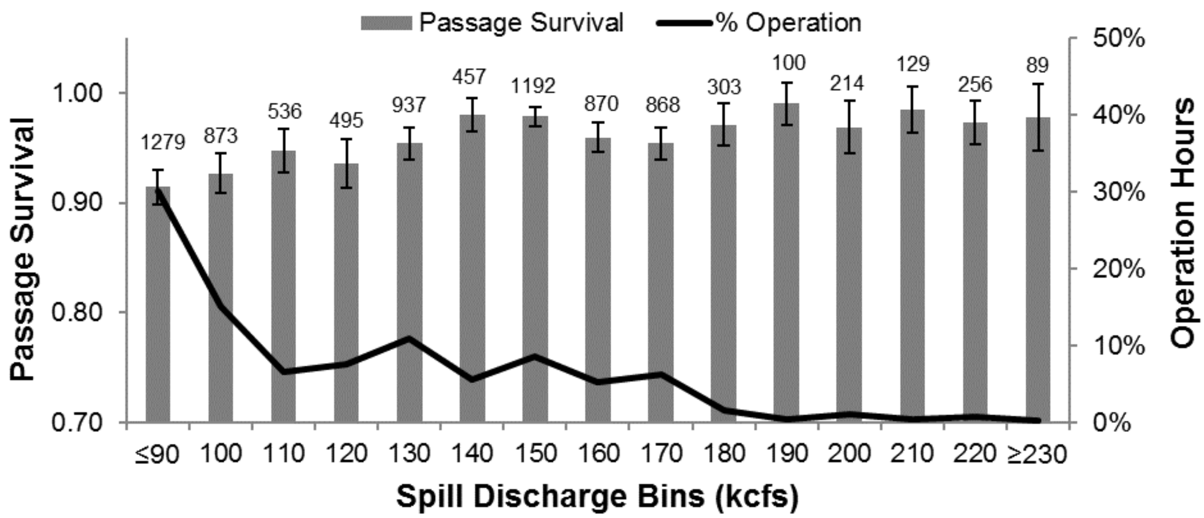

Figure 5.11. Spillway Passage Survival Estimates with 95% Confidence Intervals for CH0 at BON by 10 kcfs Spill Discharge Bins with Percent Spillway Operation. Sample sizes are shown above the bars.

Table 5.25. Survival Rates and Median Tailrace Egress Time for CH0 at BON by 10 kcfs Discharge Intervals

Discharge (10 kcfs Bins)	Survival Estimate	Median Egress Time (h)
80	---[(a)]	0.54
90	0.9141	0.51
100	0.9268	0.45
110	0.9476	0.41
120	0.9358	0.38
130	0.9538	0.36
140	0.9795	0.34
150	0.9783	0.32
160	0.9593	0.31
170	0.9539	0.30
180	0.9712	0.30
190	0.9900	0.28
200	0.9684	0.28
210	0.9845	0.28
220	0.9729	0.26
230	0.9775	0.25

(a) Survival estimates were calculated for the 80 and 90 kcfs bins combined

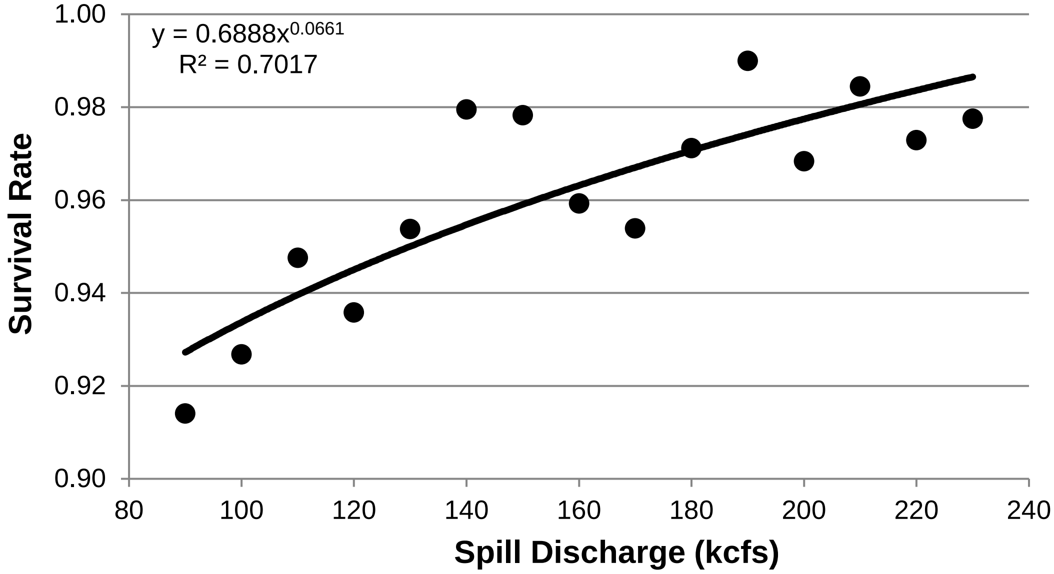

Figure 5.12. Spillway Passage Survival Rate Relative to Spillway Discharge for CH0 at BON

Table 5.26. T-tests Comparing Survival Estimates between Spillway Discharge Volumes for CH0 at the BON spillway for All Test Years Combined. Significantly different discharge volumes ($P < 0.05$, power < 80%) are identified with an 'X'.

Bins	2008, 2010 to 2012 for CH0													
	≤ 90	100	110	120	130	140	150	160	170	180	190	200	210	220
100														
110	X													
120														
130	X	X												
140	X	X	X	X	X									
150	X	X	X	X	X									
160	X	X					X							
170	X	X				X	X							
180	X	X		X										
190	X	X	X	X	X			X	X					
200	X	X												
210	X	X	X	X	X				X					
220	X	X		X										
230	X	X		X										

5.3.4 CH0 Spillway Passage Survival Rates at BON by Tailwater Elevation

CH0 survival estimates in spill that occurs when the tailwater is within the range of different elevation bins was examined in conjunction with the hours of spillbay operation (Figure 5.13; Appendix D, Table D.4). The highest CH0 survival rate was observed for discharges that occurred when tailwater was within the range of the 9 m bin (0.9709, SE 0.0083) and lowest survival estimates were observed for passage in spill discharges within the range of the 5 m bin (0.9050, SE 0.0094). The rate of survival was significantly lower for CH0 passing in 5 m, 6 m and 7 m tailwater elevation bins than those passing when tailwater elevations were within the 8 m, and 9 m tailwater elevation bins ($P < 0.05$). The survival rate of CH0 passing in the 5 m and 6 m tailwater elevation bins were also significantly lower than that of CH0 passing in the 7 m bin (Table 5.27). During the summer survival studies, the BON spillway operation durations were within the range of the 7 m and 8 m tailwater elevation bins the majority of the time, followed by the 5 m and 6 m bins. Passage proportion varied for the different tailwater elevation bins (5 m [11.6%], 6 m [7.9%], 7 m [28.8%], 8 m [46.9%], and 9 m [4.8%]) and coincided with the operation hours at each tailwater elevation (Appendix D, Table D.1).

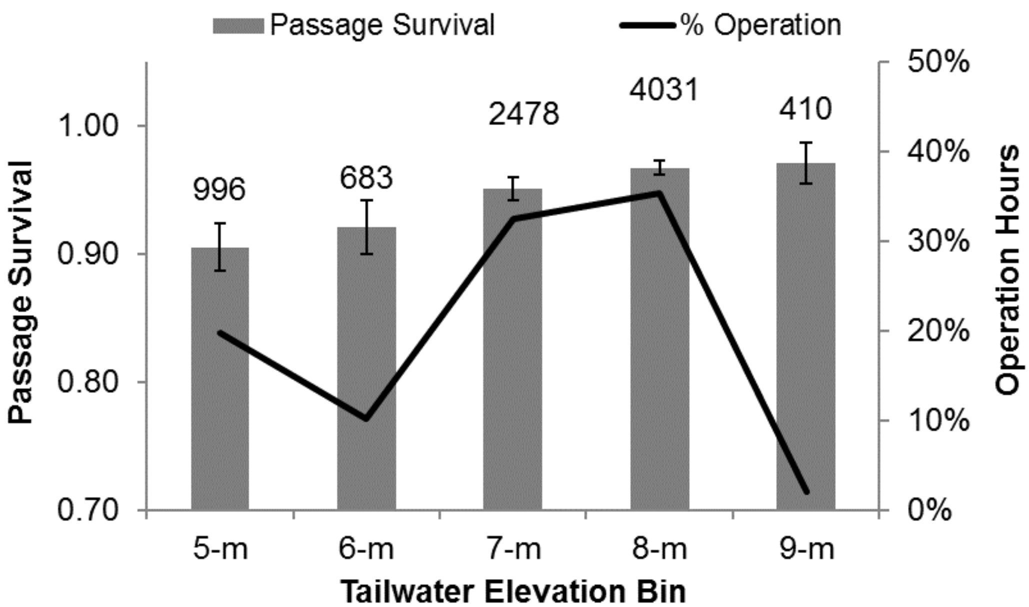

Figure 5.13. Spillway Passage Survival with 95% Confidence Intervals for CH0 at BON by Tailwater Elevation Bin with Percent Spillway Operation. Sample sizes are shown above the bars.

Table 5.27. P-values for Paired T-tests Comparing Survival Estimates Between Tailrace Elevations for CH0 at BON spillway for All Test Years Combined. Survival estimates that are significantly different (P <0.05) are bolded.

Bins	CH0			
1 / 2	5 m	6 m	7 m	8 m
6 m	0.259			
7 m	**0.001**	**0.010**		
8 m	**0.001**	**0.001**	**0.003**	
9 m	**0.001**	**0.001**	**0.034**	0.674

5.3.5 CH0 Spillway Tailrace Egress Time and Spillway Passage Survival Rates at BON

Tailrace egress for CH0 was examined using discharges grouped into 10 kcfs bins; details are provided in Appendix D (Table F.6). Median values of CH0 survival rates and median tailrace egress time for spill discharges grouped into 10 kcfs bins are shown in Table 5.26. The largest sample size for bins in the 10 kcfs discharge increment groups (N = 1,049) occurred at discharges within the 150 kcfs spill discharge bin; median egress time was 0.32 h. Longest median egress time was 0.54 h for spill discharges within the 80 kcfs bin (N = 19), and shortest egress time was 0.25 h for discharges within the 230 kcfs bin (N = 78). The average of the median egress times for spill discharge within the range of the 80 kcfs to 140 kcfs bins was 0.43 h; the average median egress time was 0.29 h for discharge within the range of the 150 kcfs to 230 kcfs bins (Appendix D, Table F.6).

6.0 Results—The Dalles Dam Spillway

The methods used to partition the spillbays and discharge volumes for TDA spillway are described under Methods (Section 2.0). Spillway passage survival estimates and other statistics describing passage of CH1, STH, and CH0 through the spillway at TDA are presented in the following sections and are also available in Appendix E. Data for passage of tagged juvenile salmonids through TDA spillway for years 2010–2012 were used for the analyses.

6.1 Yearling Chinook Salmon (CH1) at TDA

6.1.1 CH1 Spillway Passage Survival Rates at TDA by Spillbay

Spillway passage survival estimates for CH1 at TDA through spillbays at the northwest end of the spillway, inside of the new spillwall (spillbays 1–8), are shown in Figure 6.1 and Table 6.1 (Appendix E, Table E.1 and Table E.4). For combined years 2010 to 2012, CH1 passing through spillbay 3 had the highest survival estimate (0.9611, SE 0.0073) and those passing through the adjacent spillbay, spillbay 2, had the lowest survival estimate (0.9251, SE 0.0100). The survival rate of CH1 through spillbays 2 was significantly lower ($P < 0.05$) than all other spillbays, except spillbay 6 (Table 6.2). There was not a significant difference in survival rates between any of the other spillbays. Survival estimates for CH1 passing through spillbays 1 and 3–8 varied only slightly from each other (all > 0.948). Spillbay 8 passed the highest proportion of CH1 and passage numbers declined consistently across the spillway from spillbay 8 to spillbay 1 for the combined years (Table 6.2).

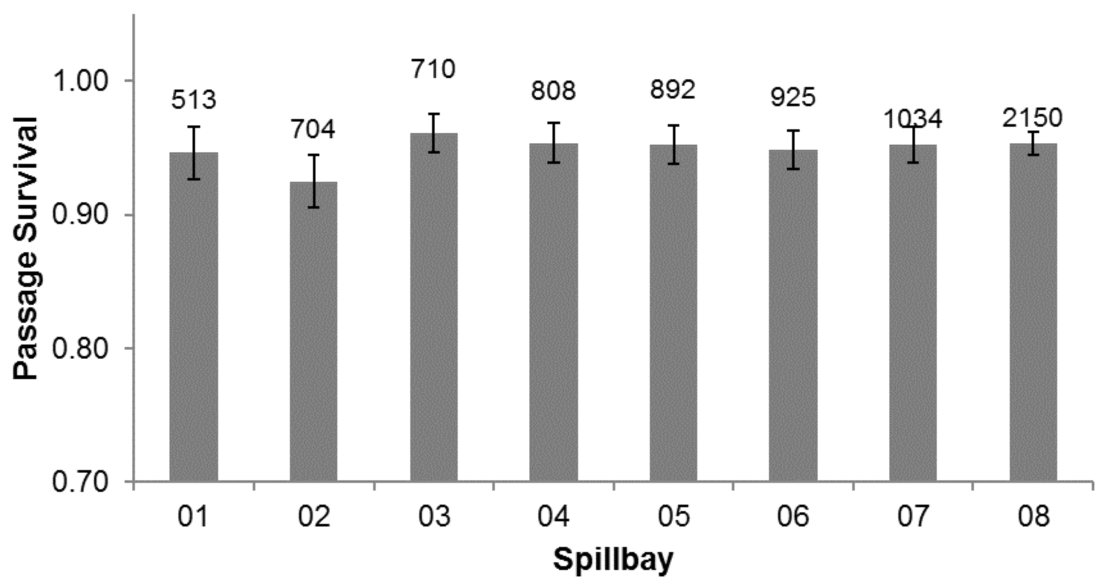

Figure 6.1. Spillway Passage Survival Estimates with 95% Confidence Intervals for CH1 at TDA by Spillbay for Combined Years (2010, 2011, and 2012). Sample sizes are shown above the bars.

Table 6.1. P-values for T-tests Comparing Survival Estimates between Spillbays for CH1 at The Dalles Dam for All Test Years Combined. Survival estimates that are significantly different (P < 0.05) are bolded.

Bay	CH1 2010 to 2012						
	1	2	3	4	5	6	7
2	0.134						
3	0.232	**0.004**					
4	0.559	**0.023**	0.474				
5	0.609	**0.026**	0.407	0.923			
6	0.853	0.058	0.226	0.633	0.697		
7	0.607	**0.023**	0.386	0.913	0.992	0.694	
8	0.513	**0.010**	0.379	0.991	0.916	0.57	0.902

Table 6.2. Survival Estimates and Passage Proportions for CH1 at TDA by Spillbay within the Spillwall

Spillbay	Survival Estimate	Passage Proportion (%)
1	0.9463	6.6
2	0.9251	9.1
3	0.9611	9.2
4	0.9536	10.4
5	0.9526	11.5
6	0.9486	12.0
7	0.9525	13.4
8	0.9535	27.8

6.1.2 CH1 Spillway Passage Survival Rates at TDA by Spillbay Group

The numbers and survival rates of CH1 that passed through two sections of TDA spillway, spillbays 1–8 and 9–23, were estimated. Spillbays 1–8 are northwest of the spillwall and spillbays 9–23 southeast of the spillwall. Spill only occurred through spillbays southeast of the spillwall when river discharge exceeded the capacity of the Powerhouse and spillbays 1–8. The survival estimate of CH1 passing through spillbays 1–8 (0.9568, SE 0.0026) and spillbays 9–23 (0.9486, SE 0.0102) were not significantly different (P < 0.05) (Figure 6.2, Appendix E, Table E. 5). Because spillbays 9–23 were only used during high river flow periods, 92.5% of the CH1 detected passing in spill passed through spillbays 1–8. The survival estimate of CH1 that passed through spillbays 9–12 (0.9472, SE 0.0133) was not significantly different (P < 0.05) from the passage survival estimate through spillbays 13–23 (0.9508, SE 0.0160), which are closer to the predator-inhabited islands near the southeast end of the spillway (Figure 6.3, Appendix E, Table E.6).

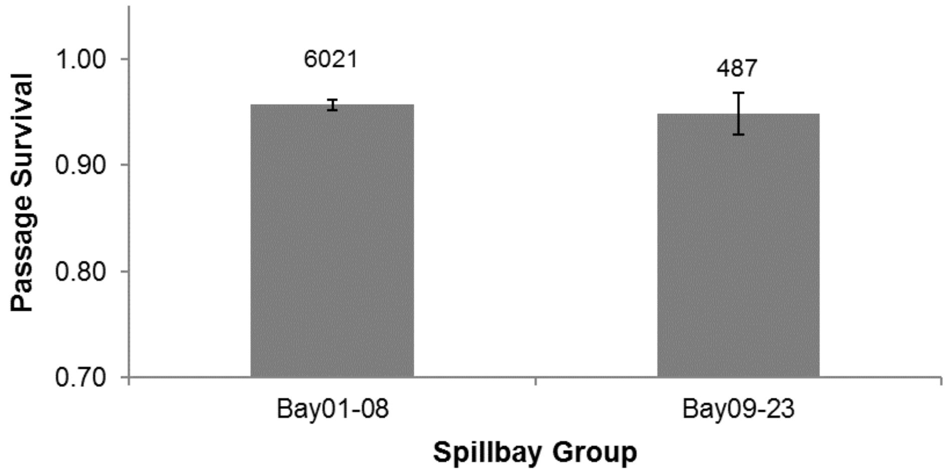

Figure 6.2. Spillway Passage Survival Estimates with 95% Confidence Intervals for CH1 at TDA by Spillbay Groups (Spillbays 1–8 and Spillbays 9–23) for Combined Years (2011 and 2012). Sample sizes are shown above the bars.

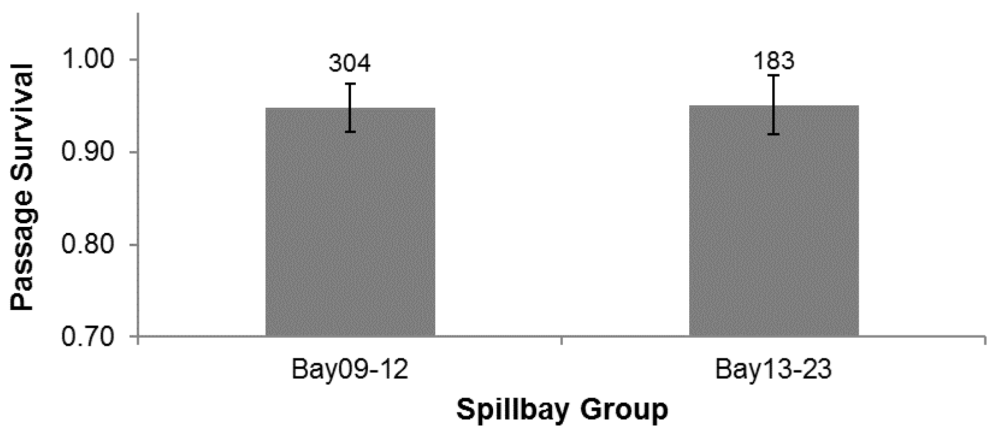

Figure 6.3. TDA Spillway Passage Survival Estimates with 95% Confidence Intervals for CH1 at TDA for Spillbays 9–12 and Spillbays 13–23 for Combined Years (2011 and 2012). Sample sizes are shown above the bars.

6.1.3 CH1 Spillway Passage Survival Rates at TDA by Discharge

The survival rates for CH1 that passed through TDA spillbays 1–8 were estimated for discharge rates combined into 10 kcfs bins. These survival estimates were analyzed to determine if the survival rate of CH1 passing in spill is dependent upon spill discharge (Figure 6.4 and Table 6.3; Appendix E, Table E.8). For the 10 kcfs spill bins, the highest proportion of CH1 passed at spill levels contained in the 100 kcfs bin (19.2%), while the lowest proportion passed when spill discharge was in the 140 kcfs bin (2.5%). The lowest survival estimate was observed for CH1 that passed in spill discharge ≤ 70 kcfs (0.9364, SE 0.0086) and highest survival estimate was observed for CH1 that passed when spill discharge was within the 150 kcfs bin (0.9675, SE 0.0097) (Figure 6.4, Table 6.3). Survival was significantly lower for CH1 passing at flows 70 kcfs or lower than for CH1 passing at flows 150 kcfs or higher ($P < 0.05$) (Table 6.4). Survival was also significantly lower for CH1 passing at 100 kcfs spill volume than when spill was 150 kcfs or higher.

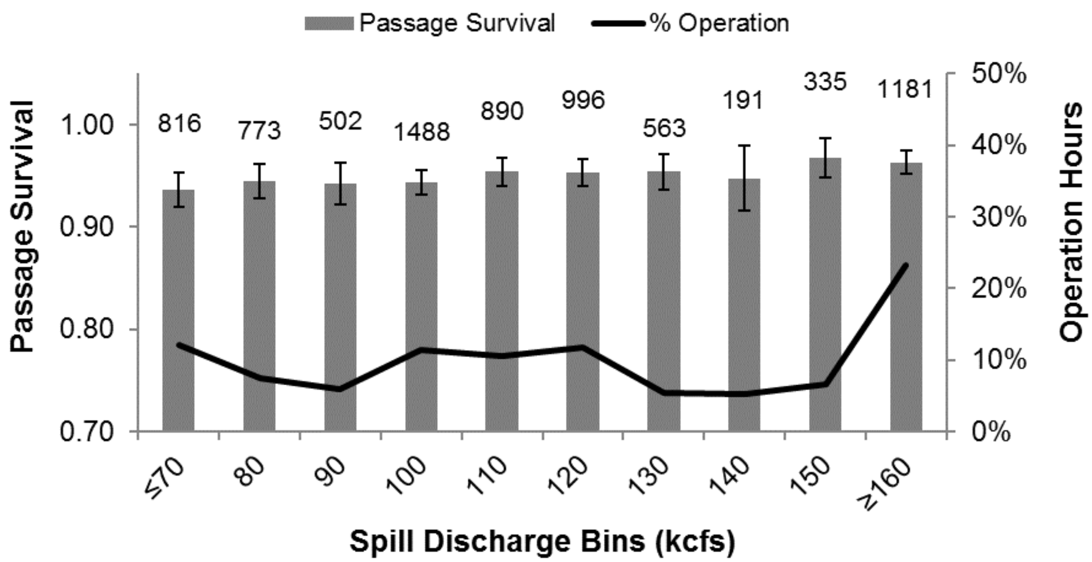

Figure 6.4. Spillway Passage Survival Estimates with 95% Confidence Intervals with Percent Spillway Operation for CH1 at TDA by 10 kcfs Spill Discharge Bins for Combined Years (2010, 2011, and 2012). Sample sizes are shown above the bars.

Table 6.3. Spillway Passage Survival Estimates and Passage Proportions for CH1 at TDA by 10 kcfs Spill Discharge Intervals

Discharge (10 kcfs Bins)	Survival Estimate	Passage Proportion (%)
≤ 70	0.9364	10.5
80	0.9448	10.0
90	0.9430	6.5
100	0.9439	19.2
110	0.9542	11.5
120	0.9532	12.9
130	0.9540	7.3
140	0.9476	2.5
150	0.9675	4.3
≥ 160	0.9634	15.3

Table 6.4. T-tests Comparing Survival Estimates between Spillway Discharge Volumes for CH1 at The Dalles Dam spillway for All Test Years Combined. Significantly different discharge volumes (P <0.05) are bolded.

Bins	CH1 2010 to 2012								
	≤ 70	80	90	100	110	120	130	140	150
80	0.482								
90	0.625	0.892							
100	0.475	0.930	0.940						
110	0.109	0.387	0.372	0.264					
120	0.124	0.431	0.410	0.301	0.918				
130	0.153	0.447	0.420	0.343	0.986	0.942			
140	0.540	0.877	0.810	0.830	0.707	0.748	0.727		
150	**0.017**	0.076	0.085	**0.039**	0.266	0.225	0.303	0.290	
≥ 160	**0.009**	0.065	0.086	**0.019**	0.308	0.246	0.370	0.355	0.716

6.1.4 CH1 Spillway Egress Time at TDA by Spillbay Discharge

Tailrace egress time for CH1 at TDA was evaluated by grouping spill discharge into 24 kcfs bins. CH1 median tailrace egress time was slowest at low discharge and median egress time decreased as spill discharge increased (Table 6.5; Appendix F, Table F.7).

Table 6.5. Tailrace Egress Time for CH1 at TDA by 24 kcfs Spill Discharge Intervals

Discharge (24 kcfs Bins)	Median Egress Time (h)
≤ 48	0.47
72	0.36
96	0.27
120	0.21
144	0.16
≥ 168	0.14

6.2 Juvenile Steelhead (STH) at TDA

6.2.1 STH Spillway Passage Survival Rates at TDA by Spillbay

STH spillway passage survival estimates at TDA through spillbays at the northwest end of the spillway, inside of the new spillwall (spillbays 1–8), are shown in Figure 6.5 and Table 6.6 (Appendix E, Table E.2 and Table E.4). STH that passed through Spillbay 4 had the highest survival estimate (0.9790, SE 0.0052) and lowest survival was observed for STH that passed through spillbay 7 (0.9565, SE 0.0062) (Table 6.6). Survival rates for STH passing through spillbay 4 were significantly higher ($P < 0.05$) than survival of STH passing at spillbays 1, 2, 5, 7, and 8 (Table 6.7). There were no other significant differences between other pairs of spillbays. Between 2010 and 2012, spillbay 8 passed the highest number of STH and passage numbers decreased from spillbay 8 to spillbay 1.

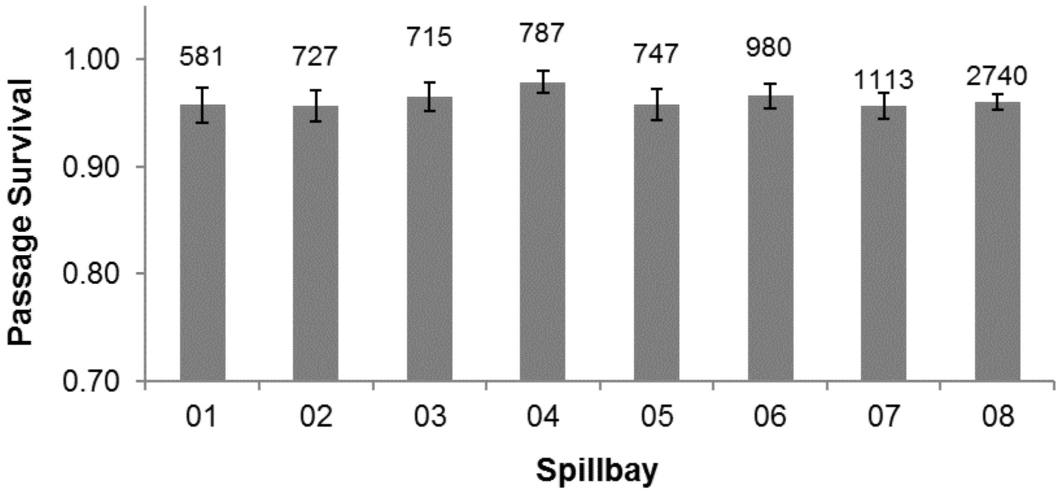

Figure 6.5. Spillway Passage Survival Estimates with 95% Confidence Intervals for STH at TDA by Spillbay for Combined Years (2010, 2011, and 2012). Sample sizes are shown above the bars.

Table 6.6. Survival Estimates and Passage Proportions for STH at TDA by Spillbay within the Spillwall

Spillbay	Survival Estimate	Passage Proportion (%)
1	0.9578	6.9
2	0.9568	8.7
3	0.9656	8.5
4	0.9790	9.4
5	0.9578	8.9
6	0.9661	11.7
7	0.9565	13.3
8	0.9603	32.6

Table 6.7. P-values for Paired T-tests Comparing Survival Estimates between Spillbays for STH at The Dalles Dam for All Test Years Combined. Survival estimates that are significantly different (P <0.05) are bolded.

Bay	STH 2010 to 2012						
	1	2	3	4	5	6	7
2	0.930						
3	0.473	0.391					
4	**0.032**	**0.016**	0.121				
5	1.000	0.925	0.441	**0.019**			
6	0.419	0.334	0.956	0.101	0.381		
7	0.901	0.976	0.327	**0.006**	0.893	0.262	
8	0.786	0.680	0.501	**0.004**	0.764	0.409	0.601

6.2.2 STH Spillway Passage Survival Rates at TDA by Spillbay Group

The survival rates were estimated for STH that passed through spillbays 1–8 and 9–23 at TDA. Spillbays 1–8 are northwest of the spillwall and spillbays 9–23 are southeast of the spillwall. Spill only occurred through spillbays southeast of the spillwall when river discharge exceeded the capacity of the Powerhouse and spillbays 1–8. The survival estimate for STH passing southeast of the spillwall (0.9802, SE 0.0056) was significantly higher ($P < 0.05$) than that of STH passing through spillbays 1–8 (0.9683, SE 0.0022) (Figure 6.6, Appendix E, Table E.5). Because spillbays 9–23 were only open when river flow was very high, 90.8% of the STH passed through spillbays 1–8. Survival estimates of STH passing through spillbays 9–12 compared to that of STH that passed through spillbays 13–23, which are closer to the predator-inhabited islands near the southeast end of the spillway, were not significantly different ($P > 0.05$) (0.9813, SE 0.0069 and 0.9784, SE 0.0096, respectively) (Figure 6.7, Appendix E, Table E.6).

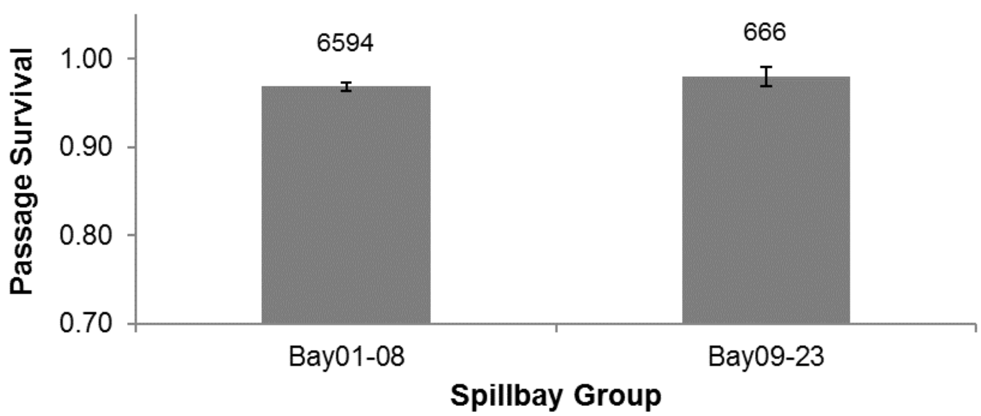

Figure 6.6. Spillway Passage Survival Estimates with 95% Confidence Intervals for STH at TDA by Spillbay Groups, Spillbays 1–8 and Spillbay 9–23 for Combined Years (2011 and 2012). Sample sizes are shown above the bars.

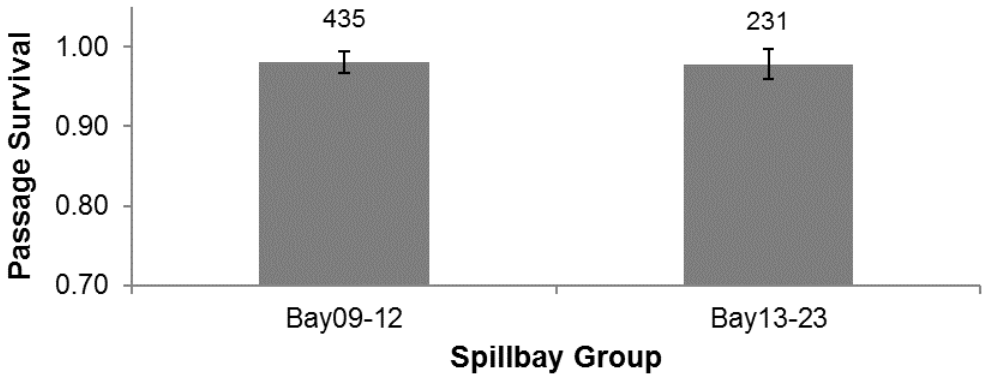

Figure 6.7. Spillway Passage Survival Estimates with 95% Confidence Intervals for STH at TDA for Spillbay Groups 9–12 and 13–23 for Combined Years (2011 and 2012). Sample sizes are shown above the bars.

6.2.3 STH Spillway Passage Survival Rates at TDA by Discharge

Survival rates were estimated for STH that passed through TDA spillbays 1–8 for discharge rates combined into 10 kcfs bins. These estimates were analyzed to determine if the survival rates of STH passing in spill is dependent upon spill discharge level (Figure 6.8 and Table 6.8; Appendix E, Table E.8). For the 10 kcfs spill discharge bins, the highest proportion of STH passed at bins between 100 kcfs and 120 kcfs and ≥ 160 kcfs; the least number of fish passed the 140 kcfs bin (2.67%). As expected, the hours of spill were higher in these bins (i.e., 100–120 kcfs), with the ≥ 160 kcfs bins having the greatest percentage of operating hours. The lowest STH survival estimate was observed for passage in spill discharges within the 90 kcfs bin (0.9349, SE 0.0110) and highest survival estimate was observed for discharges within the 150 kcfs bin (0.9839, SE 0.0060) (Figure 6.8, Table 6.9). STH survival estimates were significantly higher at spill levels of 150 kcfs and higher than those for STH that passed in spill at discharges of 130 kcfs or less ($P < 0.05$) (Table 6.10). Survival of STH passing in the 90 kcfs bin was also significantly lower ($P < 0.05$) than survival of STH passing in the 100, 120, and 140 kcfs bins.

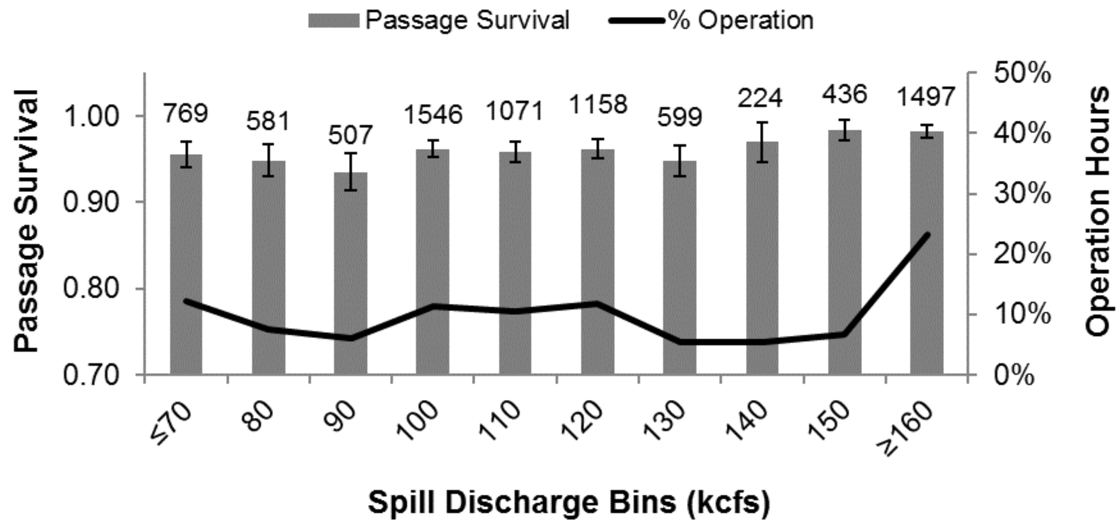

Figure 6.8. Spillway Passage Survival Estimates with 95% Confidence Intervals for STH at TDA by 10 kcfs Spill Discharge Bins Including Percent Spillway Operation for Combined Years (2010, 2011, and 2012). Sample sizes are shown above the bars.

Table 6.8. Spillway Passage Survival Estimates and Passage Proportions for STH at TDA by 10 kcfs Spill Discharge Intervals

Discharge (10 kcfs Bins)	Survival Estimate	Passage Proportion (%)
≤ 70	0.9548	9.2
80	0.9485	6.9
90	0.9349	6.1
100	0.9616	18.4
110	0.9583	12.7
120	0.9614	13.8
130	0.9484	7.1
140	0.9695	2.7
150	0.9839	5.2
≥ 160	0.9815	17.9

Table 6.9. T-tests Comparing Survival Estimates Between Spillway Discharge Volumes for CH1 at The Dalles Dam spillway for All Test Years Combined. Significantly different discharge volumes (P <0.05) are bolded.

Bins	STH 2010 to 2012								
	≤70	80	90	100	110	120	130	140	150
80	0.596								
90	0.135	0.343							
100	0.448	0.209	**0.027**						
110	0.717	0.375	0.063	0.673					
120	0.484	0.233	**0.033**	0.979	0.710				
130	0.587	0.994	0.345	0.202	0.366	0.226			
140	0.288	0.157	**0.031**	0.531	0.393	0.531	0.153		
150	**0.003**	**0.001**	**0.001**	**0.004**	**0.003**	**0.007**	**0.001**	0.271	
≥160	**0.002**	**0.001**	**0.001**	**0.001**	**0.001**	**0.003**	**0.001**	0.326	0.736

6.2.4 STH Spillway Egress time at TDA by Spillbay Discharge

Tailrace egress time for STH at TDA was analyzed by grouping spill discharge into 24 kcfs bins. Median tailrace egress time was slowest at low discharge, decreasing as spill discharge increased (Table 6.10, Appendix F, Table F.8).

Table 6.10. Tailrace Egress Time for STH at TDA by 24 kcfs Spill Discharge Intervals

Discharge (24 kcfs Bins)	Median Egress Time (h)
≤ 48	0.42
72	0.33
96	0.25
120	0.20
144	0.15
≥ 168	0.14

6.3 Subyearling Chinook Salmon (CH0) at TDA

6.3.1 CH0 Spillway Passage Survival Rates at TDA by Spillbay

The estimated survival rates of CH0 at TDA that passed through spillbays at the northwest end of the spillway, inside of the new spillwall (spillbays 1–8), are shown in Figure 6.9 and Table 6.11 (Appendix E, Table E.3 and Table E.4). For the 2010 and 2012 combined years, spillbays 2, 3, and 4 had the highest CH0 survival rate (0.9519, SE 0.0084; 0.9520, SE 0.0079; and 0.9516, SE 0.0078, respectively) and CH0 that passed through spillbay 1 had the lowest survival rate (0.9352, SE 0.0123). There were no significant differences in CH0 survival rates between spillbays, (P < 0.05) (Table 6.11). For 2010 and 2012 combined, spillbay 8 passed the largest number of CH0, and numbers consistently decreased from spillbay 8 to spillbay 1 (Table 6.12).

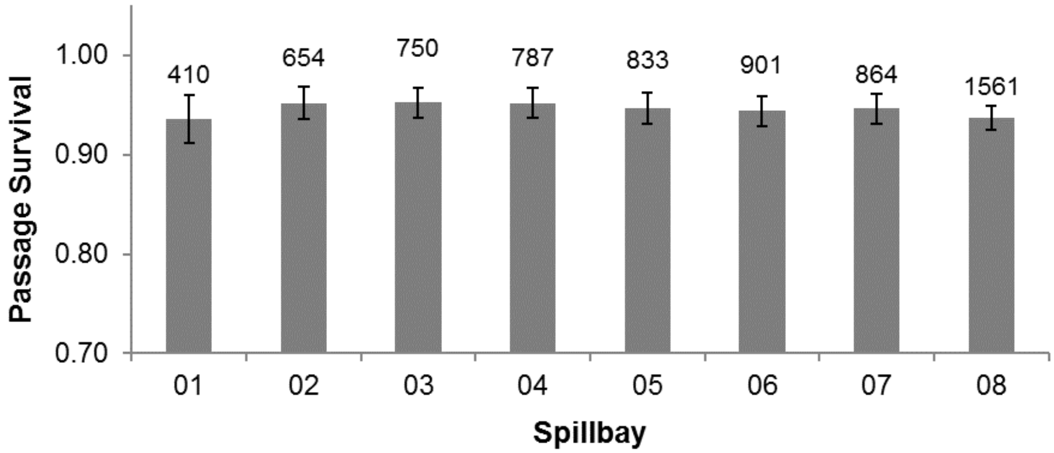

Figure 6.9. Spillway Passage Survival Estimates with 95% Confidence Intervals for CH0 at TDA by Spillbay for Combined Years (2010 and 2012). Sample sizes are shown above the bars.

Table 6.11. Spillway Passage Survival Estimates and Passage Proportions for CH0 at TDA by Spillbay within the Spillwall

Spillbay	Survival Estimate	Passage Proportion (%)
1	0.9352	6.1
2	0.9519	9.7
3	0.9520	11.1
4	0.9516	11.6
5	0.9465	12.3
6	0.9441	13.3
7	0.9464	12.8
8	0.9365	23.1

Table 6.12. P-values for T-tests Comparing Survival Estimates Between Spillbays for CH0 at The Dalles Dam for All Test Years Combined. Survival estimates that are significantly different (P <0.05) are bolded.

Bay	CH0 2010 and 2012						
	1	2	3	4	5	6	7
2	0.263						
3	0.251	0.993					
4	0.260	0.979	0.971				
5	0.438	0.638	0.620	0.644			
6	0.540	0.494	0.474	0.494	0.827		
7	0.440	0.629	0.612	0.635	0.993	0.833	
8	0.925	0.140	0.123	0.130	0.316	0.442	0.317

6.3.2 CH0 Spillway Passage Survival Rates at TDA by Spillbay Grouping

The survival rates were estimated for CH0 that passed through spillbays 1–8 and 9–23 at TDA. Spillbays 1–8 are northwest of the spillwall and spillbays 9–23 southeast of the spillwall. Spill only occurred through spillbays southeast of the spillwall when river discharge exceeded the capacity of the Powerhouse and spillbays 1–8. The survival rates of CH0 were not significantly different between spillbays 1–8 (0.9549, SE 0.0029) and spillbays 9–23 (0.9650, SE 0.0156) (P > 0.05) (Figure 6.10, Appendix E, Table E.5).

Because spillbays 9–23 were only open during periods of high flow, 97.3% of the CH0 detected passing in spill passed through spillbays 1–8. The survival rate of CH0 that passed through spillbays 9–12 was not significantly different from that of those that passed through spillbays 13–23 (0.9453, SE 0.0270 and 0.9855, SE 0.0144, respectively), even though spillbays 13–23 are closer to the predator-inhabited islands near the southeast end of the spillway (Figure 6.11; Appendix E, Table E.6). The rate of survival of CH0 that passed toward the southeast end of the spillway during high flows was about 0.04 higher than for CH0 that passed through spillbays closer to the spillwall. These survival rates were not significantly different (P > 0.05) due to small sample size and large standard errors.

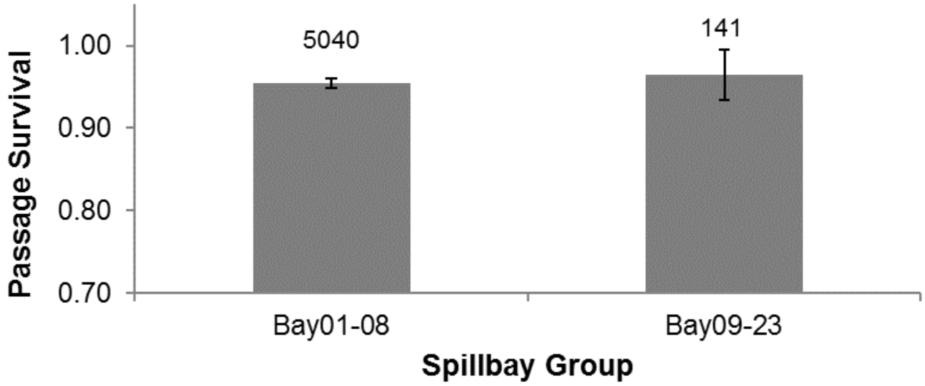

Figure 6.10. Spillway Passage Survival Estimates with 95% Confidence Intervals for CH0 at TDA by Spillbay Groups 1–8 and 9–23 for 2012. Sample sizes are shown above the bars.

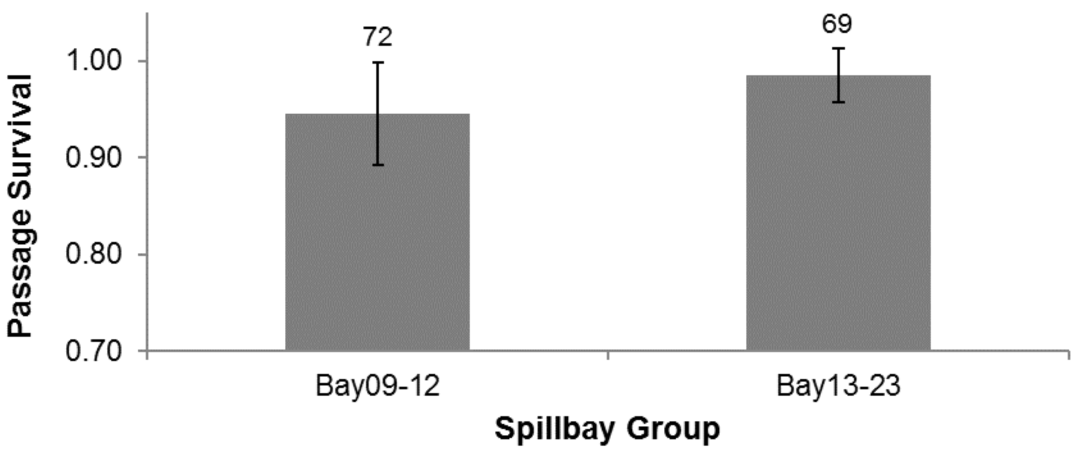

Figure 6.11. Spillway Passage Survival Estimates with 95% Confidence Intervals for CH0 at TDA by Spillbay Groups 9–12 and 13–23 for 2012. Sample sizes are shown above the bars.

6.3.3 CH0 Spillway Passage Survival Rates at TDA by Discharge

Survival rates for CH0 that passed through TDA spillbays 1–8 were estimated for discharge rates combined into 10 kcfs bins. These estimates of survival rate were analyzed to determine if the survival estimate of CH0 passing in spill is dependent upon spill discharge level (Figure 6.12 and Table 6.13; Appendix E, Table E.8). For the 10 kcfs spill intervals, the highest proportion of CH0 passed the spillway in discharge within the 130 kcfs bin (36.0%). The lowest survival estimate was observed for CH0 that passed in spill discharge ≤70 kcfs (0.8305, SE0.0225) and the highest survival estimate was observed for CH0 that passed at discharge within the 140 kcfs spill discharge bin (0.9704, SE 0.0072) (Table 6.13). There was a discernable trend of increased CH0 survival with increasing discharge, especially for passage in discharges less than about 90 kcfs (Figure 6.13). Survival rates of CH0 were significantly lower for CH0 passing the spillway in ≤70 kcfs and 80 kcfs discharge bins than CH0 passing in discharge bins 90 kcfs or greater ($P < 0.05$) (Table 6.14). Survival rates were also significantly higher for CH0 passing in the 140 kcfs bin than in the 90, 120, and 130 kcfs bins ($P < 0.05$).

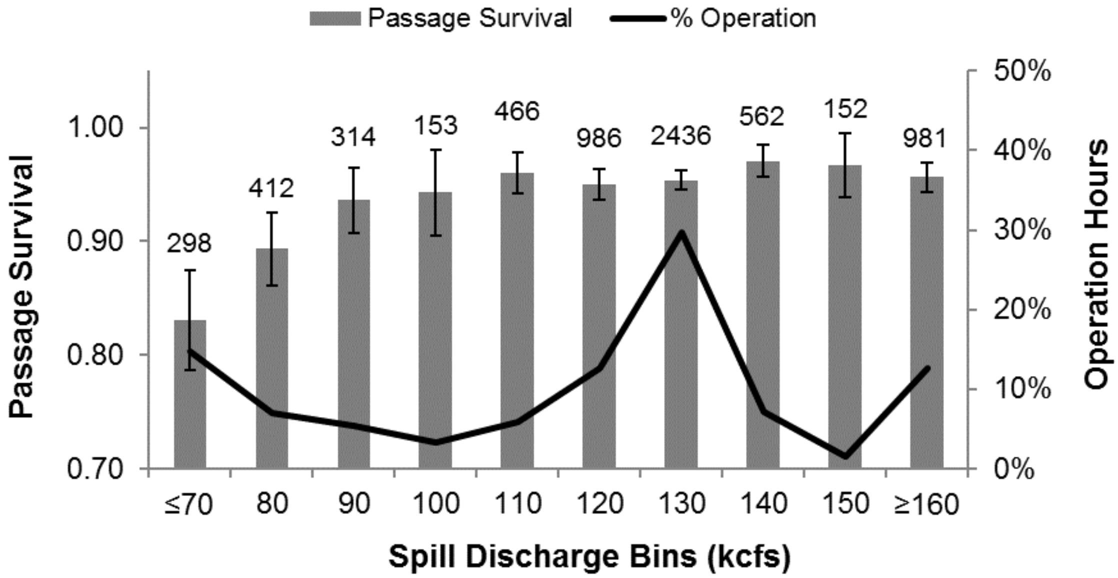

Figure 6.12. Spillway Passage Survival Estimates with 95% Confidence Intervals for CH0 at TDA by 10 kcfs Spill Discharge Bins Including Percent Spillway Operation for Combined Years (2010 and 2012). Sample sizes are shown above the bars.

Table 6.13. Spillway Passage Survival Estimates and Passage Proportions for CH0 at TDA by 10 kcfs Spill Discharge Intervals

Discharge (10 kcfs Bins)	Survival Estimate	Passage Proportion (%)
≤ 70	0.8305	4.4
80	0.8933	6.1
90	0.9362	4.6
100	0.9429	2.3
110	0.9598	6.9
120	0.9505	14.6
130	0.9535	36.0
140	0.9704	8.3
150	0.9671	2.3
≥ 160	0.9565	14.5

Table 6.14. T-tests Comparing Survival Estimates Between Spillway Discharge Volumes for CH0 at The Dalles Dam Spillway for All Test Years Combined. Significantly different discharge volumes (P <0.05) are bolded.

Bins	CH0 2010 and 2012								
1 \ 2	≤70	80	90	100	110	120	130	140	150
80	**0.024**								
90	**0.001**	**0.050**							
100	**0.001**	**0.048**	0.781						
110	**0.001**	**0.001**	0.172	0.426					
120	**0.001**	**0.001**	0.376	0.708	0.419				
130	**0.001**	**0.001**	0.256	0.588	0.535	0.712			
140	**0.001**	**0.001**	**0.036**	0.178	0.364	**0.046**	**0.044**		
150	**0.001**	**0.001**	0.134	0.314	0.671	0.302	0.369	0.839	
≥160	**0.001**	**0.001**	0.204	0.500	0.770	0.527	0.700	0.152	0.505

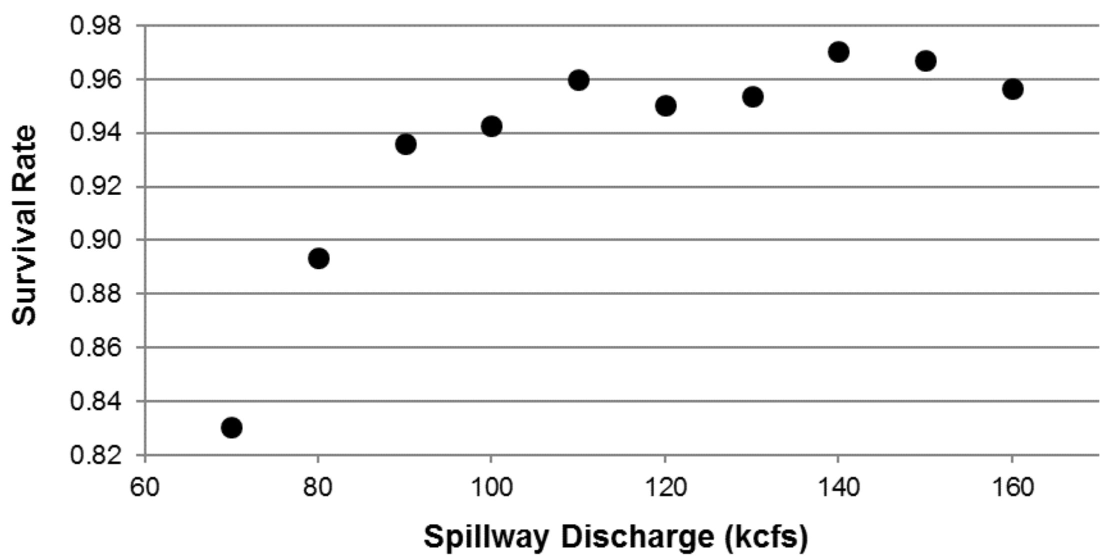

Figure 6.13. Spillway Passage Survival Rate for CH0 at TDA by Spillway Discharge at Spillbays 1–8

6.3.4 CH0 Spillway Egress Time at TDA by Spillbay Discharge

CH0 tailrace egress time at TDA was analyzed by grouping spill discharge into 24 kcfs bins. Median tailrace egress time was highest at low discharge and decreased as spill discharge increased (Table 6.15, Appendix F, Table F.9).

Table 6.15. Tailrace Egress Time for CH0 at TDA by Spill Volume in 24 kcfs Intervals

Discharge (24 kcfs Bins)	Median Egress Time (h)
≤ 48	0.42
72	0.35
96	0.30
120	0.22
144	0.19
168	0.17
216	0.24
240	0.23
≥ 312	0.16

7.0 Discussion

7.1 Bonneville Dam Powerhouse 1

Physical and numeric turbine model studies have indicated that, in general, for most large Kaplan turbines, operation of turbine units at an open geometry configuration improves hydraulic conditions in the turbine environment, better aligns wicket gates with stay vanes, and maximizes the open space between runner blades and water velocity through the runner. These results have led to the hypothesis that the operating point for B1 turbines most likely to optimize juvenile salmonid turbine passage survival is above the upper limit of the 1% of peak efficiency operating range.

Analysis of the rates of survival of CH1, STH, and CH0 passing through B1 turbines was conducted by dividing turbine discharge within the 1% of peak efficiency discharge range into 4 equal groups, quartiles Q1, Q2, Q3, and Q4. A significant difference in survival rates was detected for CH1 for which the survival rate was better in the lower half of the 1% of peak efficiency operating range curve (Q1 and Q2) than in the upper quarter (Q4), though the single-release survival estimate for Q4 was 0.9534. The rate of survival for STH was also significantly higher in the lower quarter of the operating range (Q1) than the upper half of the operating range (Q3 and Q4). The survival rate of STH in the Q4 operating range was higher than in Q2 and Q3, though this difference was not significant. There was not a significant difference in survival rates between discharge quartiles for CH0, though the survival estimates were higher in the upper half of the operating range (Q3 and Q4) than the lower half (Q1 and Q2). Few fish passed in the lower half of the operating range, resulting in large confidence intervals.

Two B1 turbine operating ranges above the upper level of the 1% of peak efficiency range were included in analysis of the effect of discharge on juvenile salmonid passage survival. These were the best operating range (BOR), which included discharges between the upper bound of the 1% of peak efficiency and the best operating point (BOP), and above best operating point (ABOP) discharge range. ABOP extended from BOP to the turbine generator limit. There was not a significant difference in the survival rates of CH1, STH, or CH0 when turbines were operated at BOR or ABOP compared to survival rates within any of the discharge quartiles (Q1–Q4) within the 1% of peak efficiency operating range.

The effect of turbine discharge on turbine passage survival was investigated by grouping discharges into four ranges and comparing the survival estimates for CH1, STH, and CH0. The four ranges were discharges within 1% of peak efficiency (LL–UL), from the lower limit of the 1% of peak efficiency range to best operating point (LL–BOP), the BOR, and ABOP. No significant differences in survival rates were detected between survival estimates for CH1 and STH for any of these turbine discharge groups. Also, no significant differences were detected for CH0 between the LL–UL and LL–BOP groups. B1 turbines were not operated above BOP in summer, so no survival estimates were available for ABOP discharge ranges for CH0.

The analysis results of the effect of turbine discharge on the survival rates of juvenile salmonids passing through B1 turbines suggest that there is not a significant turbine operation effect on fish survival. Balloon tag studies of juvenile salmonid passage through turbines that introduced test fish into B1 turbines at the wicket gates found that turbine operation (discharge) did not affect survival rates, but that the survival rates for juvenile salmonids did depend upon the route they took through the turbine; those passing near the ends of turbine blades had the lowest survival rates and those passing near the runner hub had the highest (Normandeau Inc. and Skalski 2000).

At B1, tailwater elevation is directly affected by turbine discharge; higher Powerhouse discharge results in higher tailwater elevation, because the B1 Powerhouse has a dedicated tailrace channel that is a little wider than that of the B1 Powerhouse. Juvenile salmonids passing B1 turbines were assigned to one of five tailwater elevation groups (referenced to MSL) that contained the tailwater elevation at the time they passed into the Powerhouse tailrace. These bins were 5 m (< 5.5 m), 6 m (5.5 m to < 6.5 m), 7 m (6.5 m to < 7.5 m), 8 m (7.5 m to <8.5 m), and 9 m (≥ 8.5 m). Migrant STH and CH0 passing in turbine discharge into < 5 m tailwater elevations appeared to have lower survival rates than those at higher tailwater elevations, though not significantly different. Survival rates for CH1 at the 5 m tailwater elevation level were not significantly different than at other tailwater elevations. Comparison of the differences in survival rates between the 5 m bin and other tailwater elevation groups was affected by the low sample size and resulting wide confidence limit for the lowest tailwater group. The small sample size for the less than or equal to 5 m bin resulted from B2 being designated as the priority Powerhouse for operation during lower river flow periods, which typically occur during the summer when CH0 are out-migrating.

While not significantly different given the sample sizes available for analysis, it appears that the survival rates of STH and CH0 might be lower at low tailwater levels. This finding would be consistent with early tagging studies that found a trend of lower juvenile salmonid survival rates through the B2 tailrace at lower tailwater levels (Ledgerwood et al. 1991).

Median B1 tailrace egress time decreased with increased turbine discharge for CH0, CH1, and STH, though none of these trends was significant due to wide confidence intervals. Median tailrace egress times were quite consistent, ranging from 0.46 h at Q1 to 0.30 h at ABOP for CH1, 0.63 h at Q3 to 0.42 h at ABOP for STH, and 0.46 h at Q1 to 0.39 h at Q3 for CH0. Median B1 tailrace egress times were quite consistent across all discharges considered, suggesting good overall fish egress out of the tailrace.

7.2 Bonneville Dam Powerhouse 2

Because of increased injury and mortality of juvenile salmonids in gatewells at higher turbine discharge levels, B2 turbines have been operated in the lower half of the 1% of peak efficiency operating range whenever possible to reduce injury to juvenile salmonids diverted into the gatewells. This turbine operation strategy results in reduced hydraulic capacity at B2. In addition, there is concern that while operating turbines at lower discharge may be better for guided fish, low turbine discharge may negatively affect survival of juvenile salmonids in the draft tubes because of exposure to low flow quality resulting from high turbulence and other conditions.

Analysis of the effect of discharge on juvenile salmonid survival used the same turbine discharge groups described above for B1. There were no significant differences detected in survival rates for CH1, STH, and CH0 between quartile discharge groups within 1% of peak efficiency. Neither were significant differences in survival rates detected for any juvenile salmonid group between the lower and upper halves of the 1% of peak efficiency discharge range.

In 2008 and 2011, the STSs at B2 were removed for a short time in spring due to high flows and high levels of debris in the river. In 2008, there appeared to be a difference in survival rates, with higher estimated survival rates for CH1 with screens in and higher survival rates for STH without the screens; however, the observed differences in survival estimates were not significantly different due to small sample sizes. In 2011, survival rates were similar with or without the STSs in turbines for CH1, but followed a similar trend to 2008 for STH, where survival rates were higher when the STSs were removed, though again not significantly different due to the small sample size.

Results of the analysis did not show a significant difference in survival rates for unguided CH1, STH, or CH0 between the lower and upper half of the operating range at B2. There was also no significant difference found between any of the four range bins (Q1–Q4). This suggests that the B2 turbines can be operated throughout their entire range of operation without changing survival rates through the turbines. This will allow managers to focus on fine-tuning turbine operations to optimize the survival rate of guided fish in the gatewell with less concern about the survival rate of turbine-passed fish.

The rate of survival of STH and CH0 was significantly lower when the tailwater elevation for fish passing at B2 was less than 5 m. The survival rate was also lower for CH1 when the tailwater elevation was less than 5 m, but this difference was not significantly different from that for other tailwater elevation groups.

Tailrace egress times for CH1 through the B2 tailrace showed some dependence on discharge, with a trend of decreasing median egress time from 0.65 h at Q1 to 0.55 h at Q4. STH migrants did not show a relationship between turbine discharge and tailrace egress with the median time of egress; all discharge quadrants were very near 0.70 h. CH0 migrants, like CH1 migrants, showed a trend of decreasing median egress time with increasing turbine discharge, with a median egress time of 0.73 h at Q1, decreasing to 0.64 h at Q4. No significant difference in median tailrace egress was detected for any juvenile salmonid run.

7.3 Bonneville Dam Spillway

BiOp and other studies over the last several years have indicated that the rate of survival through the BON spillway is lower than other dam passage routes. There is concern that erosion of the stilling basin and ogees of several spillbays and movement and accumulation of rock within the stilling basin may be contributing to lower survival rates.

The survival rates of CH1, STH, and CH0 migrants passing in spill at BON was investigated by examining fish survival rates through individual spillbays, groups of spillbays, and by discharge using data from BiOp studies conducted at BON in 2008 and 2010 through 2012.

No significant differences in spill passage survival rates between individual spillbays were detected for CH1, STH, and CH0. All juvenile salmonid groups showed a general trend for larger numbers of fish passing through spillbays at the ends of the spillway than through spillbays in the middle of the spillway.

BON spillbays were divided into five groups for further analysis of potential relationships between spillbay of passage and passage survival. Two of the groups, spillbays 1–3 and 16–18 are equipped with deep-flow deflectors. The three remaining groups all contain spillbays equipped with shallow-flow deflectors. Spillbays 8–12 are suspected of having structural damage and rock present in their stilling basins and spillbays 4–7 and 13–15 bracket spillbays 8–12. No significant differences were detected for any juvenile salmonid group for any of the spillbay groups. Spillbay group 8–12 did not show any significant difference in survival rate with other groups or any trends that differentiated it from other groups. The analysis did not produce any results to support the contention that spillbay erosion and/or rocks in the stilling basin were differentially affecting juvenile salmonid survival. In addition, there were no significant differences in spillbay group survival rates that would support the conclusion that passage survival over deep or shallow deflectors was different.

The effect of spillbay discharge level on juvenile salmonid survival rates was investigated by dividing detected fish into discharge bins. This resulted in 21 spillbay discharge bins in spring for CH1 and STH, and 15 spillbay discharge bins in summer for CH0. During the spring study period the majority of juvenile salmonids passed when spill discharge was in the 100 kcfs bin, which corresponded to the preferred spillbay discharge level specified in the FPP for each study year and consequently, the discharge with the most operating hours. In summer, more juvenile salmonids passed when spill discharge was in the 90 kcfs bin, followed by the 100 kcfs bin. In general, survival rates by discharge group varied without distinct pattern for CH1 and STH across discharge groups, with the exception of a definite decrease in survival rates for both groups at the highest discharge. In contrast, CH0 showed a definite increase in survival rate with increasing spillbay discharge through the highest discharges that occurred. The survival rate for CH1 was significantly different for discharges ≥ 290 kcfs than most other spillbay discharge bins. As for STH, spill passage survival was significantly lower for the ≥ 290 kcfs bin than those for other discharge groups.

Spill discharge rates above about 230 kcfs did not occur in the summer at BON. However, there was a distinct trend of increasing passage survival rates with increasing discharge with a high correlation coefficient. There was a significant difference in survival rate estimates for CH0 at many of the discharge levels in the 10 kcfs bins for discharge rates of 130 kcfs and lower compared to discharge rates of 140 kcfs and above. Survival rate estimates for CH0 passing in the 90 and 100 kcfs spill discharge bins were significantly lower than those of CH0 passing in bins 140 kcfs or greater. The survival rate of CH0 passing at the 110 kcfs spill level was significantly lower than that of CH0 passing at the 150, 190, and 210 kcfs spill levels. The passage survival rate was significantly lower for the 120 kcfs bin than for CH0 passing in the 140, 150, 190, and 210 kcfs bins, and the 130 kcfs bin survival rate was significantly lower than that of CH0 passing at 150 and 190 kcfs spill levels. There was not a significant difference in survival between any of the discharge bins 140 kcfs or above.

There were no trends in survival rates for CH1 or STH with increased spillway tailwater elevation. However, the rate of survival was significantly lower for CH0 passing in spill when tailwater elevations were < 6.5 m. Following the CH0 trend of increasing survival rate with increasing spillbay discharge, a trend in increased spill passage survival rate with increased tailwater elevation was observed for CH0. The rate of survival was significantly lower for CH0 passing in 5 m and 6 m tailwater elevation bins than for those passing in 7 m, 8 m, and 9 m bins. The survival rate of CH0 passing in the 7 m bin was also significantly lower than that of CH0 passing in the 8 m bin.

Median tailrace egress time decreased with increasing discharge rate for all three juvenile salmonid runs. Median egress times for 70 and 300 kcfs spill bins was 0.53 h and 0.28 h, respectively, for CH1 and

0.47 h and 0.33 h, respectively, for STH. The shortest tailrace egress time was observed for CH0 passing in discharges within the 230 kcfs bin and the median egress times decreased from 0.54 h for the 80 kcfs discharge group to 0.25 h for the 230 kcfs discharge group.

7.4 The Dalles Dam Spillway

High river flows in recent years have forced spill at TDA using spillbays outside (southeast) of a new extended spillwall built between spillbays 8 and 9. Spill from spillbays outside the new spillwall may carry juvenile salmonids into areas along the southern shore of the river immediately below the dam that has been shown to be habitat for large populations of predators. There is concern that juvenile salmonids that pass the dam in spill from gates outside the spillwall will have lower survival rates than fish passing through spillbays within the spillwall.

Survival rates for juvenile salmonids passing through individual spillbays within the spillwall (spillbay 1–8) were examined to determine if survival rates were different through any of the spillbays. No significant difference in survival performance through any spillbay within the spillwall was detected for STH or CH0. There was a significant difference in survival for CH1 with lower survival rates through spillbay 2 than spillbay 3. CH1 passing through spillbay 2 had the lowest or second lowest survival rates during all 3 study years. In addition, for all three runs the largest number of fish passed through spillbays near the wall (spillbays 7 and 8), decreasing across the group of spillbays and reaching a minimum at spillbay 1.

The survival rates for juvenile salmonids passing through spillbay groups 1–8, 9–23, 9–12, and 13–23 were estimated. Because spill outside of the spillwall was infrequent in the years included in this analysis, 92.5%, 90.8%, and 97.3% of detected CH1, STH, and CH0, respectively, passed through spillbays 1–8 inside of the new spillwall. No significant differences in the survival rates between passage through spillbays inside (spillbays 1–8) and those outside (spillbays 9–23) the spillwall were found for CH1, STH, or CH0. Also, no significant differences were detected for CH1, STH, or CH0 that passed through spillbays outside but nearer the spillwall (spillbays 9–12) and those that passed outside the spillwall and nearer predator habitat (spillbays 13–23).

The analysis did not find any evidence that juvenile salmonids passed in spill outside of the new spillwall during high river discharge events survived at a lower rate than those that passed through spillbays inside of the spillwall. Predation has been shown to be higher for juvenile salmonid migrants that move through the islands near the Oregon shore in the tailrace downstream of the spillway during normal river flow conditions (Martinelli and Shively 1998; Duran et al. 2003). Our results indicate that during high river flows, the south shore island area may be much less favorable habitat for predators. During high river flow conditions in 2011 and 2012, the south shore islands near the Oregon shore were underwater and flow seemed quite high in that area which may have reduced its suitability for predators.

Similar to analysis of the effect of discharge rate on juvenile salmonid survival conducted for the BON spillway, juvenile salmonids passing in spill at TDA were assigned to 10 kcfs spillway discharge groups that contained the discharge rate that was occurring at the time of their passage. Analysis was limited to those fish that passed through spillbays 1–8 inside the spillwall. There were no significant differences in spill passage survival rates between discharge groups for CH1, and the passage survival rate for STH was significantly higher for the 150 kcfs and 160 kcfs bins than that for all bins ≤130 kcfs. Spill passage survival rates for CH0 were significantly lower for the ≤ 70 kcfs bin compared to all discharge bins ≥ 90 kcfs. Survival rates of CH0 in the 80 kcfs bin was significantly lower than CH0 passing in flows of 110 kcfs or greater.

CH0 that passed through spillbays within the spillwall experienced significantly lower survival rates passing in low discharge rate spill than in high discharge rate spill. These results indicate that spill discharge less than 90 kcfs should be avoided in the summer when CH0 are out-migrating.

The spillway median egress time for all juvenile salmonid runs, CH1, STH, and CH0 decreased with increasing spillbay discharge and were very similar for all runs. Median egress times for the 24 kcfs spillbay discharge groups ≤ 48 kcfs and ≥ 168 kcfs were 0.47 h and 0.14 h, respectively, for CH1 and 0.42 h and 0.14 h, respectively for STH. The median egress times for discharge groups ≤ 48 kcfs and ≥ 312 kcfs were 0.42 h and 0.16 h, respectively, for CH0.

8.0 Conclusions

Based on the data available for this metadata analysis we make the following conclusions:

8.1 Bonneville Dam Powerhouse 1

- There is not a significant difference in survival rate between operating within the 1% of peak efficiency operating range, above the upper limit of 1% of peak efficiency operating range to the best operating point, or from the best operating point to the generator limit for CH1, STH, or CH0.
- Tailrace egress time is good across the range of turbine operating conditions and decreases with increase in discharge level.
- Estimated survival rates across the range of tailwater elevations are not significantly different. However, there is a trend toward lower survival rate at tailwater elevations less than 5 m. This trend is not significantly different due to large confidence intervals because of the small samples sizes.

8.2 Bonneville Dam Powerhouse 2

- There is not a significant difference in the survival rate of CH1, STH, or CH0 passing through the turbines at B2 across the turbine operating range.
- The survival rate of STH and CH0 is lower for fish passing in the 5 m tailrace elevation bin.
- Tailrace egress time is good across the range of turbine operating conditions and decreases with increase in discharge level, except for STH where egress time changed little between discharge levels.
- The passage survival rate of STH was higher in both 2008 and 2011 with the STSs removed, though there was not a significant difference due to the small sample size and large error bars.
- The survival rate of CH1 in 2008 was higher with STSs installed and survival was similar in 2011 with STSs installed or removed, though the sample sizes were too small to make a statistical comparison.

8.3 Bonneville Spillway

- There was not a significant difference in the rate of survival for CH1, STH, or CH0 passing through spillbays where there was damage to the spillbays or the potential of rock deposition in the stilling basin compared to spillbays without such conditions.
- The survival rates for CH1, STH, and CH0 passing through spillbays 1–3 were lower, though not significantly different.
- The rate of survival was lower for CH1 and STH passage at spillway discharges greater than 290 kcfs.
- The rate of survival was lower for CH0 passage at spillway discharges ≤100 kcfs.

- The rate of survival was lower for CH0 when the tailrace elevation was <6.5 m.
- Tailrace egress time for CH1, STH, and CH0 generally decreased with increasing spillway discharge.

8.4 The Dalles Dam Spillway

- There were no significant differences in rate of survival for CH0, CH1, or STH that passed through TDA spillway at spillbays 1–8 within the new spillwall compared to survival rates for those passing through spillbays outside of the spillwall at spillbays 9–23 during high river flows.
- The rate of survival of CH1 was significantly lower when spill discharge was ≤70 kcfs than at discharge levels ≥150 kcfs.
- The rate of survival of STH is significantly higher at spill levels at 150 kcfs or higher than spill levels 130 kcfs or lower.
- The rate of survival of CH0 declines with reduced discharge and declines rapidly below 80 kcfs.

9.0 References

Burnham KP, DR Anderson, GC White, C Brownie, and KH Pollock. 1987. "Design and analysis methods for fish survival experiments based on release-recapture." *American Fisheries Society Monograph* 5.

Duran IN, TL Liedtke, and JH Petersen. 2003. *Predator-Prey Interactions in The Dalles Dam Tailrace, 2002*. Annual Report of Research to the U. S. Army Corps of Engineers, Portland District, Portland, Oregon, USA. Final Report of Research prepared for the U.S. Army Corps of Engineers, Portland, Oregon, by the U.S. Geological Survey, Cook, Washington.

Faber DM, GR Ploskey, MA Weiland, D Deng, JS Hughes, RL McComas, J Kim, RL Townsend, T Fu, ES Fischer, TJ Monter, and JR Skalski. 2010. *Evaluation of a Behavioral Guidance Structure at Bonneville Dam Second Powerhouse including Passage Survival of Juvenile Salmon* and *Steelhead using Acoustic Telemetry, 2008*. PNNL-18753, Pacific Northwest National Laboratory, Richland, Washington.

Faber DM, GR Ploskey, MA Weiland, D Deng, JS Hughes, J Kim, T Fu, JR Skalski, and ES Fischer, TJ Monter, and JR Skalski. 2011. *Evaluation of Behavioral Guidance Structure on Juvenile Salmonid Passage* and *Survival at Bonneville Dam in 2009*. PNNL-20338, Pacific Northwest National Laboratory, Richland, Washington.

Johnson G, J Skalski, T Carlson, G Ploskey, M Weiland, D Deng, E Fischer, J Hughes, F Khan, J Kim, and R Townsend. 2011. *Survival* and *Passage Yearling* and *Subyearling Chinook Salmon* and *Steelhead at The Dalles Dam, 2010*. PNNL-20626, Pacific Northwest National Laboratory, Richland, Washington.

Johnson G, J Kim, M Hennen, D Etherington, S Zimmerman, J Skalski, G Batten, T Carlson, S Carpenter, A Cushing, Z Deng, E Fisher, T Fu, M Greiner, J Hughes, F Khan, J Martinez, T Mitchell, G Ploskey, B Rayamajhi, I Royer, A Seaburg, R Townsend, M Weiland, and C Woodley. 2012. *Survival* and *Passage Yearling Chinook Salmon* and *Steelhead at The Dalles Dam, Spring 2011*. PNNL-21826, Pacific Northwest National Laboratory, Richland, Washington.

Ledgerwood R, E Dawley, L Gilbreath, P Bentley, B Sandford, and M Schiewe. 1991. *Relative Survival of Subyearling Chinook Salmon that have passed through the Turbines or Bypass System of Bonneville Dam Second Powerhouse, 1990*. Report to U.S. Army Corps of Engineers, Contract E86900104, 90p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, Washington 98112-2097).

Martinelli TL and RS Shively. 1997. "Seasonal distribution, movements and habitat associations of northern squawfish in two lower Columbia River reservoirs." *Regulated Rivers: Research & Management* 13:543–556.

NMFS (National Marine Fisheries Service). 2008. *Biological Opinion–Consultation on Rem*and *for Operation of the Federal Columbia River Power System, 11 Bureau of Reclamation Projects in the Columbia Basin* and *ESA Section 10(a)(1)(A) Permit for Juvenile Fish Transportation Program*. National Marine Fisheries Service (NOAA Fisheries)–Northwest Region, Seattle, Washington. Available at: http://www.salmonrecovery.gov/.

Normandeau Associates Inc. and JR Skalski. 2000. *Direct Survival* and *Condition of Juvenile Chinook Salmon Passed Through an Existing* and *New Minimum Gap Runner Turbines at Bonneville Dam First Powerhouse, Columbia River*. Prepared for Department of the Army, Portland District, Corps of Engineers, Portland, Oregon.

Ploskey GR, MA Weiland, DM Faber, Z Deng, GE Johnson, JS Hughes, SA Zimmerman, TJ Monter, AW Cushing, MC Wilberding, RE Durham, RL Townsend, JR Skalski, RA Buchanan, J Kim, ES Fischer, MM Meyer, RL McComas, and JP Everett. 2009. *Survival Rates of Juvenile Salmonids Passing Through the Bonneville Dam* and *Spillway in 2008.* PNNL-18748, Pacific Northwest National Laboratory, Richland, Washington.

Ploskey GR, MA Weiland, JS Hughes, CM Woodley, Z Deng, TJ Carlson, J Kim, IM Royer, GW Batten, AW Cushing, SM Carpenter, DJ Etherington, DM Faber, ES Fischer, T Fu, MJ Hennen, TD Mitchell, TJ Monter, JR Skalski, RL Townsend, and SA Zimmerman. 2011a. *Survival* and *Passage of Juvenile Chinook Salmon* and *Steelhead Passing Through Bonneville Dam, 2010*. PNNL-20835, Pacific Northwest National Laboratory, Richland, Washington.

Ploskey GR, MA Weiland, and TJ Carlson. 2011b. *Monitoring of Subyearling Chinook Salmon Survival* and *Passage at Bonneville Dam, Summer 2010.* PNNL-20095, Pacific Northwest National Laboratory, Richland, Washington.

Ploskey GR, DM Faber, MA Weiland, and TJ Carlson. 2011c. *Monitoring of Juvenile Yearling Chinook Salmon* and *Steelhead Passage at Bonneville Dam, Spring 2010*. PNNL-19898, Pacific Northwest National Laboratory, Richland, Washington.

Ploskey GR, MA Weiland, and TJ Carlson. 2012. *Route-Specific Passage Proportions* and *Survival Rates for Fish Passing through John Day Dam, The Dalles Dam,* and *Bonneville Dam in 2010* and *2011*. PNNL-21442, Pacific Northwest National Laboratory, Richland, Washington.

Ploskey GR, GW Batten III, AW Cushing, J Kim, GE Johnson, JR Skalski, RL Townsend, AG Seaburg, TJ Carlson, SM Carpenter, Z Deng, DJ Etherington, ES Fischer, T Fu, MJ Greiner, MJ Hennen, JS Hughes, JJ Martinez, TD Mitchell, B Rayamajhi, MA Weiland, CM Woodley, and SA Zimmerman. 2013. *Survival* and *Passage of Juvenile Chinook Salmon* and *Steelhead Passing Through Bonneville Dam, 2011*. PNNL-22178, Pacific Northwest National Laboratory, Richland, Washington.

Skalski JR, GE Johnson, and TJ Carlson. 2010a. *Compliance Monitoring of Juvenile Subyearling Chinook Salmon Survival* and *Passage at The Dalles Dam, Summer 2010*. PNNL-20042, Pacific Northwest National Laboratory, Richland, Washington.

Skalski JR, GE Johnson, and TJ Carlson. 2010b. *Compliance Monitoring of Juvenile Yearling Chinook Salmon* and *Steelhead Survival* and *Passage at The Dalles Dam, Spring 2010*. PNNL-19819, Pacific Northwest National Laboratory, Richland, Washington.

Skalski JR, RL Townsend, AG Seaburg, GR Ploskey, and TJ Carlson. 2012a. *Compliance Monitoring of Yearling Chinook Salmon* and *Juvenile Steelhead Survival* and *Passage at Bonneville Dam, Spring 2011*. PNNL-21175, Pacific Northwest National Laboratory, Richland, Washington.

Skalski JR, RL Townsend, AG Seaburg, GE Johnson, and TJ Carlson. 2012b. *Compliance Monitoring of Juvenile Yearling Chinook Salmon* and *Steelhead Survival* and *Passage at The Dalles Dam, Spring 2011*. PNNL-21124, Pacific Northwest National Laboratory, Richland, Washington.

Skalski JR, RL Townsend, AG Seaburg, GR Ploskey, MA Weiland, JS Hughes, CM Woodley, Z Deng, and TJ Carlson. 2013a. *Compliance Monitoring of Subyearling Chinook Salmon Survival* and *Passage at Bonneville Dam, Summer 2012*. PNNL-22188, Pacific Northwest National Laboratory, Richland, Washington.

Skalski JR, RL Townsend, AG Seaburg, GR Ploskey, MA Weiland, JS Hughes, CM Woodley, Z Deng, TJ Carlson, and GE Johnson. 2013b. *Compliance Monitoring of Subyearling Chinook Salmon Survival* and *Passage at The Dalles Dam, Summer 2012*. PNNL-22195, Pacific Northwest National Laboratory, Richland, Washington.

Titzler PS, GA McMichael, and JA Carter. 2010. "Autonomous acoustic receiver deployment and mooring techniques for use in larger rivers and estuaries." *North American Journal of Fisheries Management* 30: 853−859.

USACE (U.S. Army Corps of Engineers). 2013. *Fish Passage Plan*. CENWD-PDW-R, Columbia Basin Water Management Division, Northwestern Division, Portland, Oregon.

Weiland MA, GR Ploskey, JS Hughes, Z Deng, T Fu, TJ Monter, GE Johnson, F Khan, MC Wilberding, AW Cushing, SA Zimmerman, DM Faber, RE Durham, RL Townsend, JR Skalski, J Kim, ES Fischer, and MM Meyer. 2009. *Acoustic Telemetry Evaluation of Juvenile Salmonid Passage* and *Survival at John Day Dam with Emphasis on the Prototype Surface Flow Outlet, 2008*. PNNL-18890, Pacific Northwest National Laboratory, Richland, Washington.

Weiland MA, ZD Deng, TA Seim, BL Lamarche, EY Choi, T Fu, TJ Carlson, AI Thronas, and MB Eppard. 2011a. "A cabled acoustic telemetry system for detecting and tracking juvenile salmon: Part 1. Engineering design and instrumentation." *Sensors* 11: 5645–5660.

Weiland MA, GR Ploskey, JS Hughes, Z Deng, T Fu, J Kim, GE Johnson, ES Fischer, F Khan, SA Zimmerman, DM Faber, KM Carter, JW Boyd, RL Townsend, JR Skalski, TJ Monter, AW Cushing, MC Wilberding, and MM Meyer. 2011b. *Acoustic Telemetry Evaluation of Juvenile Salmonid Passage* and *Survival Proportions at John Day Dam, 2009*. PNNL-20766, Pacific Northwest National Laboratory, Richland, Washington.

Appendix A

Bonneville Dam Powerhouse 1 and Powerhouse 2 Operating Condition Ranges

Appendix A

Bonneville Dam Powerhouse 1 and Powerhouse 2 Operating Condition Ranges

As detailed in the Section 2.0 Methods, operation levels for B1 were divided into six treatments (Q1, Q2, Q3, Q4, BOR, and ABOP) and B2 was divided into four treatments (Q1, Q2, Q3, and Q4). The following tables provide the modeled discharge level (cfs) relative to head differential (ft) as derived from the 2013 FPP (http://www.nwd-wc.usace.army.mil/tmt/documents/fpp/).

Table A.1. BON B1 Discharge (cfs) by Operation Treatment and Head (ft)

	Discharge (cfs)				
Head (ft)	Q1	Q2	Q3	Q4	BOP
38	7633	8061	8490	8918	10627
39	7623	8044	8465	8886	10654
40	7613	8027	8440	8854	10677
41	7643	8085	8527	8969	10759
42	7671	8140	8608	9077	10837
43	7697	8192	8686	9180	10910
44	7722	8241	8759	9278	10979
45	7745	8287	8828	9370	11045
46	7762	8313	8865	9416	11109
47	7778	8338	8899	9459	11170
48	7792	8362	8931	9500	11227
49	7807	8384	8962	9539	11282
50	7819	8405	8990	9575	11333
51	7835	8430	9024	9618	11356
52	7830	8413	8995	9577	11378
53	7825	8396	8966	9537	11398
54	7820	8380	8939	9499	11418
55	7892	8517	9143	9768	11465
56	7904	8539	9173	9808	11478
57	7916	8559	9203	9846	11518
58	7926	8579	9231	9883	11557
59	7937	8598	9258	9918	11594
60	7947	8616	9284	9952	11630
61	7955	8613	9272	9930	11610
62	7961	8610	9260	9909	11591
63	7967	8608	9248	9889	11572
64	7972	8604	9236	9868	11519

Table A.2. BON B2 Operation Range (with STS) Discharge (cfs) Grouped by Operation Treatment and Head (ft)

Head (ft)	Discharge (cfs)			
	Q1	Q2	Q3	Q4
35	12961	14664	16366	18068
36	12978	14684	16391	18097
37	12990	14700	16411	18121
38	12998	14712	16425	18139
39	13004	14720	16437	18153
40	13007	14725	16444	18162
41	12994	14728	16463	18197
42	12980	14729	16479	18228
43	12965	14728	16492	18255
44	12949	14725	16502	18278
45	12933	14722	16510	18299
46	12946	14753	16559	18366
47	12901	14668	16434	18200
48	12857	14585	16312	18040
49	12815	14506	16196	17887
50	12988	14858	16728	18598
51	13078	15002	16926	18850
52	13163	15139	17115	19091
53	13245	15271	17297	19323
54	13321	15393	17464	19536
55	13237	15197	17156	19115
56	13187	15031	16874	18718
57	13137	14870	16603	18336
58	13088	14714	16341	17967
59	13039	14563	16087	17611
60	12992	14417	15842	17267
61	12894	14255	15617	16978
62	12798	14099	15399	16699
63	12707	13947	15188	16428
64	12617	13800	14983	16166
65	12532	13659	14785	15912
66	12504	13560	14615	15671
67	12477	13464	14450	15437
68	12452	13371	14291	15210
69	12426	13281	14135	14990
70	12401	13193	13984	14775

Table A.3. BON B2 Operation Range (without STS) Discharge (cfs) Grouped by Operation Treatment and Head (ft)

	Discharge (cfs)			
Head (ft)	Q1	Q2	Q3	Q4
35	13152	14861	16569	18277
36	13168	14881	16593	18306
37	13181	14898	16614	18331
38	13190	14910	16630	18350
39	13196	14919	16641	18364
40	13199	14924	16649	18374
41	13186	14927	16668	18409
42	13172	14928	16685	18441
43	13157	14927	16698	18468
44	13141	14925	16709	18493
45	13125	14921	16718	18514
46	13138	14953	16767	18581
47	13093	14867	16641	18415
48	13049	14785	16520	18255
49	13006	14705	16403	18101
50	13182	15060	16939	18817
51	13272	15206	17139	19072
52	13359	15345	17330	19316
53	13442	15478	17515	19551
54	13435	15434	17432	19431
55	13343	15221	17098	18975
56	13294	15056	16819	18581
57	13245	14898	16550	18202
58	13198	14744	16290	17836
59	13151	14595	16039	17483
60	13106	14451	15797	17142
61	13007	14291	15574	16857
62	12913	14136	15359	16582
63	12822	13986	15151	16315
64	12733	13841	14948	16056
65	12648	13701	14753	15806
66	12622	13605	14587	15570
67	12597	13512	14426	15341
68	12573	13422	14270	15119
69	12549	13334	14118	14903
70	12526	13248	13971	14693

Appendix B

Bonneville Dam Powerhouse 1 and Powerhouse 2 Survival Estimates by Operation Treatment

Appendix B

Bonneville Dam Powerhouse 1 and Powerhouse 2 Survival Estimates by Operation Treatment

The following tables provide the survival estimates, standard errors (SEs) and sample sizes (N) for CH1, STH, and CH0 at various treatment operating ranges at B1 and B2 as described in detail in Sections 3.0 and Section 4.0. Note: Fish that passed at B2 when the STSs were removed are not included in the sample sizes or survival estimates.

Table B.1. BON B1 Survival Estimates by Operation Treatment and Species-Run

	2010–2012						2010, 2012		
	CH1			STH			CH0		
Treatment	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
Q1	0.9971	0.0110	235	0.9740	0.0098	306	0.9362	0.0357	47
Q2	1.0023	0.0147	145	0.9173	0.0267	152	0.9145	0.0376	57
Q3	0.9530	0.0180	215	0.9064	0.0234	204	0.9760	0.0149	116
Q4	0.9534	0.0086	1008	0.9300	0.0083	1199	0.9537	0.0064	1187
BOR	0.9672	0.0147	332	0.9477	0.0143	334	0.9515	0.0112	380
ABOP	0.9640	0.0085	493	0.9328	0.0114	493			
Total			2428			2688			1787

Table B.2. BON B1 Survival Estimates by Pooled Operation Treatment and Species-Run

	2010–2012						2010, 2012		
	CH1			STH			CH0		
Treatment	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
Q1–Q2	0.9990	0.0088	380	0.9546	0.0110	458	0.9237	0.0262	104
Q3–Q4	0.9534	0.0077	1223	0.9266	0.0079	1403	0.9557	0.0060	1303
Total			1603			1861			1407

Table B.3. BON B1 Survival Estimates by Operation Conditions and Species-Run

	2010–2012						2010, 2012		
	CH1			STH			CH0		
Group	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
LL - UL	0.9644	0.0063	1603	0.9335	0.0065	1861	0.9534	0.0059	1407
LL - BOP	0.9648	0.0058	1935	0.9357	0.0060	2195	0.9530	0.0052	1787

Table B.4. BON B2 with STS Survival Estimates by Operation Treatment and Species-Run

	2008–2012						2008–2010, 2012		
	CH1			STH			CH0		
Treatment	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
Q1	0.9545	0.0087	759	0.8932	0.0146	541	0.9528	0.0128	298
Q2	0.9575	0.0092	574	0.9427	0.0128	376	0.9314	0.0114	501
Q3	0.9501	0.0163	267	0.9097	0.0259	146	0.9397	0.0124	384
Q4	0.9563	0.0107	469	0.9192	0.0205	202	0.9562	0.0056	1444
Total			2069			1265			2627

Table B.5. BON B2 with STS Survival Estimates by Pooled Operation Treatment and Species-Run

	2008–2012						2008–2010, 2012		
	CH1			STH			CH0		
Treatment	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
Q1–Q2	0.9556	0.0063	1333	0.9128	0.0101	917	0.9397	0.0086	799
Q3–Q4	0.9538	0.0090	736	0.9152	0.0161	348	0.9527	0.0052	1828
Total			2069			1265			2627

Appendix C

Bonneville Dam Spillway Passage Survival Estimates by Spillbay and Spillbay Groups

Appendix C

Bonneville Dam Spillway Passage Survival Estimates by Spillbay and Spillbay Groups

The following tables provide the survival estimates, standard errors (SEs) and sample sizes (N) for CH1, STH, and CH0 passing the BON spillway during different years, by spillbay, and across groups of spillbays as described in detail in Section 5.0.

Table C.1. BON Spillway Passage Survival Estimates by Year for Each Species-Run

Year	CH1			STH			CH0		
	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
2008	0.9481	0.0102	1514	0.9362	0.0104	1473	0.9494	0.0050	2279
2009*	*	*	*	*	*	*	*	*	*
2010	0.9309	0.0068	1767	0.9404	0.0079	1363	0.9304	0.0062	1787
2011	0.9402	0.0063	3170	0.9478	0.0054	3111	**	**	**
2012	0.9378	0.0052	2225	0.9359	0.0054	2126	0.9614	0.0029	4532
Total			8676			8073			8598

*No spillway data for 2009

**No study conducted in 2011 summer due to extreme high flow in summer

Table C.2. BON Spillway Survival Estimates Spring 2011 vs. Spring 2008, 2010, and 2012 for Each Species

Year	CH1			STH		
	Estimate	SE	N	Estimate	SE	N
2011	0.9402	0.0063	3170	0.9478	0.0054	3111
2008, 2010, & 2012	0.9343	0.0038	5506	0.9367	0.0042	4962
Total			8676			8073

Table C.3. BON Spillway Passage Survival Estimates by Spillbay for Each Species-Run

Spillbay	2008, 2010–2012						2008, 2010, 2012		
	CH1			STH			CH0		
	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
1	0.9326	0.0133	576	0.9451	0.0129	521	0.9575	0.0095	496
2	0.9224	0.0113	791	0.9386	0.0119	623	0.9286	0.0113	548
3	0.9172	0.0110	783	0.9203	0.0122	650	0.9370	0.0097	668
4	0.9377	0.0109	650	0.9558	0.0121	490	0.9596	0.0063	1021
5	0.9553	0.0105	559	0.9232	0.0151	459	0.9445	0.0097	599
6	0.9550	0.0127	385	0.9198	0.0179	301	0.9573	0.0094	503
7	0.9390	0.0156	384	0.9408	0.0172	332	0.9374	0.0123	404
8	0.9527	0.0133	387	0.9438	0.0161	322	0.9494	0.0125	322
9	0.9127	0.0181	310	0.9225	0.0171	327	0.9604	0.0116	293
10	0.9518	0.0163	320	0.9477	0.0157	349	0.9739	0.0093	357
11	0.9156	0.0187	350	0.9510	0.0159	317	0.9595	0.0098	425
12	0.9253	0.0175	317	0.9541	0.0152	333	0.9438	0.0130	326
13	0.9207	0.0191	345	0.9511	0.0152	333	0.9552	0.0112	362
14	0.9612	0.0145	386	0.9405	0.0152	379	0.9560	0.0118	310
15	0.9216	0.0147	454	0.9639	0.0146	449	0.9729	0.0082	437
16	0.9525	0.0131	600	0.9434	0.0124	620	0.9578	0.0088	574
17	0.9225	0.0132	728	0.9382	0.0121	716	0.9450	0.0096	622
18	0.9532	0.0169	351	0.9528	0.0110	552	0.9422	0.0132	331
Total			8676			8073			8598

Table C.4. BON Spillway Survival Estimates by Spillbay Group for Each Species-Run

Spillbays	2008, 2010–2012						2008, 2010, 2012		
	CH1			STH			CH0		
	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
1–3	0.9229	0.0068	2150	0.9340	0.0071	1794	0.9403	0.0059	1712
4–7	0.9462	0.0061	1978	0.9361	0.0076	1582	0.9520	0.0044	2527
8–12	0.9319	0.0075	1684	0.9440	0.0072	1648	0.9577	0.0050	1723
13–15	0.9338	0.0092	1185	0.9525	0.0087	1161	0.9625	0.0059	1109
16–18	0.9401	0.0082	1679	0.9439	0.0069	1888	0.9492	0.0059	1527
Total			8676			8073			8598

Table C.5. BON Spillway CH1 Estimates by Spillbay for Individual Year

Bay	2008			2010			2011			2012		
	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
1	0.9394	0.0298	93	0.9370	0.0240	124	0.9254	0.0235	272	0.9437	0.0250	87
2	0.9650	0.0284	202	0.9017	0.0224	203	0.9444	0.0242	187	0.9045	0.0208	199
3	1.0197	0.0398	76	0.8806	0.0282	152	0.9287	0.0184	317	0.9118	0.0184	238
4	0.9799	0.0270	141	0.9317	0.0266	120	0.9413	0.0232	161	0.9212	0.0179	228
5	0.9128	0.0318	106	0.9961	0.0135	80	0.9613	0.0231	183	0.9642	0.0137	190
6	0.9482	0.0354	59	0.9717	0.0295	75	0.9089	0.0315	115	0.9867	0.0104	136
7	0.8922	0.0891	34	0.9277	0.0287	90	0.9679	0.0271	158	0.9325	0.0251	102
8	1.0008	0.0407	45	0.9710	0.0228	62	0.9478	0.0303	147	0.9560	0.0180	133
9	0.9938	0.0765	27	0.9254	0.0403	62	0.8654	0.0361	123	0.9592	0.0200	98
10	0.9830	0.0551	61	0.9293	0.0313	69	0.9760	0.0399	111	0.9762	0.0178	79
11	0.8306	0.0693	54	0.9406	0.0352	57	0.9423	0.0355	145	0.9370	0.0252	94
12	1.0041	0.0653	55	0.9589	0.0232	73	0.8971	0.0358	116	0.9187	0.0322	73
13	0.9482	0.0659	68	0.8805	0.0431	72	0.9132	0.0362	130	0.9867	0.0132	75
14	0.9772	0.0386	93	0.9494	0.0293	86	0.9805	0.0267	127	0.9388	0.0271	80
15	0.8874	0.0446	82	0.9238	0.0312	103	0.9459	0.0228	166	0.9129	0.0278	103
16	0.9650	0.0382	147	0.9206	0.0268	115	0.9950	0.0231	224	0.9218	0.0253	114
17	0.8834	0.0431	131	0.9515	0.0204	149	0.9346	0.0222	344	0.9429	0.0229	104
18	0.9685	0.0509	40	0.9802	0.0421	75	0.9552	0.0293	144	0.9265	0.0278	92
Total			1514			1767			3170			2225

Table C.6. BON Spillway STH Survival Estimates by Spillbay for Individual Year

Bay	2008			2010			2011			2012		
	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
1	0.8907	0.0411	78	0.9794	0.0232	95	0.9477	0.0193	249	0.9313	0.0259	99
2	0.9390	0.0256	169	0.9388	0.0235	127	0.9239	0.0256	182	0.9465	0.0190	145
3	0.9091	0.0403	88	0.8549	0.0352	122	0.9640	0.0164	246	0.9090	0.0209	194
4	0.9505	0.0398	103	0.9441	0.0371	64	0.9616	0.0224	135	0.9542	0.0156	188
5	0.9018	0.0414	89	0.9606	0.0293	71	0.9659	0.0271	168	0.8792	0.0287	131
6	0.9341	0.0563	63	0.8958	0.0455	52	0.9555	0.0370	82	0.9231	0.0261	104
7	0.9320	0.0433	57	0.9333	0.0426	48	0.9330	0.0309	139	0.9450	0.0248	88
8	0.9449	0.0440	52	0.9007	0.0446	48	0.9624	0.0248	133	0.9246	0.0287	89
9	0.8535	0.0728	37	0.9721	0.0287	64	0.9223	0.0309	128	0.9306	0.0261	98
10	0.9204	0.0525	68	0.9743	0.0271	56	0.9169	0.028	129	0.9718	0.0179	96
11	0.9689	0.0651	46	0.9273	0.0342	64	0.9498	0.0273	126	0.9643	0.0210	81
12	0.9539	0.0502	68	0.9708	0.0296	74	0.9742	0.0228	107	0.9177	0.0302	84
13	0.9843	0.0463	78	0.9431	0.0383	45	0.9317	0.0276	125	0.9681	0.0202	85
14	0.8654	0.0507	63	0.9202	0.0376	83	0.9696	0.0214	134	0.9525	0.0222	99
15	0.9737	0.0399	120	0.9900	0.0443	50	0.9735	0.0236	167	0.9414	0.0231	112
16	0.9667	0.0490	108	0.9058	0.0358	88	0.9588	0.0193	267	0.9442	0.0186	157
17	0.9456	0.0304	157	0.9553	0.0234	128	0.9223	0.0174	331	0.9030	0.0302	100
18	0.8922	0.0707	29	0.9861	0.0279	84	0.9508	0.0168	263	0.9520	0.0167	176
Total			1473			1363			3111			2126

Table C.7. BON Spillway CH0 Survival Estimates by Bay for Individual Year

Spillbay	2008			2010			2012		
	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
1	0.9585	0.0153	206	0.9518	0.0235	83	0.9565	0.0142	207
2	0.9547	0.0175	171	0.9075	0.0231	166	0.9242	0.0182	211
3	0.9316	0.0235	132	0.9199	0.0184	228	0.9520	0.0123	308
4	0.9548	0.0175	171	0.9373	0.0224	123	0.9650	0.0069	727
5	0.9034	0.0255	146	0.9510	0.0212	114	0.9596	0.0108	339
6	0.9204	0.0282	110	0.9332	0.0270	88	0.9783	0.0086	305
7	0.9159	0.0320	86	0.9278	0.0263	97	0.9502	0.0146	221
8	0.9333	0.0312	70	0.9000	0.0387	60	0.9705	0.0126	192
9	0.9935	0.0198	55	0.9265	0.0317	68	0.9650	0.0142	170
10	0.9747	0.0179	115	0.9802	0.0172	83	0.9692	0.0139	159
11	0.9487	0.0182	162	0.9231	0.0370	52	0.9768	0.0105	211
12	0.9590	0.0217	91	0.9383	0.0308	63	0.9365	0.0187	172
13	0.9654	0.0211	95	0.8788	0.0402	66	0.9751	0.0110	201
14	0.9340	0.0293	74	1.0024	0.0026	58	0.9501	0.0164	178
15	0.9636	0.0207	96	0.9424	0.0275	80	0.9852	0.0076	261
16	0.9695	0.0135	196	0.9297	0.0234	124	0.9616	0.0122	254
17	0.9480	0.0164	228	0.9425	0.0203	145	0.9450	0.0146	249
18	0.9549	0.0266	75	0.8835	0.0355	89	0.9701	0.0132	167
Total			2279			1787			4532

Table C.8. BON Spillway CH1 Survival Estimates by Bay Group for Individual Year

Bays	2008			2010			2011			2012		
	Estim ate	SE	N	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
1–3	0.9710	0.0189	371	0.9042	0.0145	479	0.9309	0.0125	776	0.9144	0.0122	524
4–7	0.9420	0.0179	340	0.9522	0.0131	365	0.9469	0.0128	617	0.9490	0.0087	656
8–12	0.9593	0.0279	242	0.9437	0.0136	323	0.9247	0.0156	642	0.9506	0.0100	477
13–15	0.9359	0.0272	243	0.9212	0.0198	261	0.9447	0.0162	423	0.9424	0.0146	258
16–18	0.9327	0.0258	318	0.9427	0.0151	339	0.9591	0.0143	712	0.9303	0.0146	310
Total			1514			1767			3170			2225

Table C.9. BON Spillway STH Survival Estimates by Bay Group for Individual Year

Bays	2008			2010			2011			2012		
	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
1–3	0.9206	0.0193	335	0.9197	0.0166	344	0.9474	0.0116	677	0.9267	0.0127	438
4–7	0.9324	0.0225	312	0.9368	0.0190	235	0.9531	0.0143	524	0.9270	0.0116	511
8–12	0.9403	0.0258	271	0.9552	0.0148	306	0.9439	0.0121	623	0.9419	0.0113	448
13–15	0.9502	0.0259	261	0.9428	0.0230	178	0.9598	0.0140	426	0.9530	0.0129	296
16–18	0.9449	0.0243	294	0.9510	0.0167	300	0.9418	0.0103	861	0.9379	0.0119	433
Total			1473			1363			3111			2126

Table C.10. BON Spillway CH0 Survival Estimates by Bay Group for Individual Year

Bays	2008			2010			2012		
	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
1–3	0.9504	0.0105	509	0.9211	0.0126	477	0.9452	0.0085	726
4–7	0.9263	0.0124	513	0.9377	0.0120	422	0.9643	0.0047	1592
8–12	0.9598	0.0097	493	0.9369	0.0136	326	0.9643	0.0062	904
13–15	0.9564	0.0135	265	0.9385	0.0172	204	0.9722	0.0065	640
16–18	0.9574	0.0100	499	0.9234	0.0146	358	0.9575	0.0079	670
Total			2279			1787			4532

Table C.11. BON Spillway CH1 Statistical Output for Survival Estimates by Spillbay for Individual Year. Each spillbay is listed individually.

BAY 1	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.95		95%	211783	0.24%	-7.30%	7.78%
2008 *vs.* 2011	0.7124		93%	9373	1.40%	-6.06%	8.86%
2008 *vs.* 2012	0.9121		95%	58783	-0.43%	-8.11%	7.25%
2010 *vs.* 2011	0.73		94%	12993	1.16%	-5.44%	7.76%
2010 *vs.* 2012	0.8469		95%	22203	-0.67%	-7.50%	6.16%
2011 *vs.* 2012	0.5941		92%	4822	-1.83%	-8.58%	4.92%

BAY 2	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.0809		59%	522	6.33%	-0.78%	13.44%
2008 *vs.* 2011	0.5812		91%	5065	2.06%	-5.28%	9.40%
2008 *vs.* 2012	0.0865		60%	537	6.05%	-0.87%	12.97%
2010 *vs.* 2011	0.1961		75%	915	-4.27%	-10.75%	2.21%
2010 *vs.* 2012	0.9271		95%	189087	-0.28%	-6.29%	5.73%
2011 *vs.* 2012	0.5941		92%	4822	-1.83%	-8.58%	4.92%

Table C.11 (contd)

BAY 3	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.0048	81%			13.91%	4.30%	23.52%
2008 *vs.* 2011	*0.0386*	*54%*			9.10%	0.48%	17.72%
2008 *vs.* 2012	*0.0144*	*69%*			10.79%	2.16%	19.42%
2010 *vs.* 2011	0.1538		70%	778	-4.81%	-11.43%	1.81%
2010 *vs.* 2012	0.3547		85%	1633	-3.12%	-9.74%	3.50%
2011 *vs.* 2012	0.5163		90%	5182	1.69%	-3.42%	6.80%

BAY 4	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.2046		76%	639	4.82%	-2.64%	12.28%
2008 *vs.* 2011	0.2791		81%	1005	3.86%	-3.15%	10.87%
2008 *vs.* 2012	0.0708		56%	403	5.87%	-0.50%	12.24%
2010 *vs.* 2011	0.7858		94%	14715	-0.96%	-7.91%	5.99%
2010 *vs.* 2012	0.7435		94%	11310	1.05%	-5.26%	7.36%
2011 *vs.* 2012	0.4932		90%	3119	2.01%	-3.75%	7.77%

BAY 5	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	*0.0169*	*67%*			*-8.33%*	*-15.15%*	*-1.51%*
2008 *vs.* 2011	0.2182		77%	689	-4.85%	-12.59%	2.89%
2008 *vs.* 2012	0.1388		69%	428	-5.14%	-11.95%	1.67%
2010 *vs.* 2011	0.1945		75%	733	3.48%	-1.79%	8.75%
2010 *vs.* 2012	0.0984		62%	391	3.19%	-0.60%	6.98%
2011 *vs.* 2012	0.9141		95%	125074	-0.29%	-5.57%	4.99%

BAY 6	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.6109		92%	2009	-2.35%	-11.47%	6.77%
2008 *vs.* 2011	0.408		87%	967	3.93%	-5.42%	13.28%
2008 *vs.* 2012	0.298		82%	475	-3.85%	-11.13%	3.43%
2010 *vs.* 2011	0.1473		70%	361	6.28%	-2.23%	14.79%
2010 *vs.* 2012	0.6321		92%	2817	-1.50%	-7.67%	4.67%
2011 *vs.* 2012	*0.0198*	*65%*			*-7.78%*	*-14.31%*	*-1.25%*

BAY 7	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.7052		93%	2178	-3.55%	-22.08%	14.98%
2008 *vs.* 2011	0.4173		87%	535	-7.57%	-25.94%	10.80%
2008 *vs.* 2012	0.664		93%	1639	-4.03%	-22.34%	14.28%
2010 *vs.* 2011	0.3095		83%	931	-4.02%	-11.79%	3.75%
2010 *vs.* 2012	0.8999		95%	47634	-0.48%	-8.00%	7.04%
2011 *vs.* 2012	0.3388		84%	1138	3.54%	-3.73%	10.81%

BAY 8	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.5244		90%	962	2.98%	-6.27%	12.23%
2008 *vs.* 2011	0.2976		82%	592	5.30%	-4.71%	15.31%
2008 *vs.* 2012	0.3155		83%	466	4.48%	-4.30%	13.26%
2010 *vs.* 2011	0.5413		91%	2462	2.32%	-5.16%	9.80%
2010 *vs.* 2012	0.6062		92%	2655	1.50%	-4.23%	7.23%
2011 *vs.* 2012	0.8162		94%	20931	-0.82%	-7.76%	6.12%

BAY 9	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.4311		88%	444	6.84%	-10.35%	24.03%
2008 *vs.* 2011	0.1312		68%	154	12.84%	-3.88%	29.56%
2008 *vs.* 2012	0.6625		93%	1314	3.46%	-12.19%	19.11%
2010 *vs.* 2011	0.2689		80%	576	6.00%	-4.67%	16.67%
2010 *vs.* 2012	0.4536		89%	974	-3.38%	-12.27%	5.51%
2011 *vs.* 2012	*0.024*	*62%*			*-9.38%*	*-17.51%*	*-1.25%*

BAY 10	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.3983		87%	699	5.37%	-7.17%	17.91%
2008 *vs.* 2011	0.9182		95%	58643	0.70%	-12.73%	14.13%
2008 *vs.* 2012	0.9067		95%	36195	0.68%	-10.77%	12.13%
2010 *vs.* 2011	0.3584		85%	889	-4.67%	-14.68%	5.34%
2010 *vs.* 2012	0.1948		75%	335	-4.69%	-11.81%	2.43%
2011 *vs.* 2012	0.9964		95%	40000599	-0.02%	-8.64%	8.60%

BAY 11	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.1599		71%	218	-11.00%	-26.41%	4.41%
2008 *vs.* 2011	0.153		70%	281	-11.17%	-26.53%	4.19%
2008 *vs.* 2012	0.1512		70%	225	-10.64%	-25.21%	3.93%
2010 *vs.* 2011	0.9729		95%	694861	-0.17%	-10.03%	9.69%
2010 *vs.* 2012	0.9338		95%	79969	0.36%	-8.19%	8.91%
2011 *vs.* 2012	0.9032		95%	68301	0.53%	-8.05%	9.11%

BAY 12	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.5154		90%	1069	4.52%	-9.19%	18.23%
2008 *vs.* 2011	0.1526		70%	266	10.70%	-4.00%	25.40%
2008 *vs.* 2012	0.243		79%	340	8.54%	-5.87%	22.95%
2010 *vs.* 2011	0.1491		70%	391	6.18%	-2.24%	14.60%
2010 *vs.* 2012	0.3128		83%	567	4.02%	-3.82%	11.86%
2011 *vs.* 2012	0.6542		93%	3815	-2.16%	-11.66%	7.34%

Table C.11 (contd)

BAY 13	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.3914		86%	746	6.77%	-8.80%	22.34%
2008 *vs.* 2011	0.6421		93%	3014	3.50%	-11.33%	18.33%
2008 *vs.* 2012	0.5677		91%	1656	-3.85%	-17.14%	9.44%
2010 *vs.* 2011	0.5619		91%	2255	-3.27%	-14.37%	7.83%
2010 *vs.* 2012	*0.0198*	*65%*			*-10.62%*	*-19.53%*	*-1.71%*
2011 *vs.* 2012	0.0579		53%	270	-7.35%	-14.95%	0.25%

BAY 14	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.5669		91%	2182	2.78%	-6.78%	12.34%
2008 *vs.* 2011	0.944		95%	166613	-0.33%	-9.58%	8.92%
2008 *vs.* 2012	0.4167		87%	1063	3.84%	-5.47%	13.15%
2010 *vs.* 2011	0.4336		88%	1347	-3.11%	-10.92%	4.70%
2010 *vs.* 2012	0.7909		94%	9373	1.06%	-6.82%	8.94%
2011 *vs.* 2012	0.2743		81%	681	4.17%	-3.33%	11.67%

BAY 15	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.5045		90%	1577	-3.64%	-14.38%	7.10%
2008 *vs.* 2011	0.244		79%	577	-5.85%	-15.72%	4.02%
2008 *vs.* 2012	0.6281		92%	2962	-2.55%	-12.92%	7.82%
2010 *vs.* 2011	0.5679		91%	3021	-2.21%	-9.82%	5.40%
2010 *vs.* 2012	0.7945		94%	11997	1.09%	-7.15%	9.33%
2011 *vs.* 2012	0.3595		85%	1205	3.30%	-3.78%	10.38%

BAY 16	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.3422		84%	1192	4.44%	-4.75%	13.63%
2008 *vs.* 2011	0.502		90%	2929	-3.00%	-11.78%	5.78%
2008 *vs.* 2012	0.3466		85%	1219	4.32%	-4.70%	13.34%
2010 *vs.* 2011	*0.0362*	*55%*			*-7.44%*	*-14.40%*	*-0.48%*
2010 *vs.* 2012	0.9741		95%	855276	-0.12%	-7.38%	7.14%
2011 *vs.* 2012	*0.0333*	*57%*			*7.32%*	*0.58%*	*14.06%*

BAY 17	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.1544		70%	521	-6.81%	-16.20%	2.58%
2008 *vs.* 2011	0.2915		82%	1242	-5.12%	-14.65%	4.41%
2008 *vs.* 2012	0.224		77%	666	-5.95%	-15.57%	3.67%
2010 *vs.* 2011	0.5754		91%	6389	1.69%	-4.23%	7.61%
2010 *vs.* 2012	0.7794		94%	12465	0.86%	-5.18%	6.90%
2011 *vs.* 2012	0.7948		94%	25642	-0.83%	-7.10%	5.44%

Table C.11 (contd)

BAY 18	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.8597		95%	13802	-1.17%	-14.26%	11.92%
2008 *vs.* 2011	0.8211		94%	10193	1.33%	-10.26%	12.92%
2008 *vs.* 2012	0.4703		89%	790	4.20%	-7.27%	15.67%
2010 *vs.* 2011	0.6265		92%	3252	2.50%	-7.61%	12.61%
2010 *vs.* 2012	0.2887		82%	562	5.37%	-4.59%	15.33%
2011 *vs.* 2012	0.4781		89%	1872	2.87%	-5.09%	10.83%

Table C.12. BON Spillway STH Statistical Output for Survival Estimates by Spillbay for Individual Year. Each spillbay is listed individually.

BAY 1	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.0619		54%	185	-8.87%	-18.19%	0.45%
2008 *vs.* 2011	0.2103		76%	546	-5.70%	-14.63%	3.23%
2008 *vs.* 2012	0.4044		87%	955	-4.06%	-13.65%	5.53%
2010 *vs.* 2011	0.2943		82%	1131	3.17%	-2.77%	9.11%
2010 *vs.* 2012	0.1682		72%	403	4.81%	-2.05%	11.67%
2011 *vs.* 2012	0.612		92%	4671	1.64%	-4.71%	7.99%

BAY 2	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.9954		95%	35731615	0.02%	-6.82%	6.86%
2008 *vs.* 2011	0.6769		93%	7963	1.51%	-5.61%	8.63%
2008 *vs.* 2012	0.8142		94%	22902	-0.75%	-7.02%	5.52%
2010 *vs.* 2011	0.6684		93%	6740	1.49%	-5.35%	8.33%
2010 *vs.* 2012	0.7991		94%	16332	-0.77%	-6.72%	5.18%
2011 *vs.* 2012	0.4789		89%	2654	-2.26%	-8.53%	4.01%

BAY 3	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.3123		83%	794	5.42%	-5.13%	15.97%
2008 *vs.* 2011	0.2079		76%	548	-5.49%	-14.05%	3.07%
2008 *vs.* 2012	0.9982		95%	179939973	0.01%	-8.93%	8.95%
2010 *vs.* 2011	0.0052	80%			-10.91%	-18.55%	-3.27%
2010 *vs.* 2012	0.1873		74%	637	-5.41%	-13.46%	2.64%
2011 *vs.* 2012	0.039	54%			5.50%	0.28%	10.72%

BAY 4	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.9065		95%	48720	0.64%	-10.10%	11.38%
2008 *vs.* 2011	0.8082		94%	14832	-1.11%	-10.11%	7.89%
2008 *vs.* 2012	0.9311		95%	120586	-0.37%	-8.78%	8.04%
2010 *vs.* 2011	0.6868		93%	4034	-1.75%	-10.30%	6.80%
2010 *vs.* 2012	0.8021		94%	10379	-1.01%	-8.94%	6.92%
2011 *vs.* 2012	0.7865		94%	16366	0.74%	-4.63%	6.11%

Table C.12 (contd)

BAY 5	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.2481		79%	491	-5.88%	-15.90%	4.14%
2008 *vs.* 2011	0.1963		75%	532	-6.41%	-16.15%	3.33%
2008 *vs.* 2012	0.6541		93%	4039	2.26%	-7.67%	12.19%
2010 *vs.* 2011	0.8945		95%	51933	-0.53%	-8.39%	7.33%
2010 *vs.* 2012	0.0485	51%			8.14%	0.05%	16.23%
2011 *vs.* 2012	0.0288	59%			8.67%	0.90%	16.44%

BAY 6	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.5978		92%	1674	3.83%	-10.51%	18.17%
2008 *vs.* 2011	0.7512		94%	5421	-2.14%	-15.46%	11.18%
2008 *vs.* 2012	0.8595		95%	17759	1.10%	-11.15%	13.35%
2010 *vs.* 2011	0.3105		83%	492	-5.97%	-17.57%	5.63%
2010 *vs.* 2012	0.6035		92%	1904	-2.73%	-13.09%	7.63%
2011 *vs.* 2012	0.4752		89%	1384	3.24%	-5.69%	12.17%

BAY 7	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.983		95%	918211	-0.13%	-12.18%	11.92%
2008 *vs.* 2011	0.985		95%	1899550	-0.10%	-10.59%	10.39%
2008 *vs.* 2012	0.7948		94%	7581	-1.30%	-11.16%	8.56%
2010 *vs.* 2011	0.9955		95%	19374888	0.03%	-10.35%	10.41%
2010 *vs.* 2012	0.8127		94%	8218	-1.17%	-10.92%	8.58%
2011 *vs.* 2012	0.7623		94%	10273	-1.20%	-9.01%	6.61%

BAY 8	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.4822		89%	804	4.42%	-8.01%	16.85%
2008 *vs.* 2011	0.7294		94%	4727	-1.75%	-11.72%	8.22%
2008 *vs.* 2012	0.6998		93%	3361	2.03%	-8.36%	12.42%
2010 *vs.* 2011	0.2282		78%	370	-6.17%	-16.24%	3.90%
2010 *vs.* 2012	0.653		93%	2354	-2.39%	-12.88%	8.10%
2011 *vs.* 2012	0.3201		83%	860	3.78%	-3.70%	11.26%

Table C.12 (contd)

BAY 9	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.1328		68%	142	-11.86%	-27.39%	3.67%
2008 *vs.* 2011	0.3856		86%	535	-6.88%	-22.50%	8.74%
2008 *vs.* 2012	0.3206		83%	353	-7.71%	-23.01%	7.59%
2010 *vs.* 2011	0.2391		78%	560	4.98%	-3.34%	13.30%
2010 *vs.* 2012	0.2863		82%	552	4.15%	-3.51%	11.81%
2011 *vs.* 2012	0.8376		95%	21720	-0.83%	-8.80%	7.14%

BAY 10	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.3634		85%	628	-5.39%	-17.09%	6.31%
2008 *vs.* 2011	0.9532		95%	186753	0.35%	-11.38%	12.08%
2008 *vs.* 2012	0.3555		85%	657	-5.14%	-16.09%	5.81%
2010 *vs.* 2011	0.1425		69%	343	5.74%	-1.95%	13.43%
2010 *vs.* 2012	0.9387		95%	91463	0.25%	-6.17%	6.67%
2011 *vs.* 2012	0.0999		62%	347	-5.49%	-12.04%	1.06%

BAY 11	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.5728		91%	1247	4.16%	-10.42%	18.74%
2008 *vs.* 2011	0.7871		94%	6287	1.91%	-12.03%	15.85%
2008 *vs.* 2012	0.9465		95%	86915	0.46%	-13.08%	14.00%
2010 *vs.* 2011	0.6077		92%	2644	-2.25%	-10.88%	6.38%
2010 *vs.* 2012	0.3581		85%	643	-3.70%	-11.63%	4.23%
2011 *vs.* 2012	0.6742		93%	4886	-1.45%	-8.24%	5.34%

BAY 12	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.7722		94%	6583	-1.69%	-13.21%	9.83%
2008 *vs.* 2011	0.7132		93%	4373	-2.03%	-12.91%	8.85%
2008 *vs.* 2012	0.5376		91%	1505	3.62%	-7.96%	15.20%
2010 *vs.* 2011	0.9276		95%	82687	-0.34%	-7.71%	7.03%
2010 *vs.* 2012	0.2111		76%	399	5.31%	-3.04%	13.66%
2011 *vs.* 2012	0.1371		68%	329	5.65%	-1.81%	13.11%

Table C.12 (contd)

BAY 13	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.4942		90%	1096	4.12%	-7.78%	16.02%
2008 *vs.* 2011	0.3303		84%	752	5.26%	-5.37%	15.89%
2008 *vs.* 2012	0.7489		94%	6112	1.62%	-8.36%	11.60%
2010 *vs.* 2011	0.8095		94%	9852	1.14%	-8.18%	10.46%
2010 *vs.* 2012	0.5647		91%	1285	-2.50%	-11.07%	6.07%
2011 *vs.* 2012	0.2884		82%	777	-3.64%	-10.38%	3.10%

BAY 14	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.3867		86%	740	-5.48%	-17.96%	7.00%
2008 *vs.* 2011	0.0598		53%	164	-10.42%	-21.27%	0.43%
2008 *vs.* 2012	0.1175		66%	221	-8.71%	-19.64%	2.22%
2010 *vs.* 2011	0.2548		80%	581	-4.94%	-13.47%	3.59%
2010 *vs.* 2012	0.4604		89%	1264	-3.23%	-11.85%	5.39%
2011 *vs.* 2012	0.5797		91%	2982	1.71%	-4.37%	7.79%

BAY 15	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.7849		94%	8643	-1.63%	-13.40%	10.14%
2008 *vs.* 2011	0.9966		95%	56121051	0.02%	-9.10%	9.14%
2008 *vs.* 2012	0.4843		89%	1903	3.23%	-5.85%	12.31%
2010 *vs.* 2011	0.7427		94%	5561	1.65%	-8.24%	11.54%
2010 *vs.* 2012	0.3321		84%	532	4.86%	-5.01%	14.73%
2011 *vs.* 2012	0.3319		84%	1172	3.21%	-3.29%	9.71%

BAY 16	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.3168		83%	796	6.09%	-5.88%	18.06%
2008 *vs.* 2011	0.8808		95%	45357	0.79%	-9.57%	11.15%
2008 *vs.* 2012	0.6681		93%	4899	2.25%	-8.07%	12.57%
2010 *vs.* 2011	0.1934		75%	597	-5.30%	-13.30%	2.70%
2010 *vs.* 2012	0.3421		84%	897	-3.84%	-11.79%	4.11%
2011 *vs.* 2012	0.5862		92%	5689	1.46%	-3.81%	6.73%

Table C.12 (contd)

BAY 17	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.8006		94%	18075	-0.97%	-8.52%	6.58%
2008 *vs.* 2011	0.5062		90%	3561	2.33%	-4.55%	9.21%
2008 *vs.* 2012	0.3211		83%	1030	4.26%	-4.18%	12.70%
2010 *vs.* 2011	0.2584		80%	1233	3.30%	-2.43%	9.03%
2010 *vs.* 2012	0.1724		73%	467	5.23%	-2.30%	12.76%
2011 *vs.* 2012	0.58		91%	4052	1.93%	-4.92%	8.78%

BAY 18	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 *vs.* 2010	0.2193		77%	191	-9.39%	-24.45%	5.67%
2008 *vs.* 2011	0.4207		87%	505	-5.86%	-20.16%	8.44%
2008 *vs.* 2012	0.4114		87%	431	-5.98%	-20.30%	8.34%
2010 *vs.* 2011	0.2792		81%	885	3.53%	-2.88%	9.94%
2010 *vs.* 2012	0.2953		82%	779	3.41%	-2.99%	9.81%
2011 *vs.* 2012	0.9596		95%	675146	-0.12%	-4.78%	4.54%

Table C.13. BON Spillway CH0 Statistical Output for Survival Estimates by Spillbay for Individual Year. Each spillbay is listed individually.

Yr	Bay 1						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.8113		94%	16559	0.67%	-4.85%	6.19%
2008 and 2012	0.9237		95%	177367	0.20%	-3.90%	4.30%
2010 and 2012	0.8642		95%	31329	-0.47%	-5.87%	4.93%

Yr	Bay 2						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.1043		63%	500	4.72%	-0.98%	10.42%
2008 and 2012	0.2278		77%	1037	3.05%	-1.91%	8.01%
2010 and 2012	0.5705		91%	4484	-1.67%	-7.45%	4.11%

Yr	Bay 3						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.6953		93%	8653	1.17%	-4.70%	7.04%
2008 and 2012	0.4422		88%	2264	-2.04%	-7.25%	3.17%
2010 and 2012	0.1475		70%	947	-3.21%	-7.56%	1.14%

Yr	Bay 4						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.5386		91%	2944	1.75%	-3.84%	7.34%
2008 and 2012	0.5878		92%	6577	-1.02%	-4.71%	2.67%
2010 and 2012	0.2376		78%	988	-2.77%	-7.37%	1.83%

Yr	Bay 5						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.1524		70%	511	-4.76%	-11.29%	1.77%
2008 and 2012	0.043	53%			-5.62%	-11.06%	-0.18%
2010 and 2012	0.7179		94%	9676	-0.86%	-5.54%	3.82%

Yr	Bay 6						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.7434		94%	7337	-1.28%	-8.98%	6.42%
2008 and 2012	0.0502		50%	259	-5.79%	-11.59%	0.01%
2010 and 2012	0.1123		65%	337	-4.51%	-10.08%	1.06%

Table C.13 (contd)

Yr	Bay 7						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.7742		94%	8694	-1.19%	-9.36%	6.98%
2008 and 2012	0.3302		84%	908	-3.43%	-10.35%	3.49%
2010 and 2012	0.457		89%	1798	-2.24%	-8.16%	3.68%

Yr	Bay 8						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.5041		90%	1136	3.33%	-6.51%	13.17%
2008 and 2012	0.2699		80%	564	-3.72%	-10.35%	2.91%
2010 and 2012	0.0845		59%	192	-7.05%	-15.07%	0.97%

Yr	Bay 9						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.0755		57%	160	6.70%	-0.70%	14.10%
2008 and 2012	0.2434		79%	545	2.85%	-1.95%	7.65%
2010 and 2012	0.2688		80%	548	-3.85%	-10.69%	2.99%

Yr	Bay 10						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.8249		94%	16092	-0.55%	-5.45%	4.35%
2008 and 2012	0.8084		94%	17658	0.55%	-3.91%	5.01%
2010 and 2012	0.6194		92%	3615	1.10%	-3.26%	5.46%

Yr	Bay 11						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.5354		91%	1510	2.56%	-5.57%	10.69%
2008 and 2012	0.1819		73%	769	-2.81%	-6.94%	1.32%
2010 and 2012	0.1638		72%	260	-5.37%	-12.94%	2.20%

Yr	Bay 12						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.5835		92%	1905	2.07%	-5.37%	9.51%
2008 and 2012	0.4329		88%	1609	2.25%	-3.39%	7.89%
2010 and 2012	0.9602		95%	292932	0.18%	-6.92%	7.28%

Table C.13 (contd)

Yr	Bay 13						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.0583		53%	158	8.66%	-0.31%	17.63%
2008 and 2012	0.6838		93%	5595	-0.97%	-5.65%	3.71%
2010 and 2012	0.0216	63%			-9.63%	-17.84%	-1.42%

Yr	Bay 14						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.0216	64%			-6.84%	-12.66%	-1.02%
2008 and 2012	0.632		92%	3400	-1.61%	-8.22%	5.00%
2010 and 2012	0.0018	88%			5.23%	1.96%	8.50%

Yr	Bay 15						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.5388		91%	1795	2.12%	-4.67%	8.91%
2008 and 2012	0.328		84%	951	-2.16%	-6.50%	2.18%
2010 and 2012	0.1345		68%	326	-4.28%	-9.89%	1.33%

Yr	Bay 16						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.1417		69%	517	3.98%	-1.34%	9.30%
2008 and 2012	0.6644		93%	9288	0.79%	-2.79%	4.37%
2010 and 2012	0.2275		77%	820	-3.19%	-8.38%	2.00%

Yr	Bay 17						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.8332		95%	31582	0.55%	-4.58%	5.68%
2008 and 2012	0.8914		95%	100179	0.30%	-4.01%	4.61%
2010 and 2012	0.9204		95%	142402	-0.25%	-5.17%	4.67%

Yr	Bay 18						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.1094		64%	258	7.14%	-1.62%	15.90%
2008 and 2012	0.6092		92%	2815	-1.52%	-7.37%	4.33%
2010 and 2012	0.023	62%			-8.66%	-16.12%	-1.20%

Table C.14. BON Spillway CH1 Statistical Output for Survival Estimates by Spillbay Passage by Grouped Bays and each Individual Year. Grouped spillbay are listed individually.

Yr	Bays 1 to 3						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.0052	80%			6.68%	2.00%	11.36%
2008 and 2011	0.077		58%	1241	4.01%	-0.44%	8.46%
2008 and 2012	0.012	71%			5.66%	1.24%	10.08%
2010 and 2011	0.1634		71%	2448	-2.67%	-6.43%	1.09%
2010 and 2012	0.5905		92%	13508	-1.02%	-4.74%	2.70%
2011 and 2012	0.345		84%	5753	1.65%	-1.78%	5.08%

Yr	Bays 4 to 7						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.6458		93%	12980	-1.02%	-5.37%	3.33%
2008 and 2011	0.8238		94%	68799	-0.49%	-4.81%	3.83%
2008 and 2012	0.7251		94%	25454	-0.70%	-4.61%	3.21%
2010 and 2011	0.7724		94%	45840	0.53%	-3.06%	4.12%
2010 and 2012	0.8388		95%	86235	0.32%	-2.77%	3.41%
2011 and 2012	0.8921		95%	268702	-0.21%	-3.25%	2.83%

Yr	Bays 8 to 12						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.6154		92%	8031	1.56%	-4.54%	7.66%
2008 and 2011	0.2794		81%	2265	3.46%	-2.81%	9.73%
2008 and 2012	0.7692		94%	24548	0.87%	-4.95%	6.69%
2010 and 2011	0.3588		85%	4706	1.90%	-2.16%	5.96%
2010 and 2012	0.6828		93%	17757	-0.69%	-4.00%	2.62%
2011 and 2012	0.1625		71%	2391	-2.59%	-6.23%	1.05%

Table C.14 (contd)

Yr	Bays 13 to 15						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.6623		93%	10287	1.47%	-5.14%	8.08%
2008 and 2011	0.7811		94%	29560	-0.88%	-7.10%	5.34%
2008 and 2012	0.8333		95%	43786	-0.65%	-6.72%	5.42%
2010 and 2011	0.3586		85%	3041	-2.35%	-7.37%	2.67%
2010 and 2012	0.3892		86%	2758	-2.12%	-6.95%	2.71%
2011 and 2012	0.916		95%	247018	0.23%	-4.05%	4.51%

Yr	Bays 16 to 18						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.7381		94%	22749	-1.00%	-6.87%	4.87%
2008 and 2011	0.371		85%	4032	-2.64%	-8.43%	3.15%
2008 and 2012	0.9355		95%	379664	0.24%	-5.58%	6.06%
2010 and 2011	0.4305		88%	6517	-1.64%	-5.72%	2.44%
2010 and 2012	0.5552		91%	7341	1.24%	-2.88%	5.36%
2011 and 2012	0.1591		71%	2007	2.88%	-1.13%	6.89%

Table C.15. BON Spillway STH Statistical Output for Survival Estimates by Spillbay Passage by Grouped Bays and each Individual Year. Grouped spillbay are listed individually.

Yr	Bays 1 to 3						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.9718		95%	2133837	0.09%	-4.91%	5.09%
2008 and 2011	0.2343		78%	2364	-2.68%	-7.10%	1.74%
2008 and 2012	0.7918		94%	41328	-0.61%	-5.15%	3.93%
2010 and 2011	0.1717		72%	1906	-2.77%	-6.74%	1.20%
2010 and 2012	0.7378		94%	26567	-0.70%	-4.80%	3.40%
2011 and 2012	0.2291		78%	2968	2.07%	-1.30%	5.44%

Yr	Bays 4 to 7						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.8813		95%	98783	-0.44%	-6.22%	5.34%
2008 and 2011	0.4377		88%	4868	-2.07%	-7.30%	3.16%
2008 and 2012	0.8311		94%	61168	0.54%	-4.43%	5.51%
2010 and 2011	0.4933		90%	5687	-1.63%	-6.30%	3.04%
2010 and 2012	0.6599		93%	12586	0.98%	-3.39%	5.35%
2011 and 2012	0.1567		71%	2031	2.61%	-1.00%	6.22%

Yr	Bays 8 to 12						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.6166		92%	8777	-1.49%	-7.33%	4.35%
2008 and 2011	0.8995		95%	164849	-0.36%	-5.95%	5.23%
2008 and 2012	0.9547		95%	730441	-0.16%	-5.69%	5.37%
2010 and 2011	0.5546		91%	9748	1.13%	-2.62%	4.88%
2010 and 2012	0.4753		89%	5527	1.33%	-2.33%	4.99%
2011 and 2012	0.9039		95%	291762	0.20%	-3.05%	3.45%

Yr	Bays 13 to 15						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.8309		94%	38765	0.74%	-6.07%	7.55%
2008 and 2011	0.7445		94%	22085	-0.96%	-6.74%	4.82%
2008 and 2012	0.9229		95%	225385	-0.28%	-5.96%	5.40%
2010 and 2011	0.528		90%	4841	-1.70%	-6.99%	3.59%
2010 and 2012	0.6991		93%	10865	-1.02%	-6.20%	4.16%
2011 and 2012	0.721		94%	22596	0.68%	-3.06%	4.42%

Table C.15 (contd)

Yr	Bays 16 to 18						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.8362		95%	54447	-0.61%	-6.40%	5.18%
2008 and 2011	0.9065		95%	216760	0.31%	-4.87%	5.49%
2008 and 2012	0.7959		94%	37732	0.70%	-4.61%	6.01%
2010 and 2011	0.6392		92%	16257	0.92%	-2.93%	4.77%
2010 and 2012	0.5231		90%	6649	1.31%	-2.72%	5.34%
2011 and 2012	0.8043		94%	78898	0.39%	-2.70%	3.48%

Table C.16. Spillway CH0 Statistical Output for Survival Estimates by Spillbay Passage by Grouped Bays and each Individual Year. Grouped spillbay are listed individually.

Yr	Bays 1 to 3						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.0743		57%	1208	2.93%	-0.29%	6.15%
2008 and 2012	0.7004		93%	31565	0.52%	-2.13%	3.17%
2010 and 2012	0.1131		65%	1736	-2.41%	-5.39%	0.57%

Yr	Bays 4 to 7						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.509		90%	8452	-1.14%	-4.53%	2.25%
2008 and 2012	0.0042	82%			-3.80%	-6.40%	-1.20%
2010 and 2012	0.0391	54%			-2.66%	-5.19%	-0.13%

Yr	Bays 8 to 12						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.1708		72%	1601	2.29%	-0.99%	5.57%
2008 and 2012	0.6959		93%	31493	-0.45%	-2.71%	1.81%
2010 and 2012	0.067		55%	996	-2.74%	-5.67%	0.19%

Yr	Bays 13 to 15						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.4134		87%	2673	1.79%	-2.51%	6.09%
2008 and 2012	0.2919		82%	2374	-1.58%	-4.52%	1.36%
2010 and 2012	0.0672		55%	606	-3.37%	-6.98%	0.24%

Yr	Bays 16 to 18						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
2008 and 2010	0.055		52%	859	3.40%	-0.07%	6.87%
2008 and 2012	0.9937		95%	72106220	-0.01%	-2.51%	2.49%
2010 and 2012	0.0402	54%			-3.41%	-6.67%	-0.15%

Table C.17. BON Spillway CH1 Statistical Output for Survival Estimates by Grouped Spillbay Passage by Grouped Years

Bays	2008, 2010 to 2012 for CH1						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
1 to 3 *vs.* 4 to 7	0.0108	72%			-2.33%	-4.12%	-0.54%
1 to 3 *vs.* 8 to 12	0.3741		86%	18822	-0.90%	-2.88%	1.08%
1 to 3 *vs.* 13 to 15	0.3408		84%	13202	-1.09%	-3.33%	1.15%
1 to 3 *vs.* 16 to 18	0.1065		64%	5636	-1.72%	-3.81%	0.37%
4 to 7 *vs.* 8 to 12	0.1392		68%	6465	1.43%	-0.47%	3.33%
4 to 7 *vs.* 13 to 15	0.2614		80%	8883	1.24%	-0.92%	3.40%
4 to 7 *vs.* 16 to 18	0.5506		91%	39360	0.61%	-1.39%	2.61%
8 to 12 *vs.* 13 to 15	0.8728		95%	424310	-0.19%	-2.52%	2.14%
8 to 12 *vs.* 16 to 18	0.4606		89%	24250	-0.82%	-3.00%	1.36%
13 to 15 *vs.* 16 to 18	0.6093		92%	42189	-0.63%	-3.05%	1.79%

Table C.18. BON Spillway STH Statistical Output for Survival Estimates by Grouped Spillbay Passage by Grouped Years

Bays	2008, 2010 to 2012 for STH						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
1 to 3 *vs.* 4 to 7	0.84		95%	323775	-0.21%	-2.25%	1.83%
1 to 3 *vs.* 8 to 12	0.3228		83%	13812	-1.00%	-2.98%	0.98%
1 to 3 *vs.* 13 to 15	0.0996		62%	4092	-1.85%	-4.05%	0.35%
1 to 3 *vs.* 16 to 18	0.3174		83%	14449	-0.99%	-2.93%	0.95%
4 to 7 *vs.* 8 to 12	0.4505		88%	22250	-0.79%	-2.84%	1.26%
4 to 7 *vs.* 13 to 15	0.1558		71%	5235	-1.64%	-3.91%	0.63%
4 to 7 *vs.* 16 to 18	0.4474		88%	23398	-0.78%	-2.79%	1.23%
8 to 12 *vs.* 13 to 15	0.4517		88%	18841	-0.85%	-3.06%	1.36%
8 to 12 *vs.* 16 to 18	0.992		95%	137682527	0.01%	-1.95%	1.97%
13 to 15 *vs.* 16 to 18	0.4387		88%	18877	0.86%	-1.32%	3.04%

Table C.19. BON Spillway CH0 Statistical Output for Survival Estimates by Grouped Spillbay Passage by Grouped Years

Bays	2008, 2010 to 2012 for CH0						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
1 to 3 *vs.* 4 to 7	0.112		64%	6225	-1.17%	-2.61%	0.27%
1 to 3 *vs.* 8 to 12	0.0245	61%			-1.74%	-3.26%	-0.22%
1 to 3 *vs.* 13 to 15	0.0078	76%			-2.22%	-3.86%	-0.58%
1 to 3 *vs.* 16 to 18	0.2862		81%	11180	-0.89%	-2.53%	0.75%
4 to 7 *vs.* 8 to 12	0.3921		86%	22235	-0.57%	-1.88%	0.74%
4 to 7 *vs.* 13 to 15	0.1538		70%	6235	-1.05%	-2.49%	0.39%
4 to 7 *vs.* 16 to 18	0.7036		93%	102243	0.28%	-1.16%	1.72%
8 to 12 *vs.* 13 to 15	0.5349		90%	27845	-0.48%	-2.00%	1.04%
8 to 12 *vs.* 16 to 18	0.2718		80%	10461	0.85%	-0.67%	2.37%
13 to 15 *vs.* 16 to 18	0.1111		64%	4075	1.33%	-0.31%	2.97%

Table C.20. BON Spillway CH1 Statistical Output for Survival Estimates for Spillway Passage by Grouped Spillbays and Individual Years. Each year is listed individually.

Bays	2008						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
1 to 3 *vs.* 4 to 7	0.2656		80%	2260	2.90%	-2.21%	8.01%
1 to 3 *vs.* 8 to 12	0.7286		94%	18459	1.17%	-5.45%	7.79%
1 to 3 *vs.* 13 to 15	0.2897		82%	1996	3.51%	-2.99%	10.01%
1 to 3 *vs.* 16 to 18	0.2315		78%	1847	3.83%	-2.45%	10.11%
4 to 7 *vs.* 8 to 12	0.6019		92%	7824	-1.73%	-8.24%	4.78%
4 to 7 *vs.* 13 to 15	0.8515		95%	61107	0.61%	-5.79%	7.01%
4 to 7 *vs.* 16 to 18	0.7672		94%	29182	0.93%	-5.24%	7.10%
8 to 12 *vs.* 13 to 15	0.5484		91%	5299	2.34%	-5.32%	10.00%
8 to 12 *vs.* 16 to 18	0.4842		89%	4454	2.66%	-4.80%	10.12%
13 to 15 *vs.* 16 to 18	0.932		95%	301097	0.32%	-7.04%	7.68%

Table C.20 (contd)

Bays	2010						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
1 to 3 *vs.* 4 to 7	0.0142	69%			-4.80%	-8.64%	-0.96%
1 to 3 *vs.* 8 to 12	0.0473	51%			-3.95%	-7.85%	-0.05%
1 to 3 *vs.* 13 to 15	0.4887		89%	5529	-1.70%	-6.52%	3.12%
1 to 3 *vs.* 16 to 18	0.0663		55%	945	-3.85%	-7.96%	0.26%
4 to 7 *vs.* 8 to 12	0.6528		93%	13333	0.85%	-2.86%	4.56%
4 to 7 *vs.* 13 to 15	0.1921		74%	1352	3.10%	-1.56%	7.76%
4 to 7 *vs.* 16 to 18	0.6348		92%	12204	0.95%	-2.97%	4.87%
8 to 12 *vs.* 13 to 15	0.3493		85%	2522	2.25%	-2.47%	6.97%
8 to 12 *vs.* 16 to 18	0.9608		95%	1078777	0.10%	-3.89%	4.09%
13 to 15 *vs.* 16 to 18	0.3882		86%	3060	-2.15%	-7.04%	2.74%

Bays	2011						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
1 to 3 *vs.* 4 to 7	0.3713		85%	6827	-1.60%	-5.11%	1.91%
1 to 3 *vs.* 8 to 12	0.7565		94%	56737	0.62%	-3.30%	4.54%
1 to 3 *vs.* 13 to 15	0.5002		90%	9589	-1.38%	-5.39%	2.63%
1 to 3 *vs.* 16 to 18	0.1378		68%	2638	-2.82%	-6.55%	0.91%
4 to 7 *vs.* 8 to 12	0.2715		80%	4105	2.22%	-1.74%	6.18%
4 to 7 *vs.* 13 to 15	0.9152		95%	344606	0.22%	-3.83%	4.27%
4 to 7 *vs.* 16 to 18	0.5251		90%	13028	-1.22%	-4.98%	2.54%
8 to 12 *vs.* 13 to 15	0.3741		86%	5254	-2.00%	-6.41%	2.41%
8 to 12 *vs.* 16 to 18	0.1043		63%	2005	-3.44%	-7.59%	0.71%
13 to 15 *vs.* 16 to 18	0.5053		90%	9730	-1.44%	-5.68%	2.80%

Bays	2012						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
1 to 3 *vs.* 4 to 7	0.0211	63%			-3.46%	-6.40%	-0.52%
1 to 3 *vs.* 8 to 12	0.022	63%			-3.62%	-6.72%	-0.52%
1 to 3 *vs.* 13 to 15	0.1415		69%	1335	-2.80%	-6.53%	0.93%
1 to 3 *vs.* 16 to 18	0.4036		87%	4484	-1.59%	-5.32%	2.14%
4 to 7 *vs.* 8 to 12	0.9039		95%	298996	-0.16%	-2.76%	2.44%
4 to 7 *vs.* 13 to 15	0.6979		93%	18897	0.66%	-2.68%	4.00%
4 to 7 *vs.* 16 to 18	0.2715		80%	2603	1.87%	-1.47%	5.21%
8 to 12 *vs.* 13 to 15	0.6432		93%	12020	0.82%	-2.65%	4.29%
8 to 12 *vs.* 16 to 18	0.2517		79%	2173	2.03%	-1.44%	5.50%
13 to 15 *vs.* 16 to 18	0.5581		91%	6514	1.21%	-2.85%	5.27%

Table C.21. BON Spillway STH Statistical Output for Survival Estimates for Spillway Passage by Grouped Spillbays and Individual Years. Each year is listed individually.

Bays	2008						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
1 to 3 *vs.* 4 to 7	0.6907		93%	15986	-1.18%	-7.00%	4.64%
1 to 3 *vs.* 8 to 12	0.5412		91%	6192	-1.97%	-8.30%	4.36%
1 to 3 *vs.* 13 to 15	0.3598		85%	2696	-2.96%	-9.30%	3.38%
1 to 3 *vs.* 16 to 18	0.4339		88%	3979	-2.43%	-8.52%	3.66%
4 to 7 *vs.* 8 to 12	0.8176		94%	42694	-0.79%	-7.51%	5.93%
4 to 7 *vs.* 13 to 15	0.6041		92%	8279	-1.78%	-8.52%	4.96%
4 to 7 *vs.* 16 to 18	0.706		93%	16709	-1.25%	-7.75%	5.25%
8 to 12 *vs.* 13 to 15	0.7866		94%	28572	-0.99%	-8.17%	6.19%
8 to 12 *vs.* 16 to 18	0.8968		95%	131763	-0.46%	-7.42%	6.50%
13 to 15 *vs.* 16 to 18	0.8814		95%	97774	0.53%	-6.45%	7.51%

Bays	2010						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
1 to 3 *vs.* 4 to 7	0.4982		90%	4838	-1.71%	-6.67%	3.25%
1 to 3 *vs.* 8 to 12	0.1109		64%	1011	-3.55%	-7.92%	0.82%
1 to 3 *vs.* 13 to 15	0.4158		87%	2790	-2.31%	-7.88%	3.26%
1 to 3 *vs.* 16 to 18	0.1842		74%	1435	-3.13%	-7.75%	1.49%
4 to 7 *vs.* 8 to 12	0.4452		88%	3534	-1.84%	-6.57%	2.89%
4 to 7 *vs.* 13 to 15	0.8407		95%	39212	-0.60%	-6.46%	5.26%
4 to 7 *vs.* 16 to 18	0.5748		91%	6584	-1.42%	-6.39%	3.55%
8 to 12 *vs.* 13 to 15	0.6505		93%	8262	1.24%	-4.13%	6.61%
8 to 12 *vs.* 16 to 18	0.8508		95%	67268	0.42%	-3.96%	4.80%
13 to 15 *vs.* 16 to 18	0.7731		94%	20844	-0.82%	-6.41%	4.77%

Table C.21 (contd)

Bays	2011						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
1 to 3 *vs.* 4 to 7	0.757		94%	47971	-0.57%	-4.18%	3.04%
1 to 3 *vs.* 8 to 12	0.8346		95%	116987	0.35%	-2.94%	3.64%
1 to 3 *vs.* 13 to 15	0.4954		90%	8929	-1.24%	-4.81%	2.33%
1 to 3 *vs.* 16 to 18	0.7182		94%	45720	0.56%	-2.48%	3.60%
4 to 7 *vs.* 8 to 12	0.6234		92%	18427	0.92%	-2.76%	4.60%
4 to 7 *vs.* 13 to 15	0.7379		94%	33404	-0.67%	-4.60%	3.26%
4 to 7 *vs.* 16 to 18	0.5215		90%	12219	1.13%	-2.33%	4.59%
8 to 12 *vs.* 13 to 15	0.3904		86%	5435	-1.59%	-5.22%	2.04%
8 to 12 *vs.* 16 to 18	0.8949		95%	325342	0.21%	-2.91%	3.33%
13 to 15 *vs.* 16 to 18	0.3006		82%	4242	1.80%	-1.61%	5.21%

Bays	2012						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
1 to 3 *vs.* 4 to 7	0.9861		0.95	12182572	-0.03%	-3.41%	3.35%
1 to 3 *vs.* 8 to 12	0.3715		86%	4353	-1.52%	-4.86%	1.82%
1 to 3 *vs.* 13 to 15	0.1467		69%	1365	-2.63%	-6.18%	0.92%
1 to 3 *vs.* 16 to 18	0.5201		90%	8276	-1.12%	-4.54%	2.30%
4 to 7 *vs.* 8 to 12	0.3578		85%	4463	-1.49%	-4.67%	1.69%
4 to 7 *vs.* 13 to 15	0.1343		68%	1374	-2.60%	-6.01%	0.81%
4 to 7 *vs.* 16 to 18	0.512		90%	8612	-1.09%	-4.35%	2.17%
8 to 12 *vs.* 13 to 15	0.5177		90%	6800	-1.11%	-4.48%	2.26%
8 to 12 *vs.* 16 to 18	0.8075		94%	58271	0.40%	-2.82%	3.62%
13 to 15 *vs.* 16 to 18	0.3899		86%	3817	1.51%	-1.94%	4.96%

Table C.22. BON Spillway CH0 Statistical Output for Survival Estimates for Spillway Passage by Grouped Spillbays and Individual Years. Each year is listed individually.

Bays	2008						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
1 to 3 *vs.* 4 to 7	0.1383		68%	1828	2.41%	-0.78%	5.60%
1 to 3 *vs.* 8 to 12	0.511		90%	9124	-0.94%	-3.75%	1.87%
1 to 3 *vs.* 13 to 15	0.7258		94%	22823	-0.60%	-3.96%	2.76%
1 to 3 *vs.* 16 to 18	0.6294		92%	17015	-0.70%	-3.55%	2.15%
4 to 7 *vs.* 8 to 12	0.0336	57%			-3.35%	-6.44%	-0.26%
4 to 7 *vs.* 13 to 15	0.101		63%	1105	-3.01%	-6.61%	0.59%
4 to 7 *vs.* 16 to 18	0.0512		50%	1048	-3.11%	-6.24%	0.02%
8 to 12 *vs.* 13 to 15	0.838		95%	64453	0.34%	-2.92%	3.60%
8 to 12 *vs.* 16 to 18	0.8633		95%	131464	0.24%	-2.49%	2.97%
13 to 15 *vs.* 16 to 18	0.9526		95%	772708	-0.10%	-3.40%	3.20%

Bays	2010						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
1 to 3 *vs.* 4 to 7	0.3403		84%	3897	-1.66%	-5.07%	1.75%
1 to 3 *vs.* 8 to 12	0.3943		86%	4288	-1.58%	-5.22%	2.06%
1 to 3 *vs.* 13 to 15	0.4147		87%	3538	-1.74%	-5.93%	2.45%
1 to 3 *vs.* 16 to 18	0.9051		95%	226114	-0.23%	-4.02%	3.56%
4 to 7 *vs.* 8 to 12	0.9648		95%	1488615	0.08%	-3.48%	3.64%
4 to 7 *vs.* 13 to 15	0.9696		95%	1490047	-0.08%	-4.20%	4.04%
4 to 7 *vs.* 16 to 18	0.4495		88%	5275	1.43%	-2.28%	5.14%
8 to 12 *vs.* 13 to 15	0.9419		95%	371275	-0.16%	-4.47%	4.15%
8 to 12 *vs.* 16 to 18	0.4989		90%	5901	1.35%	-2.57%	5.27%
13 to 15 *vs.* 16 to 18	0.5036		90%	4721	1.51%	-2.92%	5.94%

Table C.22 (contd)

Bays	2012						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
1 to 3 *vs.* 4 to 7	0.0494	50%			-1.91%	-3.81%	-0.01%
1 to 3 *vs.* 8 to 12	0.0696		56%	1879	-1.91%	-3.97%	0.15%
1 to 3 *vs.* 13 to 15	0.0117	71%			-2.70%	-4.80%	-0.60%
1 to 3 *vs.* 16 to 18	0.2894		82%	4898	-1.23%	-3.51%	1.05%
4 to 7 *vs.* 8 to 12	1		95%	65535	0.00%	-1.53%	1.53%
4 to 7 *vs.* 13 to 15	0.3248		83%	7831	-0.79%	-2.36%	0.78%
4 to 7 *vs.* 16 to 18	0.4595		89%	13079	0.68%	-1.12%	2.48%
8 to 12 *vs.* 13 to 15	0.3793		86%	7781	-0.79%	-2.55%	0.97%
8 to 12 *vs.* 16 to 18	0.4984		90%	13013	0.68%	-1.29%	2.65%
13 to 15 *vs.* 16 to 18	0.151		70%	2505	1.47%	-0.54%	3.48%

Table C.23. BON Spillway CH1 Statistical Output for Survival Estimates for Spillway Discharge by 10 kcfs Bins and Grouped Years (2008, 2010 to 2012)

≥ 90 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
≥ 90 *vs.* 100	0.4622		89%	19565	0.74%	-1.23%	2.71%
≥ 90 *vs.* 110	0.6458		93%	11722	-0.87%	-4.58%	2.84%
≥ 90 *vs.* 120	0.6044		92%	15172	-0.77%	-3.69%	2.15%
≥ 90 *vs.* 130	0.173		72%	1858	-2.39%	-5.83%	1.05%
≥ 90 *vs.* 140	0.2136		76%	1480	2.77%	-1.60%	7.14%
≥ 90 *vs.* 150	0.1182		65%	2104	-1.99%	-4.49%	0.51%
≥ 90 *vs.* 160	0.8932		95%	102052	0.32%	-4.36%	5.00%
≥ 90 *vs.* 170	0.2089		76%	1211	-2.81%	-7.20%	1.58%
≥ 90 *vs.* 180	0.665		93%	13127	0.96%	-3.39%	5.31%
≥ 90 *vs.* 190	0.8653		95%	82818	0.39%	-4.12%	4.90%
≥ 90 *vs.* 200	0.4047		87%	3771	-1.84%	-6.17%	2.49%
≥ 90 *vs.* 210	0.448		88%	2816	2.39%	-3.79%	8.57%
≥ 90 *vs.* 220	0.0988		62%	788	-3.89%	-8.51%	0.73%
≥ 90 *vs.* 230	0.7706		94%	15796	-1.11%	-8.58%	6.36%
≥ 90 *vs.* 240	0.6422		93%	10456	-1.37%	-7.15%	4.41%
≥ 90 *vs.* 250	0.0129	70%			-5.98%	-10.69%	-1.27%
≥ 90 *vs.* 260	0.6027		92%	9316	-1.49%	-7.11%	4.13%
≥ 90 *vs.* 270	0.6433		93%	11709	-1.26%	-6.60%	4.08%
≥ 90 *vs.* 280	0.2088		76%	2034	-3.48%	-8.91%	1.95%
≥ 90 *vs.* ≤ 290	0.0563		52%	503	8.41%	-0.23%	17.05%

Table C.23 (contd)

100 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
100 *vs.* 110	0.3535		85%	3674	-1.61%	-5.01%	1.79%
100 *vs.* 120	0.238		78%	4232	-1.51%	-4.02%	1.00%
100 *vs.* 130	0.0479	51%			-3.13%	-6.23%	-0.03%
100 *vs.* 140	0.3323		84%	2912	2.03%	-2.07%	6.13%
100 *vs.* 150	0.0077	76%			-2.73%	-4.74%	-0.72%
100 *vs.* 160	0.8525		95%	62907	-0.42%	-4.85%	4.01%
100 *vs.* 170	0.0915		61%	811	-3.55%	-7.67%	0.57%
100 *vs.* 180	0.9159		95%	263294	0.22%	-3.87%	4.31%
100 *vs.* 190	0.872		95%	108096	-0.35%	-4.61%	3.91%
100 *vs.* 200	0.2136		76%	2015	-2.58%	-6.65%	1.49%
100 *vs.* 210	0.5893		92%	6141	1.65%	-4.34%	7.64%
100 *vs.* 220	0.038	55%			-4.63%	-9.00%	-0.26%
100 *vs.* 230	0.6199		92%	5872	-1.85%	-9.16%	5.46%
100 *vs.* 240	0.459		89%	4551	-2.11%	-7.70%	3.48%
100 *vs.* 250	0.0032	84%			-6.72%	-11.19%	-2.25%
100 *vs.* 260	0.4192		87%	4287	-2.23%	-7.64%	3.18%
100 *vs.* 270	0.444		88%	4807	-2.00%	-7.12%	3.12%
100 *vs.* 280	0.113		65%	1419	-4.22%	-9.44%	1.00%
100 *vs.* ≤ 290	0.077		58%	616	7.67%	-0.83%	16.17%

Table C.23 (contd)

110 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
110 *vs.* 120	0.9611		95%	781637	0.10%	-3.93%	4.13%
110 *vs.* 130	0.4999		90%	4084	-1.52%	-5.94%	2.90%
110 *vs.* 140	0.1682		72%	770	3.64%	-1.54%	8.82%
110 *vs.* 150	0.5561		91%	5698	-1.12%	-4.85%	2.61%
110 *vs.* 160	0.6678		93%	6563	1.19%	-4.26%	6.64%
110 *vs.* 170	0.4637		89%	2233	-1.94%	-7.14%	3.26%
110 *vs.* 180	0.4867		89%	3266	1.83%	-3.34%	7.00%
110 *vs.* 190	0.6408		93%	7205	1.26%	-4.05%	6.57%
110 *vs.* 200	0.7115		93%	12333	-0.97%	-6.12%	4.18%
110 *vs.* 210	0.3455		84%	1407	3.26%	-3.53%	10.05%
110 *vs.* 220	0.2722		81%	1179	-3.02%	-8.42%	2.38%
110 *vs.* 230	0.9529		95%	318500	-0.24%	-8.23%	7.75%
110 *vs.* 240	0.8785		95%	73933	-0.50%	-6.93%	5.93%
110 *vs.* 250	0.0673		55%	577	-5.11%	-10.58%	0.36%
110 *vs.* 260	0.8461		95%	50826	-0.62%	-6.89%	5.65%
110 *vs.* 270	0.8988		95%	114659	-0.39%	-6.41%	5.63%
110 *vs.* 280	0.4013		87%	3446	-2.61%	-8.71%	3.49%
110 *vs.* $\leq$ 290	0.0454	52%			9.28%	0.19%	18.37%

Table C.23 (contd)

120 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
120 *vs.* 130	0.3997		87%	3640	-1.62%	-5.40%	2.16%
120 *vs.* 140	0.1345		68%	822	3.54%	-1.10%	8.18%
120 *vs.* 150	0.4157		87%	4884	-1.22%	-4.16%	1.72%
120 *vs.* 160	0.6643		93%	7912	1.09%	-3.84%	6.02%
120 *vs.* 170	0.3899		86%	2045	-2.04%	-6.70%	2.62%
120 *vs.* 180	0.4625		89%	3691	1.73%	-2.89%	6.35%
120 *vs.* 190	0.6334		92%	8581	1.16%	-3.62%	5.94%
120 *vs.* 200	0.6483		93%	10232	-1.07%	-5.67%	3.53%
120 *vs.* 210	0.3308		84%	1507	3.16%	-3.22%	9.54%
120 *vs.* 220	0.2096		76%	1116	-3.12%	-8.00%	1.76%
120 *vs.* 230	0.9303		95%	159420	-0.34%	-7.98%	7.30%
120 *vs.* 240	0.8442		95%	51619	-0.60%	-6.59%	5.39%
120 *vs.* 250	0.0397	54%			-5.21%	-10.17%	-0.25%
120 *vs.* 260	0.8085		94%	37884	-0.72%	-6.55%	5.11%
120 *vs.* 270	0.8627		95%	73066	-0.49%	-6.05%	5.07%
120 *vs.* 280	0.3466		84%	3211	-2.71%	-8.36%	2.94%
120 *vs.* ≤ 290	0.0405	54%			9.18%	0.40%	17.96%

Table C.23 (contd)

130 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
130 *vs.* 140	0.0426	53%			5.16%	0.17%	10.15%
130 *vs.* 150	0.8206		94%	55515	0.40%	-3.06%	3.86%
130 *vs.* 160	0.3119		83%	1501	2.71%	-2.55%	7.97%
130 *vs.* 170	0.8691		95%	57421	-0.42%	-5.42%	4.58%
130 *vs.* 180	0.186		74%	1129	3.35%	-1.62%	8.32%
130 *vs.* 190	0.286		81%	1704	2.78%	-2.33%	7.89%
130 *vs.* 200	0.8274		94%	44071	0.55%	-4.40%	5.50%
130 *vs.* 210	0.1575		71%	730	4.78%	-1.86%	11.42%
130 *vs.* 220	0.5719		91%	5546	-1.50%	-6.71%	3.71%
130 *vs.* 230	0.7489		94%	12240	1.28%	-6.57%	9.13%
130 *vs.* 240	0.7493		94%	19418	1.02%	-5.25%	7.29%
130 *vs.* 250	0.183		74%	1303	-3.59%	-8.88%	1.70%
130 *vs.* 260	0.7725		94%	26245	0.90%	-5.21%	7.01%
130 *vs.* 270	0.7048		93%	15007	1.13%	-4.72%	6.98%
130 *vs.* 280	0.7186		94%	21208	-1.09%	-7.03%	4.85%
130 *vs.* ≤ 290	0.0184	66%			10.80%	1.83%	19.77%

140 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
140 *vs.* 150	0.0334	57%			-4.76%	-9.15%	-0.37%
140 *vs.* 160	0.4159		87%	1963	-2.45%	-8.37%	3.47%
140 *vs.* 170	0.0545		52%	350	-5.58%	-11.27%	0.11%
140 *vs.* 180	0.5298		90%	4097	-1.81%	-7.47%	3.85%
140 *vs.* 190	0.419		87%	2458	-2.38%	-8.16%	3.40%
140 *vs.* 200	0.1091		64%	663	-4.61%	-10.25%	1.03%
140 *vs.* 210	0.917		95%	120683	-0.38%	-7.55%	6.79%
140 *vs.* 220	0.0263	60%			-6.66%	-12.53%	-0.79%
140 *vs.* 230	0.3591		85%	1384	-3.88%	-12.19%	4.43%
140 *vs.* 240	0.2338		78%	1224	-4.14%	-10.97%	2.69%
140 *vs.* 250	0.004	82%			-8.75%	-14.69%	-2.81%
140 *vs.* 260	0.2109		76%	1214	-4.26%	-10.94%	2.42%
140 *vs.* 270	0.22		77%	1227	-4.03%	-10.48%	2.42%
140 *vs.* 280	0.0603		53%	665	-6.25%	-12.77%	0.27%
140 *vs.* ≤ 290	0.2376		78%	1162	5.64%	-3.73%	15.01%

Table C.23 (contd)

150 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
150 *vs.* 160	0.3341		84%	1636	2.31%	-2.38%	7.00%
150 *vs.* 170	0.7148		93%	11657	-0.82%	-5.22%	3.58%
150 *vs.* 180	0.1852		74%	1193	2.95%	-1.42%	7.32%
150 *vs.* 190	0.3026		82%	1920	2.38%	-2.15%	6.91%
150 *vs.* 200	0.946		95%	490782	0.15%	-4.20%	4.50%
150 *vs.* 210	0.1654		72%	749	4.38%	-1.81%	10.57%
150 *vs.* 220	0.4215		87%	2823	-1.90%	-6.54%	2.74%
150 *vs.* 230	0.8174		94%	22919	0.88%	-6.60%	8.36%
150 *vs.* 240	0.8338		95%	46584	0.62%	-5.18%	6.42%
150 *vs.* 250	0.098		62%	911	-3.99%	-8.72%	0.74%
150 *vs.* 260	0.8617		95%	75855	0.50%	-5.13%	6.13%
150 *vs.* 270	0.789		94%	31655	0.73%	-4.62%	6.08%
150 *vs.* 280	0.5913		92%	10317	-1.49%	-6.93%	3.95%
150 *vs.* ≤ 290	0.0185	65%			10.40%	1.75%	19.05%

160 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
160 *vs.* 170	0.3		82%	1021	-3.13%	-9.06%	2.80%
160 *vs.* 180	0.8312		94%	30578	0.64%	-5.26%	6.54%
160 *vs.* 190	0.9818		95%	2658397	0.07%	-5.95%	6.09%
160 *vs.* 200	0.4711		89%	2828	-2.16%	-8.05%	3.73%
160 *vs.* 210	0.5806		91%	3860	2.07%	-5.30%	9.44%
160 *vs.* 220	0.176		73%	697	-4.21%	-10.32%	1.90%
160 *vs.* 230	0.7403		94%	9754	-1.43%	-9.91%	7.05%
160 *vs.* 240	0.6367		92%	7029	-1.69%	-8.72%	5.34%
160 *vs.* 250	0.0454	52%			-6.30%	-12.47%	-0.13%
160 *vs.* 260	0.6058		92%	6449	-1.81%	-8.70%	5.08%
160 *vs.* 270	0.6414		93%	7623	-1.58%	-8.24%	5.08%
160 *vs.* 280	0.2681		80%	1736	-3.80%	-10.53%	2.93%
160 *vs.* ≤ 290	0.0958		62%	552	8.09%	-1.44%	17.62%

Table C.23 (contd)

170 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
170 *vs.* 180	0.1921		74%	819	3.77%	-1.90%	9.44%
170 *vs.* 190	0.2786		81%	1186	3.20%	-2.60%	9.00%
170 *vs.* 200	0.7363		94%	13074	0.97%	-4.69%	6.63%
170 *vs.* 210	0.1553		71%	579	5.20%	-1.98%	12.38%
170 *vs.* 220	0.7184		94%	9819	-1.08%	-6.97%	4.81%
170 *vs.* 230	0.6881		93%	6594	1.70%	-6.63%	10.03%
170 *vs.* 240	0.6791		93%	9252	1.44%	-5.40%	8.28%
170 *vs.* 250	0.2959		82%	1568	-3.17%	-9.12%	2.78%
170 *vs.* 260	0.6986		93%	11615	1.32%	-5.38%	8.02%
170 *vs.* 270	0.6376		92%	7550	1.55%	-4.91%	8.01%
170 *vs.* 280	0.8405		95%	53846	-0.67%	-7.21%	5.87%
170 *vs.* ≤ 290	0.0193	65%			11.22%	1.83%	20.61%

180 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
180 *vs.* 190	0.8461		95%	45142	-0.57%	-6.34%	5.20%
180 *vs.* 200	0.3287		84%	1892	-2.80%	-8.43%	2.83%
180 *vs.* 210	0.6946		93%	8886	1.43%	-5.73%	8.59%
180 *vs.* 220	0.1043		63%	595	-4.85%	-10.71%	1.01%
180 *vs.* 230	0.6241		92%	5034	-2.07%	-10.37%	6.23%
180 *vs.* 240	0.5018		90%	3999	-2.33%	-9.14%	4.48%
180 *vs.* 250	0.0218	63%			-6.94%	-12.86%	-1.02%
180 *vs.* 260	0.4707		89%	3793	-2.45%	-9.12%	4.22%
180 *vs.* 270	0.4982		90%	4194	-2.22%	-8.66%	4.22%
180 *vs.* 280	0.1809		73%	1355	-4.44%	-10.95%	2.07%
180 *vs.* ≤ 290	0.1186		66%	680	7.45%	-1.91%	16.81%

Table C.23 (contd)

190 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
190 *vs.* 200	0.4467		88%	3084	-2.23%	-7.98%	3.52%
190 *vs.* 210	0.5881		92%	4669	2.00%	-5.26%	9.26%
190 *vs.* 220	0.1601		71%	791	-4.28%	-10.26%	1.70%
190 *vs.* 230	0.7252		94%	9810	-1.50%	-9.89%	6.89%
190 *vs.* 240	0.6173		92%	7171	-1.76%	-8.68%	5.16%
190 *vs.* 250	0.0389	54%			-6.37%	-12.42%	-0.32%
190 *vs.* 260	0.5859		92%	6583	-1.88%	-8.66%	4.90%
190 *vs.* 270	0.6206		92%	7775	-1.65%	-8.20%	4.90%
190 *vs.* 280	0.2513		79%	1817	-3.87%	-10.49%	2.75%
190 *vs.* ≤ 290	0.0957		62%	594	8.02%	-1.42%	17.46%

200 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
200 *vs.* 210	0.245		79%	1053	4.23%	-2.91%	11.37%
200 *vs.* 220	0.4907		89%	3486	-2.05%	-7.89%	3.79%
200 *vs.* 230	0.8626		95%	41721	0.73%	-7.56%	9.02%
200 *vs.* 240	0.892		95%	101289	0.47%	-6.33%	7.27%
200 *vs.* 250	0.1694		72%	1106	-4.14%	-10.05%	1.77%
200 *vs.* 260	0.9178		95%	191257	0.35%	-6.31%	7.01%
200 *vs.* 270	0.8592		95%	63413	0.58%	-5.84%	7.00%
200 *vs.* 280	0.6203		92%	10175	-1.64%	-8.14%	4.86%
200 *vs.* ≤ 290	0.0318	57%			10.25%	0.90%	19.60%

210 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
210 *vs.* 220	0.0927		61%	457	-6.28%	-13.61%	1.05%
210 *vs.* 230	0.4643		89%	2090	-3.50%	-12.90%	5.90%
210 *vs.* 240	0.3626		85%	1820	-3.76%	-11.87%	4.35%
210 *vs.* 250	0.0263	60%			-8.37%	-15.75%	-0.99%
210 *vs.* 260	0.3403		84%	1779	-3.88%	-11.87%	4.11%
210 *vs.* 270	0.3579		85%	1852	-3.65%	-11.45%	4.15%
210 *vs.* 280	0.1427		69%	891	-5.87%	-13.72%	1.98%
210 *vs.* ≤ 290	0.2534		79%	1152	6.02%	-4.33%	16.37%

Table C.23 (contd)

220 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
220 *vs.* 230	0.5179		90%	2769	2.78%	-5.67%	11.23%
220 *vs.* 240	0.479		89%	3391	2.52%	-4.47%	9.51%
220 *vs.* 250	0.5031		90%	4145	-2.09%	-8.22%	4.04%
220 *vs.* 260	0.4915		89%	3921	2.40%	-4.45%	9.25%
220 *vs.* 270	0.4356		88%	2962	2.63%	-3.99%	9.25%
220 *vs.* 280	0.9043		95%	157739	0.41%	-6.29%	7.11%
220 *vs.* ≤ 290	0.0113	72%			12.30%	2.80%	21.80%

230 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
230 *vs.* 240	0.9554		95%	430729	-0.26%	-9.40%	8.88%
230 *vs.* 250	0.2603		80%	1083	-4.87%	-13.36%	3.62%
230 *vs.* 260	0.9341		95%	208904	-0.38%	-9.41%	8.65%
230 *vs.* 270	0.9735		95%	1247472	-0.15%	-9.01%	8.71%
230 *vs.* 280	0.6014		92%	6070	-2.37%	-11.28%	6.54%
230 *vs.* ≤ 290	0.0947		61%	498	9.52%	-1.65%	20.69%

240 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
240 *vs.* 250	0.1993		75%	1216	-4.61%	-11.66%	2.44%
240 *vs.* 260	0.9755		95%	2104339	-0.12%	-7.80%	7.56%
240 *vs.* 270	0.977		95%	2331077	0.11%	-7.37%	7.59%
240 *vs.* 280	0.5831		92%	7690	-2.11%	-9.66%	5.44%
240 *vs.* ≤ 290	0.058		53%	473	9.78%	-0.33%	19.89%

250 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
250 *vs.* 260	0.2023		75%	1334	4.49%	-2.42%	11.40%
250 *vs.* 270	0.166		72%	1113	4.72%	-1.96%	11.40%
250 *vs.* 280	0.4677		89%	4931	2.50%	-4.26%	9.26%
250 *vs.* ≤ 290	0.0032	84%			14.39%	4.86%	23.92%

Table C.23 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
260 *vs.* 270	0.951		95%	553103	0.23%	-7.12%	7.58%
260 *vs.* 280	0.5984		92%	8911	-1.99%	-9.41%	5.43%
260 *vs.* ≤ 290	0.0527		51%	473	9.90%	-0.11%	19.91%
270 *vs.* 280	0.5455		91%	6735	-2.22%	-9.43%	4.99%
270 *vs.* ≤ 290	0.0546		52%	473	9.67%	-0.19%	19.53%
280 *vs.* ≤ 290	0.0187	65%			11.89%	1.98%	21.80%

Table C.24. BON Spillway STH Statistical Output for Survival Estimates for Spillway Discharge by 10 kcfs Bins and Grouped Years (2008, 2010 to 2012)

≥ 90 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
≥ 90 *vs.* 100	0.8335		94%	466904	0.44%	-3.66%	4.54%
≥ 90 *vs.* 110	0.812		94%	29404	-0.35%	-3.24%	2.54%
≥ 90 *vs.* 120	0.5718		91%	8902	-0.88%	-3.93%	2.17%
≥ 90 *vs.* 130	0.2579		80%	2112	2.02%	-1.48%	5.52%
≥ 90 *vs.* 140	0.6356		92%	11085	0.64%	-2.01%	3.29%
≥ 90 *vs.* 150	0.9666		95%	2125421	0.10%	-4.58%	4.78%
≥ 90 *vs.* 160	0.1468		69%	533	-3.28%	-7.71%	1.15%
≥ 90 *vs.* 170	0.8723		95%	48567	-0.29%	-3.83%	3.25%
≥ 90 *vs.* 180	0.7929		94%	33743	-0.67%	-5.68%	4.34%
≥ 90 *vs.* 190	0.8405		95%	53060	-0.50%	-5.37%	4.37%
≥ 90 *vs.* 200	0.8477		95%	45898	0.92%	-8.48%	10.32%
≥ 90 *vs.* 210	0.2428		79%	796	-6.34%	-16.99%	4.31%
≥ 90 *vs.* 220	0.8902		95%	76630	-0.52%	-7.91%	6.87%
≥ 90 *vs.* 230	0.007	77%			-6.45%	-11.13%	-1.77%
≥ 90 *vs.* 240	0.0023	86%			-5.61%	-9.21%	-2.01%
≥ 90 *vs.* 250	0.0079	76%			-5.08%	-8.83%	-1.33%
≥ 90 *vs.* 260	0.6445		93%	12020	-1.02%	-5.36%	3.32%
≥ 90 *vs.* 270	0.3715		86%	3197	-1.69%	-5.40%	2.02%
≥ 90 *vs.* 280	0.0542		51%	955	-2.32%	-4.68%	0.04%
≥ 90 *vs.* ≤ 290	0.0208	64%			9.13%	1.39%	16.87%

Table C.24 (contd)

100 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
100 *vs.* 110	0.7476		94%	146663	-0.79%	-5.60%	4.02%
100 *vs.* 120	0.5985		92%	54418	-1.32%	-6.23%	3.59%
100 *vs.* 130	0.5517		91%	38671	1.58%	-3.62%	6.78%
100 *vs.* 140	0.9331		95%	2311691	0.20%	-4.47%	4.87%
100 *vs.* 150	0.9124		95%	944287	-0.34%	-6.40%	5.72%
100 *vs.* 160	0.2141		76%	6768	-3.72%	-9.59%	2.15%
100 *vs.* 170	0.7843		94%	172667	-0.73%	-5.96%	4.50%
100 *vs.* 180	0.7304		94%	83645	-1.11%	-7.42%	5.20%
100 *vs.* 190	0.7666		94%	114507	-0.94%	-7.15%	5.27%
100 *vs.* 200	0.9261		95%	549983	0.48%	-9.67%	10.63%
100 *vs.* 210	0.24		78%	2608	-6.78%	-18.09%	4.53%
100 *vs.* 220	0.8212		94%	117860	-0.96%	-9.29%	7.37%
100 *vs.* 230	0.0259	61%			-6.89%	-12.95%	-0.83%
100 *vs.* 240	0.0244	61%			-6.05%	-11.32%	-0.78%
100 *vs.* 250	0.044	52%			-5.52%	-10.89%	-0.15%
100 *vs.* 260	0.6215		92%	47111	-1.46%	-7.26%	4.34%
100 *vs.* 270	0.4347		88%	21391	-2.13%	-7.48%	3.22%
100 *vs.* 280	0.2311		78%	12217	-2.76%	-7.28%	1.76%
100 *vs.* ≤ 290	0.0486	50%			8.69%	0.05%	17.33%

Table C.24 (contd)

110 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
110 *vs.* 120	0.7928		94%	28629	-0.53%	-4.49%	3.43%
110 *vs.* 130	0.2813		81%	1740	2.37%	-1.95%	6.69%
110 *vs.* 140	0.5952		92%	5803	0.99%	-2.67%	4.65%
110 *vs.* 150	0.8681		95%	110697	0.45%	-4.87%	5.77%
110 *vs.* 160	0.2602		80%	803	-2.93%	-8.04%	2.18%
110 *vs.* 170	0.9784		95%	1455816	0.06%	-4.30%	4.42%
110 *vs.* 180	0.9108		95%	159344	-0.32%	-5.93%	5.29%
110 *vs.* 190	0.9572		95%	641480	-0.15%	-5.64%	5.34%
110 *vs.* 200	0.7979		94%	24861	1.27%	-8.48%	11.02%
110 *vs.* 210	0.2834		81%	927	-5.99%	-16.96%	4.98%
110 *vs.* 220	0.9659		95%	758730	-0.17%	-7.99%	7.65%
110 *vs.* 230	0.0251	61%			-6.10%	-11.43%	-0.77%
110 *vs.* 240	0.0192	65%			-5.26%	-9.66%	-0.86%
110 *vs.* 250	0.0403	54%			-4.73%	-9.25%	-0.21%
110 *vs.* 260	0.7932		94%	30444	-0.67%	-5.69%	4.35%
110 *vs.* 270	0.5577		91%	5727	-1.34%	-5.83%	3.15%
110 *vs.* 280	0.2631		80%	1619	-1.97%	-5.42%	1.48%
110 *vs.* ≤ 290	0.0228	63%			9.48%	1.32%	17.64%

Table C.24 (contd)

120 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
120 *vs.* 130	0.1989		75%	1553	2.90%	-1.53%	7.33%
120 *vs.* 140	0.4312		88%	3886	1.52%	-2.27%	5.31%
120 *vs.* 150	0.7221		94%	26755	0.98%	-4.43%	6.39%
120 *vs.* 160	0.3649		85%	1767	-2.40%	-7.60%	2.80%
120 *vs.* 170	0.7951		94%	24496	0.59%	-3.87%	5.05%
120 *vs.* 180	0.9423		95%	444281	0.21%	-5.49%	5.91%
120 *vs.* 190	0.8936		95%	122648	0.38%	-5.20%	5.96%
120 *vs.* 200	0.718		94%	13373	1.80%	-7.99%	11.59%
120 *vs.* 210	0.3298		84%	1224	-5.46%	-16.46%	5.54%
120 *vs.* 220	0.9285		95%	194306	0.36%	-7.52%	8.24%
120 *vs.* 230	0.0438	52%			-5.57%	-10.98%	-0.16%
120 *vs.* 240	0.0396	54%			-4.73%	-9.23%	-0.23%
120 *vs.* 250	0.075		57%	734	-4.20%	-8.83%	0.43%
120 *vs.* 260	0.9571		95%	864627	-0.14%	-5.25%	4.97%
120 *vs.* 270	0.7293		94%	20679	-0.81%	-5.40%	3.78%
120 *vs.* 280	0.4316		88%	4616	-1.44%	-5.03%	2.15%
120 *vs.* ≤ 290	0.0169	67%			10.01%	1.80%	18.22%

Table C.24 (contd)

130 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
130 *vs.* 140	0.515		90%	5620	-1.38%	-5.54%	2.78%
130 *vs.* 150	0.5067		90%	7439	-1.92%	-7.59%	3.75%
130 *vs.* 160	0.0578		53%	424	-5.30%	-10.78%	0.18%
130 *vs.* 170	0.3428		84%	1922	-2.31%	-7.09%	2.47%
130 *vs.* 180	0.3748		86%	2947	-2.69%	-8.64%	3.26%
130 *vs.* 190	0.3967		87%	3061	-2.52%	-8.36%	3.32%
130 *vs.* 200	0.8279		94%	37237	-1.10%	-11.04%	8.84%
130 *vs.* 210	0.1407		69%	547	-8.36%	-19.49%	2.77%
130 *vs.* 220	0.5362		91%	4172	-2.54%	-10.60%	5.52%
130 *vs.* 230	0.0036	83%			-8.47%	-14.15%	-2.79%
130 *vs.* 240	0.002	87%			-7.63%	-12.45%	-2.81%
130 *vs.* 250	0.0049	81%			-7.10%	-12.03%	-2.17%
130 *vs.* 260	0.2689		80%	2021	-3.04%	-8.43%	2.35%
130 *vs.* 270	0.1379		68%	1112	-3.71%	-8.61%	1.19%
130 *vs.* 280	0.0327	57%			-4.34%	-8.32%	-0.36%
130 *vs.* ≤ 290	0.0963		62%	600	7.11%	-1.27%	15.49%

Table C.24 (contd)

140 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
140 *vs.* 150	0.8382		95%	80060	-0.54%	-5.73%	4.65%
140 *vs.* 160	0.1222		66%	509	-3.92%	-8.89%	1.05%
140 *vs.* 170	0.6633		93%	7137	-0.93%	-5.13%	3.27%
140 *vs.* 180	0.6395		92%	10048	-1.31%	-6.80%	4.18%
140 *vs.* 190	0.6767		93%	11819	-1.14%	-6.51%	4.23%
140 *vs.* 200	0.9547		95%	522828	0.28%	-9.39%	9.95%
140 *vs.* 210	0.2087		76%	701	-6.98%	-17.88%	3.92%
140 *vs.* 220	0.7682		94%	16972	-1.16%	-8.89%	6.57%
140 *vs.* 230	0.0076	76%			-7.09%	-12.29%	-1.89%
140 *vs.* 240	0.004	82%			-6.25%	-10.49%	-2.01%
140 *vs.* 250	0.0104	73%			-5.72%	-10.09%	-1.35%
140 *vs.* 260	0.5047		90%	5297	-1.66%	-6.54%	3.22%
140 *vs.* 270	0.2917		82%	2066	-2.33%	-6.67%	2.01%
140 *vs.* 280	0.0747		57%	824	-2.96%	-6.22%	0.30%
140 *vs.* ≤ 290	0.0392	54%			8.49%	0.42%	16.56%

150 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
150 *vs.* 160	0.292		82%	2149	-3.38%	-9.67%	2.91%
150 *vs.* 170	0.8931		95%	150578	-0.39%	-6.09%	5.31%
150 *vs.* 180	0.8218		94%	57271	-0.77%	-7.48%	5.94%
150 *vs.* 190	0.8586		95%	89096	-0.60%	-7.21%	6.01%
150 *vs.* 200	0.8771		95%	85774	0.82%	-9.59%	11.23%
150 *vs.* 210	0.274		81%	1226	-6.44%	-17.99%	5.11%
150 *vs.* 220	0.8879		95%	102866	-0.62%	-9.26%	8.02%
150 *vs.* 230	0.0473	51%			-6.55%	-13.02%	-0.08%
150 *vs.* 240	0.0509		50%	798	-5.71%	-11.44%	0.02%
150 *vs.* 250	0.0814		59%	1018	-5.18%	-11.01%	0.65%
150 *vs.* 260	0.724		94%	24961	-1.12%	-7.34%	5.10%
150 *vs.* 270	0.5451		91%	8718	-1.79%	-7.59%	4.01%
150 *vs.* 280	0.3471		84%	4088	-2.42%	-7.47%	2.63%
150 *vs.* ≤ 290	0.0477	51%			9.03%	0.09%	17.97%

Table C.24 (contd)

160 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
160 *vs.* 170	0.2865		81%	827	2.99%	-2.52%	8.50%
160 *vs.* 180	0.4337		88%	2710	2.61%	-3.94%	9.16%
160 *vs.* 190	0.3969		87%	2145	2.78%	-3.67%	9.23%
160 *vs.* 200	0.4237		87%	2396	4.20%	-6.12%	14.52%
160 *vs.* 210	0.6002		92%	3784	-3.06%	-14.54%	8.42%
160 *vs.* 220	0.5244		90%	3162	2.76%	-5.76%	11.28%
160 *vs.* 230	0.3236		83%	972	-3.17%	-9.48%	3.14%
160 *vs.* 240	0.4088		87%	1934	-2.33%	-7.87%	3.21%
160 *vs.* 250	0.5306		90%	3641	-1.80%	-7.44%	3.84%
160 *vs.* 260	0.4629		89%	3094	2.26%	-3.79%	8.31%
160 *vs.* 270	0.5779		91%	4912	1.59%	-4.02%	7.20%
160 *vs.* 280	0.696		93%	9127	0.96%	-3.86%	5.78%
160 *vs.* ≤ 290	0.006	79%			12.41%	3.58%	21.24%

170 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
170 *vs.* 180	0.9006		95%	116389	-0.38%	-6.36%	5.60%
170 *vs.* 190	0.9439		95%	338394	-0.21%	-6.08%	5.66%
170 *vs.* 200	0.8113		94%	27735	1.21%	-8.75%	11.17%
170 *vs.* 210	0.287		81%	923	-6.05%	-17.22%	5.12%
170 *vs.* 220	0.9554		95%	423955	-0.23%	-8.32%	7.86%
170 *vs.* 230	0.0348	56%			-6.16%	-11.88%	-0.44%
170 *vs.* 240	0.0318	58%			-5.32%	-10.17%	-0.47%
170 *vs.* 250	0.0586		53%	443	-4.79%	-9.76%	0.18%
170 *vs.* 260	0.7915		94%	26561	-0.73%	-6.15%	4.69%
170 *vs.* 270	0.5775		91%	5495	-1.40%	-6.34%	3.54%
170 *vs.* 280	0.3213		83%	1642	-2.03%	-6.05%	1.99%
170 *vs.* ≤ 290	0.0283	59%			9.42%	1.01%	17.83%

Table C.24 (contd)

180 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
180 *vs.* 190	0.9611		95%	898973	0.17%	-6.68%	7.02%
180 *vs.* 200	0.7676		94%	20415	1.59%	-8.97%	12.15%
180 *vs.* 210	0.3412		84%	1393	-5.67%	-17.37%	6.03%
180 *vs.* 220	0.9734		95%	1487222	0.15%	-8.67%	8.97%
180 *vs.* 230	0.0915		61%	574	-5.78%	-12.50%	0.94%
180 *vs.* 240	0.1067		64%	816	-4.94%	-10.95%	1.07%
180 *vs.* 250	0.156		71%	1091	-4.41%	-10.51%	1.69%
180 *vs.* 260	0.9155		95%	205822	-0.35%	-6.83%	6.13%
180 *vs.* 270	0.7416		94%	20986	-1.02%	-7.09%	5.05%
180 *vs.* 280	0.5454		91%	6550	-1.65%	-7.00%	3.70%
180 *vs.* ≤ 290	0.0352	56%			9.80%	0.68%	18.92%

190 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
190 *vs.* 200	0.7906		94%	24665	1.42%	-9.08%	11.92%
190 *vs.* 210	0.3246		83%	1258	-5.84%	-17.48%	5.80%
190 *vs.* 220	0.9964		95%	78957551	-0.02%	-8.77%	8.73%
190 *vs.* 230	0.078		58%	489	-5.95%	-12.57%	0.67%
190 *vs.* 240	0.0892		60%	691	-5.11%	-11.00%	0.78%
190 *vs.* 250	0.1335		68%	922	-4.58%	-10.57%	1.41%
190 *vs.* 260	0.8727		95%	86285	-0.52%	-6.89%	5.85%
190 *vs.* 270	0.6952		93%	14089	-1.19%	-7.15%	4.77%
190 *vs.* 280	0.4946		90%	4815	-1.82%	-7.05%	3.41%
190 *vs.* ≤ 290	0.037	55%			9.63%	0.58%	18.68%

Table C.24 (contd)

200 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
200 *vs.* 210	0.3139		83%	1302	-7.26%	-21.42%	6.90%
200 *vs.* 220	0.8119		94%	27609	-1.44%	-13.33%	10.45%
200 *vs.* 230	0.1653		72%	792	-7.37%	-17.80%	3.06%
200 *vs.* 240	0.1989		75%	1025	-6.53%	-16.50%	3.44%
200 *vs.* 250	0.2403		78%	1249	-6.00%	-16.03%	4.03%
200 *vs.* 260	0.7105		93%	13008	-1.94%	-12.20%	8.32%
200 *vs.* 270	0.6088		92%	6691	-2.61%	-12.62%	7.40%
200 *vs.* 280	0.5073		90%	3959	-3.24%	-12.83%	6.35%
200 *vs.* ≤ 290	0.1834		74%	900	8.21%	-3.90%	20.32%

210 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
210 *vs.* 220	0.3759		86%	1489	5.82%	-7.09%	18.73%
210 *vs.* 230	0.9851		95%	2987160	-0.11%	-11.69%	11.47%
210 *vs.* 240	0.8978		95%	69086	0.73%	-10.44%	11.90%
210 *vs.* 250	0.8253		94%	24003	1.26%	-9.95%	12.47%
210 *vs.* 260	0.3605		85%	1488	5.32%	-6.10%	16.74%
210 *vs.* 270	0.4149		87%	1791	4.65%	-6.55%	15.85%
210 *vs.* 280	0.4659		89%	2147	4.02%	-6.80%	14.84%
210 *vs.* ≤ 290	0.0209	64%			15.47%	2.35%	28.59%

220 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
220 *vs.* 230	0.1786		73%	706	-5.93%	-14.58%	2.72%
220 *vs.* 240	0.2178		77%	985	-5.09%	-13.20%	3.02%
220 *vs.* 250	0.2735		81%	1290	-4.56%	-12.73%	3.61%
220 *vs.* 260	0.9076		95%	123234	-0.50%	-8.96%	7.96%
220 *vs.* 270	0.7781		94%	20036	-1.17%	-9.33%	6.99%
220 *vs.* 280	0.6434		93%	7227	-1.80%	-9.43%	5.83%
220 *vs.* ≤ 290	0.075		57%	456	9.65%	-0.98%	20.28%

Table C.24 (contd)

230 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
230 *vs.* 240	0.7738		94%	15895	0.84%	-4.90%	6.58%
230 *vs.* 250	0.6447		93%	6668	1.37%	-4.47%	7.21%
230 *vs.* 260	0.0875		60%	561	5.43%	-0.80%	11.66%
230 *vs.* 270	0.1081		64%	580	4.76%	-1.05%	10.57%
230 *vs.* 280	0.109		64%	536	4.13%	-0.92%	9.18%
230 *vs.* ≤ 290	0.0007	93%			15.58%	6.62%	24.54%

240 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
240 *vs.* 250	0.8352		95%	47210	0.53%	-4.47%	5.53%
240 *vs.* 260	0.0991		62%	820	4.59%	-0.87%	10.05%
240 *vs.* 270	0.1221		66%	904	3.92%	-1.05%	8.89%
240 *vs.* 280	0.1125		65%	914	3.29%	-0.77%	7.35%
240 *vs.* ≤ 290	0.0006	93%			14.74%	6.31%	23.17%

250 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
250 *vs.* 260	0.1519		70%	1127	4.06%	-1.50%	9.62%
250 *vs.* 270	0.1908		74%	1322	3.39%	-1.69%	8.47%
250 *vs.* 280	0.1973		75%	1469	2.76%	-1.44%	6.96%
250 *vs.* ≤ 290	0.0011	91%			14.21%	5.72%	22.70%

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
260 *vs.* 270	0.8121		94%	42741	-0.67%	-6.20%	4.86%
260 *vs.* 280	0.5898		92%	8986	-1.30%	-6.03%	3.43%
260 *vs.* ≤ 290	0.0233	62%			10.15%	1.38%	18.92%
270 *vs.* 280	0.7666		94%	29750	-0.63%	-4.79%	3.53%
270 *vs.* ≤ 290	0.0124	71%			10.82%	2.35%	19.29%
280 *vs.* ≤ 290	0.0049	80%			11.45%	3.48%	19.42%

Table C.25. BON Spillway CH0 Statistical Output for Survival Estimates for Spillway Discharge by 10 kcfs Bins and Grouped Years (2008, 2010 to 2012)

≥ 90 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
≥ 90 *vs.* 100	0.2917		82%	7432	-1.27%	-3.63%	1.09%
≥ 90 *vs.* 110	0.0098	73%			-3.35%	-5.89%	-0.81%
≥ 90 *vs.* 120	0.1172		65%	2421	-2.17%	-4.89%	0.55%
≥ 90 *vs.* 130	0.0002	96%			-3.97%	-6.08%	-1.86%
≥ 90 *vs.* 140	0	100%			-6.54%	-8.72%	-4.36%
≥ 90 *vs.* 150	0	100%			-6.42%	-8.22%	-4.62%
≥ 90 *vs.* 160	0	99%			-4.52%	-6.59%	-2.45%
≥ 90 *vs.* 170	0.0003	95%			-3.98%	-6.12%	-1.84%
≥ 90 *vs.* 180	0	99%			-5.71%	-8.19%	-3.23%
≥ 90 *vs.* 190	0	100%			-7.59%	-10.09%	-5.09%
≥ 90 *vs.* 200	0.0002	96%			-5.43%	-8.29%	-2.57%
≥ 90 *vs.* 210	0	100%			-7.04%	-9.69%	-4.39%
≥ 90 *vs.* 220	0	99%			-5.88%	-8.42%	-3.34%
≥ 90 *vs.* 230	0.0003	95%			-6.34%	-9.80%	-2.88%

100 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
100 *vs.* 110	0.1265		67%	2298	-2.08%	-4.75%	0.59%
100 *vs.* 120	0.5334		90%	12996	-0.90%	-3.73%	1.93%
100 *vs.* 130	0.0193	65%			-2.70%	-4.96%	-0.44%
100 *vs.* 140	0	99%			-5.27%	-7.59%	-2.95%
100 *vs.* 150	0	100%			-5.15%	-7.12%	-3.18%
100 *vs.* 160	0.0042	82%			-3.25%	-5.47%	-1.03%
100 *vs.* 170	0.0201	64%			-2.71%	-5.00%	-0.42%
100 *vs.* 180	0.0009	92%			-4.44%	-7.05%	-1.83%
100 *vs.* 190	0	100%			-6.32%	-8.95%	-3.69%
100 *vs.* 200	0.0062	78%			-4.16%	-7.13%	-1.19%
100 *vs.* 210	0	98%			-5.77%	-8.54%	-3.00%
100 *vs.* 220	0.0007	92%			-4.61%	-7.28%	-1.94%
100 *vs.* 230	0.0052	80%			-5.07%	-8.62%	-1.52%

Table C.25 (contd)

110 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
110 *vs.* 120	0.4384		88%	6720	1.18%	-1.81%	4.17%
110 *vs.* 130	0.6196		92%	21333	-0.62%	-3.07%	1.83%
110 *vs.* 140	0.0127	70%			-3.19%	-5.70%	-0.68%
110 *vs.* 150	0.006	79%			-3.07%	-5.26%	-0.88%
110 *vs.* 160	0.3422		84%	5581	-1.17%	-3.59%	1.25%
110 *vs.* 170	0.6172		92%	20456	-0.63%	-3.10%	1.84%
110 *vs.* 180	0.0956		62%	1199	-2.36%	-5.14%	0.42%
110 *vs.* 190	0.003	85%			-4.24%	-7.03%	-1.45%
110 *vs.* 200	0.1913		74%	1594	-2.08%	-5.20%	1.04%
110 *vs.* 210	0.0137	69%			-3.69%	-6.62%	-0.76%
110 *vs.* 220	0.0798		58%	1013	-2.53%	-5.36%	0.30%
110 *vs.* 230	0.1108		64%	685	-2.99%	-6.67%	0.69%

120 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
120 *vs.* 130	0.1794		73%	2712	-1.80%	-4.43%	0.83%
120 *vs.* 140	0.0014	89%			-4.37%	-7.05%	-1.69%
120 *vs.* 150	0.0005	94%			-4.25%	-6.64%	-1.86%
120 *vs.* 160	0.0761		57%	1490	-2.35%	-4.95%	0.25%
120 *vs.* 170	0.1805		73%	2657	-1.81%	-4.46%	0.84%
120 *vs.* 180	0.0182	66%			-3.54%	-6.48%	-0.60%
120 *vs.* 190	0.0003	95%			-5.42%	-8.37%	-2.47%
120 *vs.* 200	0.0503		50%	704	-3.26%	-6.52%	0.00%
120 *vs.* 210	0.002	87%			-4.87%	-7.95%	-1.79%
120 *vs.* 220	0.015	68%			-3.71%	-6.70%	-0.72%
120 *vs.* 230	0.0315	58%			-4.17%	-7.97%	-0.37%

Table C.25 (contd)

130 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
130 *vs.* 140	0.0149	68%			-2.57%	-4.64%	-0.50%
130 *vs.* 150	0.0039	82%			-2.45%	-4.12%	-0.78%
130 *vs.* 160	0.5813		91%	23376	-0.55%	-2.51%	1.41%
130 *vs.* 170	0.9923		95%	75513914	-0.01%	-2.03%	2.01%
130 *vs.* 180	0.1527		70%	2017	-1.74%	-4.13%	0.65%
130 *vs.* 190	0.0032	84%			-3.62%	-6.02%	-1.22%
130 *vs.* 200	0.3029		82%	2967	-1.46%	-4.24%	1.32%
130 *vs.* 210	0.019	65%			-3.07%	-5.63%	-0.51%
130 *vs.* 220	0.1263		67%	1621	-1.91%	-4.36%	0.54%
130 *vs.* 230	0.1703		72%	988	-2.37%	-5.76%	1.02%

140 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
140 *vs.* 150	0.893		95%	279586	0.12%	-1.63%	1.87%
140 *vs.* 160	0.0509		50%	1320	2.02%	-0.01%	4.05%
140 *vs.* 170	0.0167	67%			2.56%	0.46%	4.66%
140 *vs.* 180	0.5056		90%	6420	0.83%	-1.62%	3.28%
140 *vs.* 190	0.4028		87%	2636	-1.05%	-3.51%	1.41%
140 *vs.* 200	0.4419		88%	3767	1.11%	-1.72%	3.94%
140 *vs.* 210	0.708		93%	13364	-0.50%	-3.12%	2.12%
140 *vs.* 220	0.6057		92%	9708	0.66%	-1.85%	3.17%
140 *vs.* 230	0.909		95%	96560	0.20%	-3.23%	3.63%

150 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
150 *vs.* 160	0.0212	64%			1.90%	0.28%	3.52%
150 *vs.* 170	0.0049	80%			2.44%	0.74%	4.14%
150 *vs.* 180	0.5104		90%	8301	0.71%	-1.41%	2.83%
150 *vs.* 190	0.2822		81%	1949	-1.17%	-3.30%	0.96%
150 *vs.* 200	0.4466		88%	4491	0.99%	-1.56%	3.54%
150 *vs.* 210	0.5991		92%	8070	-0.62%	-2.93%	1.69%
150 *vs.* 220	0.6282		92%	13685	0.54%	-1.65%	2.73%
150 *vs.* 230	0.9609		95%	565929	0.08%	-3.12%	3.28%

Table C.25 (contd)

160 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
160 *vs.* 170	0.5936		92%	23970	0.54%	-1.44%	2.52%
160 *vs.* 180	0.321		83%	3916	-1.19%	-3.54%	1.16%
160 *vs.* 190	0.0111	72%			-3.07%	-5.44%	-0.70%
160 *vs.* 200	0.5163		90%	6958	-0.91%	-3.66%	1.84%
160 *vs.* 210	0.051		50%	703	-2.52%	-5.05%	0.01%
160 *vs.* 220	0.2697		80%	2893	-1.36%	-3.78%	1.06%
160 *vs.* 230	0.2888		81%	1505	-1.82%	-5.19%	1.55%

170 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
170 *vs.* 180	0.1592		71%	2014	-1.73%	-4.14%	0.68%
170 *vs.* 190	0.0036	83%			-3.61%	-6.04%	-1.18%
170 *vs.* 200	0.3098		83%	2969	-1.45%	-4.25%	1.35%
170 *vs.* 210	0.0204	64%			-3.06%	-5.65%	-0.47%
170 *vs.* 220	0.1319		67%	1616	-1.90%	-4.37%	0.57%
170 *vs.* 230	0.1742		73%	981	-2.36%	-5.77%	1.05%

180 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
180 *vs.* 190	0.1779		73%	869	-1.88%	-4.62%	0.86%
180 *vs.* 200	0.8581		95%	61253	0.28%	-2.79%	3.35%
180 *vs.* 210	0.3647		85%	1981	-1.33%	-4.21%	1.55%
180 *vs.* 220	0.9044		95%	151900	-0.17%	-2.95%	2.61%
180 *vs.* 230	0.7337		94%	10144	-0.63%	-4.27%	3.01%

190 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
190 *vs.* 200	0.1702		72%	706	2.16%	-0.93%	5.25%
190 *vs.* 210	0.7091		93%	6577	0.55%	-2.35%	3.45%
190 *vs.* 220	0.2298		78%	984	1.71%	-1.09%	4.51%
190 *vs.* 230	0.5015		90%	1612	1.25%	-2.41%	4.91%

Table C.25 (contd)

kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
200 *vs.* 210	0.3258		84%	1437	-1.61%	-4.83%	1.61%
200 *vs.* 220	0.7773		94%	22764	-0.45%	-3.57%	2.67%
200 *vs.* 230	0.6475		93%	5132	-0.91%	-4.82%	3.00%
210 *vs.* 220	0.4376		88%	2461	1.16%	-1.78%	4.10%
210 *vs.* 230	0.7145		93%	6024	0.70%	-3.07%	4.47%
220 *vs.* 230	0.8061		94%	18120	-0.46%	-4.14%	3.22%

Table C.26. BON Spillway CH1 Statistical Output for Survival Estimates for Spillway Discharge by 20 kcfs Bins and Grouped Years (2008, 2010 to 2012). Each 20 kcfs is listed individually.

Bins	2008, 2010 to 2012 for CH1						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
≤ 80 *vs.* 100	0.4954		90%	22747	0.68%	-1.28%	2.64%
≤ 80 *vs.* 120	0.3903		86%	7824	-1.10%	-3.61%	1.41%
≤ 80 *vs.* 140	0.6016		92%	21761	-0.65%	-3.09%	1.79%
≤ 80 *vs.* 160	0.4937		90%	6956	-1.20%	-4.64%	2.24%
≤ 80 *vs.* 180	0.6967		93%	27557	0.67%	-2.70%	4.04%
≤ 80 *vs.* 200	0.9215		95%	390913	-0.19%	-3.97%	3.59%
≤ 80 *vs.* 220	0.2074		76%	1975	-2.75%	-7.03%	1.53%
≤ 80 *vs.* 240	0.0475	51%			-3.93%	-7.82%	-0.04%
≤ 80 *vs.* 260	0.4476		88%	7914	-1.58%	-5.66%	2.50%
≤ 80 *vs.* ≥ 280	0.7457		94%	45022	0.80%	-4.04%	5.64%

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
100 *vs.* 120	0.0823		59%	3133	-1.78%	-3.79%	0.23%
100 *vs.* 140	0.1746		73%	5457	-1.33%	-3.25%	0.59%
100 *vs.* 160	0.2329		78%	2963	-1.88%	-4.97%	1.21%
100 *vs.* 180	0.9948		95%	128232173	-0.01%	-3.02%	3.00%
100 *vs.* 200	0.6227		92%	19241	-0.87%	-4.34%	2.60%
100 *vs.* 220	0.0928		61%	1308	-3.43%	-7.43%	0.57%
100 *vs.* 240	0.0116	71%			-4.61%	-8.19%	-1.03%
100 *vs.* 260	0.2424		78%	3956	-2.26%	-6.05%	1.53%
100 *vs.* ≥ 280	0.9592		95%	2031509	0.12%	-4.47%	4.71%

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
120 *vs.* 140	0.7224		94%	42479	0.45%	-2.03%	2.93%
120 *vs.* 160	0.9549		95%	942572	-0.10%	-3.57%	3.37%
120 *vs.* 180	0.3076		83%	3760	1.77%	-1.63%	5.17%
120 *vs.* 200	0.6394		92%	16329	0.91%	-2.90%	4.72%
120 *vs.* 220	0.4519		88%	5269	-1.65%	-5.95%	2.65%
120 *vs.* 240	0.1563		71%	2157	-2.83%	-6.74%	1.08%
120 *vs.* 260	0.8187		94%	83182	-0.48%	-4.59%	3.63%
120 *vs.* ≥ 280	0.4432		88%	7819	1.90%	-2.96%	6.76%

Table C.26 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
140 *vs.* 160	0.7524		94%	30255	-0.55%	-3.97%	2.87%
140 *vs.* 180	0.4398		88%	6604	1.32%	-2.03%	4.67%
140 *vs.* 200	0.8106		94%	62608	0.46%	-3.30%	4.22%
140 *vs.* 220	0.3338		84%	3191	-2.10%	-6.36%	2.16%
140 *vs.* 240	0.0966		62%	1580	-3.28%	-7.15%	0.59%
140 *vs.* 260	0.6536		93%	21843	-0.93%	-4.99%	3.13%
140 *vs.* ≥ 280	0.5555		91%	13295	1.45%	-3.37%	6.27%

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
160 *vs.* 180	0.3752		86%	3528	1.87%	-2.27%	6.01%
160 *vs.* 200	0.6581		93%	13805	1.01%	-3.47%	5.49%
160 *vs.* 220	0.5352		91%	6206	-1.55%	-6.46%	3.36%
160 *vs.* 240	0.241		78%	2393	-2.73%	-7.30%	1.84%
160 *vs.* 260	0.8748		95%	136605	-0.38%	-5.11%	4.35%
160 *vs.* ≥ 280	0.4675		89%	7198	2.00%	-3.40%	7.40%

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
180 *vs.* 200	0.703		93%	22217	-0.86%	-5.29%	3.57%
180 *vs.* 220	0.1673		72%	1476	-3.42%	-8.28%	1.44%
180 *vs.* 240	0.0459	51%			-4.60%	-9.12%	-0.08%
180 *vs.* 260	0.346		84%	4361	-2.25%	-6.93%	2.43%
180 *vs.* ≥ 280	0.962		95%	1842447	0.13%	-5.23%	5.49%

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
200 *vs.* 220	0.3295		84%	2900	-2.56%	-7.71%	2.59%
200 *vs.* 240	0.1289		67%	1568	-3.74%	-8.57%	1.09%
200 *vs.* 260	0.5845		92%	12328	-1.39%	-6.38%	3.60%
200 *vs.* ≥ 280	0.7298		94%	33550	0.99%	-4.63%	6.61%

Table C.26 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
220 *vs.* 240	0.6578		93%	16338	-1.18%	-6.41%	4.05%
220 *vs.* 260	0.6692		93%	18003	1.17%	-4.20%	6.54%
220 *vs.* ≥ 280	0.2434		79%	2675	3.55%	-2.42%	9.52%
240 *vs.* 260	0.363		85%	4992	2.35%	-2.72%	7.42%
240 *vs.* ≥ 280	0.1034		63%	1638	4.73%	-0.96%	10.42%
260 *vs.* ≥ 280	0.4232		87%	6801	2.38%	-3.45%	8.21%

Table C.27. BON Spillway STH Statistical Output for Survival Estimates for Spillway Discharge by 20 kcfs Bins and Grouped Years (2008, 2010 to 2012). Each 20 kcfs is listed individually.

Bins	2008, 2010 to 2012 for STH						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
≤ 80 *vs.* 100	0.0484	51%			2.36%	0.02%	4.70%
≤ 80 *vs.* 120	0.2419		78%	3593	1.74%	-1.18%	4.66%
≤ 80 *vs.* 140	0.019	65%			3.49%	0.57%	6.41%
≤ 80 *vs.* 160	0.6341		92%	12403	0.91%	-2.84%	4.66%
≤ 80 *vs.* 180	0.2277		77%	3045	2.18%	-1.36%	5.72%
≤ 80 *vs.* 200	0.2596		80%	2442	2.79%	-2.06%	7.64%
≤ 80 *vs.* 220	0.8488		95%	71609	-0.65%	-7.34%	6.04%
≤ 80 *vs.* 240	0.0452	52%			-3.59%	-7.10%	-0.08%
≤ 80 *vs.* 260	0.6658		93%	25659	-0.77%	-4.27%	2.73%
≤ 80 *vs.* ≥ 280	0.0526		51%	1267	4.00%	-0.04%	8.04%

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
100 *vs.* 120	0.5808		91%	27919	-0.62%	-2.82%	1.58%
100 *vs.* 140	0.3142		83%	8932	1.13%	-1.07%	3.33%
100 *vs.* 160	0.378		86%	4814	-1.45%	-4.67%	1.77%
100 *vs.* 180	0.9058		95%	441944	-0.18%	-3.16%	2.80%
100 *vs.* 200	0.85		95%	101928	0.43%	-4.03%	4.89%
100 *vs.* 220	0.3569		85%	3320	-3.01%	-9.42%	3.40%
100 *vs.* 240	0.0001	98%			-5.95%	-8.90%	-3.00%
100 *vs.* 260	0.0361	55%			-3.13%	-6.06%	-0.20%
100 *vs.* ≥ 280	0.3669		85%	7479	1.64%	-1.92%	5.20%

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
120 *vs.* 140	0.2207		77%	3645	1.75%	-1.05%	4.55%
120 *vs.* 160	0.6567		93%	14345	-0.83%	-4.49%	2.83%
120 *vs.* 180	0.8025		94%	72731	0.44%	-3.01%	3.89%
120 *vs.* 200	0.6669		93%	16888	1.05%	-3.74%	5.84%
120 *vs.* 220	0.4802		89%	5229	-2.39%	-9.03%	4.25%
120 *vs.* 240	0.0023	86%			-5.33%	-8.75%	-1.91%
120 *vs.* 260	0.1481		70%	2354	-2.51%	-5.91%	0.89%
120 *vs.* ≥ 280	0.2636		80%	3893	2.26%	-1.70%	6.22%

Table C.27 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
140 *vs.* 160	0.1673		72%	1586	-2.58%	-6.24%	1.08%
140 *vs.* 180	0.4565		88%	8597	-1.31%	-4.76%	2.14%
140 *vs.* 200	0.7742		94%	39366	-0.70%	-5.49%	4.09%
140 *vs.* 220	0.2215		77%	1782	-4.14%	-10.78%	2.50%
140 *vs.* 240	0.0001	98%			-7.08%	-10.50%	-3.66%
140 *vs.* 260	0.0142	69%			-4.26%	-7.66%	-0.86%
140 *vs.* ≥ 280	0.8008		94%	79021	0.51%	-3.45%	4.47%

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
160 *vs.* 180	0.5513		91%	8357	1.27%	-2.91%	5.45%
160 *vs.* 200	0.4896		89%	5102	1.88%	-3.46%	7.22%
160 *vs.* 220	0.6642		93%	12039	-1.56%	-8.61%	5.49%
160 *vs.* 240	0.0338	56%			-4.50%	-8.66%	-0.34%
160 *vs.* 260	0.4262		88%	5039	-1.68%	-5.82%	2.46%
160 *vs.* ≥ 280	0.1891		74%	2020	3.09%	-1.52%	7.70%

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
180 *vs.* 200	0.8177		94%	59704	0.61%	-4.58%	5.80%
180 *vs.* 220	0.4238		87%	4179	-2.83%	-9.77%	4.11%
180 *vs.* 240	0.0044	81%			-5.77%	-9.74%	-1.80%
180 *vs.* 260	0.1435		69%	2117	-2.95%	-6.90%	1.00%
180 *vs.* ≥ 280	0.4221		87%	7088	1.82%	-2.63%	6.27%

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
200 *vs.* 220	0.3804		86%	3214	-3.44%	-11.14%	4.26%
200 *vs.* 240	0.0157	68%			-6.38%	-11.55%	-1.21%
200 *vs.* 260	0.1762		73%	1812	-3.56%	-8.72%	1.60%
200 *vs.* ≥ 280	0.6687		93%	19137	1.21%	-4.34%	6.76%

Table C.27 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
220 *vs.* 240	0.4049		87%	3800	-2.94%	-9.87%	3.99%
220 *vs.* 260	0.9728		95%	2375322	-0.12%	-7.04%	6.80%
220 *vs.* ≥ 280	0.2059		76%	1816	4.65%	-2.56%	11.86%
240 *vs.* 260	0.159		71%	2238	2.82%	-1.11%	6.75%
240 *vs.* ≥ 280	0.0008	92%			7.59%	3.17%	12.01%
260 *vs.* ≥ 280	0.034	56%			4.77%	0.36%	9.18%

Table C.28. BON Spillway CH0 Statistical Output for Survival Estimates for Spillway Discharge by 20 kcfs Bins and Grouped Years (2008, 2010 to 2012). Each 20 kcfs is listed individually.

Bins	2008, 2010 to 2012 for CH0						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
≤ 80 *vs.* 100	0.051		50%	2748	-2.05%	-4.11%	0.01%
≤ 80 *vs.* 120	0.0009	91%			-3.34%	-5.31%	-1.37%
≤ 80 *vs.* 140	0	100%			-6.45%	-8.20%	-4.70%
≤ 80 *vs.* 160	0	99%			-4.24%	-6.10%	-2.38%
≤ 80 *vs.* 180	0	100%			-6.17%	-8.36%	-3.98%
≤ 80 *vs.* 200	0	100%			-6.07%	-8.39%	-3.75%
≤ 80 *vs.* 220	0	100%			-6.00%	-8.30%	-3.70%

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
100 *vs.* 120	0.158		71%	5591	-1.29%	-3.08%	0.50%
100 *vs.* 140	0	100%			-4.40%	-5.94%	-2.86%
100 *vs.* 160	0.01	73%			-2.19%	-3.86%	-0.52%
100 *vs.* 180	0.0001	98%			-4.12%	-6.15%	-2.09%
100 *vs.* 200	0.0003	95%			-4.02%	-6.19%	-1.85%
100 *vs.* 220	0.0003	95%			-3.95%	-6.10%	-1.80%

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
120 *vs.* 140	0	99%			-3.11%	-4.53%	-1.69%
120 *vs.* 160	0.2578		80%	9550	-0.90%	-2.46%	0.66%
120 *vs.* 180	0.0043	82%			-2.83%	-4.77%	-0.89%
120 *vs.* 200	0.0103	73%			-2.73%	-4.81%	-0.65%
120 *vs.* 220	0.0117	71%			-2.66%	-4.73%	-0.59%

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
140 *vs.* 160	0.0006	93%			2.21%	0.95%	3.47%
140 *vs.* 180	0.7482		94%	49704	0.28%	-1.43%	1.99%
140 *vs.* 200	0.6903		93%	27772	0.38%	-1.49%	2.25%
140 *vs.* 220	0.6337		92%	19631	0.45%	-1.40%	2.30%

Table C.28 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
160 *vs.* 180	0.0385	54%			-1.93%	-3.76%	-0.10%
160 *vs.* 200	0.0697		56%	1670	-1.83%	-3.81%	0.15%
160 *vs.* 220	0.0785		58%	1794	-1.76%	-3.72%	0.20%

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
180 *vs.* 200	0.9318		95%	397254	0.10%	-2.19%	2.39%
180 *vs.* 220	0.8836		95%	136245	0.17%	-2.11%	2.45%
200 *vs.* 220	0.9544		95%	826929	0.07%	-2.33%	2.47%

Table C.29. BON All Tailrace Egress Time for Spill Discharge by 10 kcfs Bins and Grouped Years

	2008, 2010 to 2012 for CH1						
Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
≤ 70 *vs.* 80	0.4158		87%	3166	-0.93	-3.2	1.3
≤ 70 *vs.* 90	0.1218		66%	80	0.25	-0.1	0.6
≤ 70 *vs.* 100	0.2079		76%	2120	0.22	-0.1	0.6
≤ 70 *vs.* 110	0.4075		87%	1006	0.2	-0.3	0.7
≤ 70 *vs.* 120	0.0077	76%			0.43	0.1	0.7
≤ 70 *vs.* 130	0.0044	82%			0.46	0.1	0.8
≤ 70 *vs.* 140	0.0039	83%			0.47	0.2	0.8
≤ 70 *vs.* 150	0.002	88%			0.5	0.2	0.8
≤ 70 *vs.* 160	0.0018	89%			0.51	0.2	0.8
≤ 70 *vs.* 170	0.5345		91%	1009	-0.88	-3.7	1.9
≤ 70 *vs.* 180	0.0012	91%			0.53	0.2	0.8
≤ 70 *vs.* 190	0.0464	51%			0.41	0.0	0.8
≤ 70 *vs.* 200	0.002	88%			0.51	0.2	0.8
≤ 70 *vs.* 210	0.0013	92%			0.55	0.2	0.9
≤ 70 *vs.* 220	0.5236		91%	226	-0.68	-2.8	1.5
≤ 70 *vs.* 230	0.0017	90%			0.53	0.2	0.9
≤ 70 *vs.* 240	0.0185	66%			0.43	0.1	0.8
≤ 70 *vs.* 250	0.0237	62%			0.42	0.1	0.8
≤ 70 *vs.* 260	0.001	92%			0.54	0.2	0.9
≤ 70 *vs.* 270	0.0011	91%			0.54	0.2	0.9
≤ 70 *vs.* 280	0.001	92%			0.54	0.2	0.9
≤ 70 *vs.* 290	0.0008	93%			0.57	0.2	0.9
≤ 70 *vs.* ≥ 300	0.0018	91%			0.56	0.2	0.9

Table C.29 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
80 *vs.* 90	0.2968		82%	1958	1.18	-1.0	3.4
80 *vs.* 100	0.3098		83%	2130	1.15	-1.1	3.4
80 *vs.* 110	0.324		83%	2166	1.13	-1.1	3.4
80 *vs.* 120	0.2293		78%	1474	1.36	-0.9	3.6
80 *vs.* 130	0.2192		77%	1412	1.39	-0.8	3.6
80 *vs.* 140	0.2161		77%	1393	1.4	-0.8	3.6
80 *vs.* 150	0.2062		76%	1333	1.43	-0.8	3.6
80 *vs.* 160	0.2033		75%	1317	1.44	-0.8	3.7
80 *vs.* 170	0.9778		95%	1396487	0.05	-3.5	3.6
80 *vs.* 180	0.1971		75%	1281	1.46	-0.8	3.7
80 *vs.* 190	0.2393		78%	1525	1.34	-0.9	3.6
80 *vs.* 200	0.2034		75%	1318	1.44	-0.8	3.7
80 *vs.* 210	0.1914		74%	1249	1.48	-0.7	3.7
80 *vs.* 220	0.8708		95%	45266	0.25	-2.8	3.3
80 *vs.* 230	0.1974		75%	1283	1.46	-0.8	3.7
80 *vs.* 240	0.2308		78%	1479	1.36	-0.9	3.6
0 *vs.* 250	0.2344		78%	1503	1.35	-0.9	3.6
80 *vs.* 260	0.1941		75%	1264	1.47	-0.8	3.7
80 *vs.* 270	0.1942		75%	1264	1.47	-0.8	3.7
80 *vs.* 280	0.1941		75%	1264	1.47	-0.8	3.7
80 *vs.* 290	0.1854		74%	1215	1.5	-0.7	3.7
80 *vs.* ≥ 300	0.1886		74%	1232	1.49	-0.7	3.7

Table C.29 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
90 *vs.* 100	0.6803		93%	111397	-0.03	-0.2	0.1
90 *vs.* 110	0.7826		94%	15022	-0.05	-0.4	0.3
90 *vs.* 120	0	100%			0.18	0.1	0.2
90 *vs.* 130	0	100%			0.21	0.2	0.3
90 *vs.* 140	0	100%			0.22	0.2	0.3
90 *vs.* 150	0	100%			0.25	0.2	0.3
90 *vs.* 160	0	100%			0.26	0.2	0.3
90 *vs.* 170	0.42		87%	594	-1.13	-3.9	1.6
90 *vs.* 180	0	100%			0.28	0.2	0.3
90 *vs.* 190	0.1891		74%	176	0.16	-0.1	0.4
90 *vs.* 200	0	100%			0.26	0.2	0.3
90 *vs.* 210	0	100%			0.3	0.2	0.4
90 *vs.* 220	0.3718		86%	111	-0.93	-3.0	1.1
90 *vs.* 230	0	100%			0.28	0.2	0.3
90 *vs.* 240	0.0295	59%			0.18	0.0	0.3
90 *vs.* 250	0.0657		55%	315	0.17	0.0	0.4
90 *vs.* 260	0	100%			0.29	0.2	0.3
90 *vs.* 270	0	100%			0.29	0.2	0.3
90 *vs.* 280	0	100%			0.29	0.2	0.3
90 *vs.* 290	0	100%			0.32	0.3	0.4
90 *vs.* ≥ 300	0	100%			0.31	0.2	0.4

Table C.29 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
100 *vs.* 110	0.9175		95%	337720	-0.02	-0.4	0.4
100 *vs.* 120	0.003	84%			0.21	0.1	0.3
100 *vs.* 130	0.0007	92%			0.24	0.1	0.4
100 *vs.* 140	0.0004	94%			0.25	0.1	0.4
100 *vs.* 150	0.0001	98%			0.28	0.1	0.4
100 *vs.* 160	0	99%			0.29	0.2	0.4
100 *vs.* 170	0.4327		88%	706	-1.1	-3.8	1.6
100 *vs.* 180	0	99%			0.31	0.2	0.4
100 *vs.* 190	0.1715		72%	2829	0.19	-0.1	0.5
100 *vs.* 200	0.0001	98%			0.29	0.1	0.4
100 *vs.* 210	0	99%			0.33	0.2	0.5
100 *vs.* 220	0.388		86%	239	-0.9	-2.9	1.1
100 *vs.* 230	0	99%			0.31	0.2	0.5
100 *vs.* 240	0.0483	51%			0.21	0.0	0.4
100 *vs.* 250	0.0795		58%	2668	0.2	0.0	0.4
100 *vs.* 260	0	99%			0.32	0.2	0.5
100 *vs.* 270	0	99%			0.32	0.2	0.5
100 *vs.* 280	0	99%			0.32	0.2	0.5
100 *vs.* 290	0	100%			0.35	0.2	0.5
100 *vs.* ≥ 300	0	99%			0.34	0.2	0.5

Table C.29 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
110 *vs.* 120	0.2028		75%	690	0.23	-0.1	0.6
110 *vs.* 130	0.15		70%	540	0.26	-0.1	0.6
110 *vs.* 140	0.1354		68%	501	0.27	-0.1	0.6
110 *vs.* 150	0.0963		62%	404	0.3	-0.1	0.7
110 *vs.* 160	0.0863		60%	379	0.31	0.0	0.7
110 *vs.* 170	0.4451		88%	685	-1.08	-3.9	1.7
110 *vs.* 180	0.0679		55%	335	0.33	0.0	0.7
110 *vs.* 190	0.3331		84%	902	0.21	-0.2	0.6
110 *vs.* 200	0.0883		60%	382	0.31	0.0	0.7
110 *vs.* 210	0.0549		52%	299	0.35	0.0	0.7
110 *vs.* 220	0.4057		87%	170	-0.88	-3.0	1.2
110 *vs.* 230	0.0701		56%	337	0.33	0.0	0.7
110 *vs.* 240	0.2443		79%	753	0.23	-0.2	0.6
110 *vs.* 250	0.2753		81%	914	0.22	-0.2	0.6
110 *vs.* 260	0.0603		53%	316	0.34	0.0	0.7
110 *vs.* 270	0.0616		54%	318	0.34	0.0	0.7
110 *vs.* 280	0.0604		53%	316	0.34	0.0	0.7
110 *vs.* 290	0.0425	53%			0.37	0.0	0.7
110 *vs.* ≥ 300	0.0527		51%	284	0.36	0.0	0.7

Table C.29 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
120 *vs.* 130	0.0344	56%			0.03	0.0	0.1
120 *vs.* 140	0.0049	81%			0.04	0.0	0.1
120 *vs.* 150	0	100%			0.07	0.1	0.1
120 *vs.* 160	0	100%			0.08	0.1	0.1
120 *vs.* 170	0.3502		85%	443	-1.31	-4.1	1.4
120 *vs.* 180	0	100%			0.1	0.1	0.1
120 *vs.* 190	0.8682		95%	8487	-0.02	-0.3	0.2
120 *vs.* 200	0.0004	95%			0.08	0.0	0.1
120 *vs.* 210	0	100%			0.12	0.1	0.2
120 *vs.* 220	0.2868		81%	77	-1.11	-3.2	0.9
120 *vs.* 230	0	99%			0.1	0.1	0.1
120 *vs.* 240	1		95%	65535	0	-0.2	0.2
120 *vs.* 250	0.9121		95%	80041	-0.01	-0.2	0.2
120 *vs.* 260	0	100%			0.11	0.1	0.1
120 *vs.* 270	0	100%			0.11	0.1	0.2
120 *vs.* 280	0	100%			0.11	0.1	0.1
120 *vs.* 290	0	100%			0.14	0.1	0.2
120 *vs.* ≥ 300	0.0018	88%			0.13	0.0	0.2

Table C.29 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
130 *vs.* 140	0.4799		89%	2951	0.01	0.0	0.0
130 *vs.* 150	0.0001	98%			0.04	0.0	0.1
130 *vs.* 160	0	100%			0.05	0.0	0.1
130 *vs.* 170	0.3393		84%	423	-1.34	-4.1	1.4
130 *vs.* 180	0	100%			0.07	0.1	0.1
130 *vs.* 190	0.6783		93%	1354	-0.05	-0.3	0.2
130 *vs.* 200	0.026	61%			0.05	0.0	0.1
130 *vs.* 210	0.0001	98%			0.09	0.0	0.1
130 *vs.* 220	0.2741		81%	73	-1.14	-3.2	0.9
130 *vs.* 230	0.0019	88%			0.07	0.0	0.1
130 *vs.* 240	0.7101		93%	3927	-0.03	-0.2	0.1
130 *vs.* 250	0.6589		93%	4997	-0.04	-0.2	0.1
130 *vs.* 260	0	100%			0.08	0.1	0.1
130 *vs.* 270	0.0004	95%			0.08	0.0	0.1
130 *vs.* 280	0	100%			0.08	0.1	0.1
130 *vs.* 290	0	100%			0.11	0.1	0.2
130 *vs.* ≥ 300	0.016	68%			0.1	0.0	0.2

Table C.29 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
140 *vs.* 150	0.0029	85%			0.03	0.0	0.0
140 *vs.* 160	0.0001	98%			0.04	0.0	0.1
140 *vs.* 170	0.3363		84%	419	-1.35	-4.1	1.4
140 *vs.* 180	0	100%			0.06	0.0	0.1
140 *vs.* 190	0.619		92%	919	-0.06	-0.3	0.2
140 *vs.* 200	0.0751		57%	242	0.04	0.0	0.1
140 *vs.* 210	0.0005	94%			0.08	0.0	0.1
140 *vs.* 220	0.2708		81%	72	-1.15	-3.2	0.9
140 *vs.* 230	0.008	76%			0.06	0.0	0.1
140 *vs.* 240	0.6204		92%	2156	-0.04	-0.2	0.1
140 *vs.* 250	0.5813		92%	3167	-0.05	-0.2	0.1
140 *vs.* 260	0	100%			0.07	0.0	0.1
140 *vs.* 270	0.002	88%			0.07	0.0	0.1
140 *vs.* 280	0	100%			0.07	0.0	0.1
140 *vs.* 290	0	99%			0.1	0.1	0.1
140 *vs.* ≥ 300	0.0307	58%			0.09	0.0	0.2

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
150 *vs.* 160	0	100%			0.01	0.0	0.0
150 *vs.* 170	0.325		83%	399	-1.38	-4.1	1.4
150 *vs.* 180	0	100%			0.03	0.0	0.0
150 *vs.* 190	0.4538		88%	394	-0.09	-0.3	0.1
150 *vs.* 200	0.6174		92%	2872	0.01	0.0	0.0
150 *vs.* 210	0.0129	70%			0.05	0.0	0.1
150 *vs.* 220	0.2575		80%	69	-1.18	-3.2	0.9
150 *vs.* 230	0.1346		68%	151	0.03	0.0	0.1
150 *vs.* 240	0.3822		86%	681	-0.07	-0.2	0.1
150 *vs.* 250	0.3746		86%	1218	-0.08	-0.3	0.1
150 *vs.* 260	0.0001	98%			0.04	0.0	0.1
150 *vs.* 270	0.0462	51%			0.04	0.0	0.1
150 *vs.* 280	0.0001	98%			0.04	0.0	0.1
150 *vs.* 290	0.0005	94%			0.07	0.0	0.1
150 *vs.* ≥ 300	0.1347		68%	57	0.06	0.0	0.1

Table C.29 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
160 *vs.* 170	0.3223		83%	395	-1.39	-4.2	1.4
160 *vs.* 180	0	100%			0.02	0.0	0.0
160 *vs.* 190	0.4061		87%	321	-0.1	-0.3	0.1
160 *vs.* 200	1		95%	65535	0	0.0	0.0
160 *vs.* 210	0.0474	51%			0.04	0.0	0.1
160 *vs.* 220	0.2548		80%	68	-1.19	-3.2	0.9
160 *vs.* 230	0.3189		83%	342	0.02	0.0	0.1
160 *vs.* 240	0.3187		83%	524	-0.08	-0.2	0.1
160 *vs.* 250	0.3183		83%	966	-0.09	-0.3	0.1
160 *vs.* 260	0.003	85%			0.03	0.0	0.0
160 *vs.* 270	0.135		68%	388	0.03	0.0	0.1
160 *vs.* 280	0.003	85%			0.03	0.0	0.0
160 *vs.* 290	0.0032	85%			0.06	0.0	0.1
160 *vs.* ≥ 300	0.2136		77%	82	0.05	0.0	0.1

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
170 *vs.* 180	0.3154		83%	384	1.41	-1.4	4.2
170 *vs.* 190	0.3615		85%	467	1.29	-1.5	4.1
170 *vs.* 200	0.3226		84%	396	1.39	-1.4	4.2
170 *vs.* 210	0.3103		83%	379	1.43	-1.4	4.2
170 *vs.* 220	0.9091		95%	21912	0.2	-3.3	3.7
170 *vs.* 230	0.3166		83%	388	1.41	-1.4	4.2
170 *vs.* 240	0.3522		85%	449	1.31	-1.5	4.1
170 *vs.* 250	0.3554		85%	456	1.3	-1.5	4.1
170 *vs.* 260	0.3118		83%	378	1.42	-1.3	4.2
170 *vs.* 270	0.3121		83%	379	1.42	-1.3	4.2
170 *vs.* 280	0.3119		83%	379	1.42	-1.3	4.2
170 *vs.* 290	0.3033		83%	367	1.45	-1.3	4.2
170 *vs.* ≥ 300	0.3078		83%	376	1.44	-1.4	4.2

Table C.29 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
180 *vs.* 190	0.319		83%	223	-0.12	-0.4	0.1
180 *vs.* 200	0.3185		83%	722	-0.02	-0.1	0.0
180 *vs.* 210	0.319		83%	247	0.02	0.0	0.1
180 *vs.* 220	0.2469		79%	65	-1.21	-3.3	0.8
180 *vs.* 230	1		95%	65535	0	0.0	0.0
180 *vs.* 240	0.2129		76%	336	-0.1	-0.3	0.1
180 *vs.* 250	0.2228		77%	647	-0.11	-0.3	0.1
180 *vs.* 260	0.3183		83%	1076	0.01	0.0	0.0
180 *vs.* 270	0.6176		92%	3484	0.01	0.0	0.0
180 *vs.* 280	0.3183		83%	1021	0.01	0.0	0.0
180 *vs.* 290	0.0473	51%			0.04	0.0	0.1
180 *vs.* ≥ 300	0.4546		89%	227	0.03	0.0	0.1

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
190 *vs.* 200	0.4128		87%	351	0.1	-0.1	0.3
190 *vs.* 210	0.2546		80%	173	0.14	-0.1	0.4
190 *vs.* 220	0.3046		83%	86	-1.09	-3.2	1.0
190 *vs.* 230	0.3274		84%	236	0.12	-0.1	0.4
190 *vs.* 240	0.89		95%	16550	0.02	-0.3	0.3
190 *vs.* 250	0.9469		95%	110664	0.01	-0.3	0.3
190 *vs.* 260	0.2819		81%	196	0.13	-0.1	0.4
190 *vs.* 270	0.2871		82%	211	0.13	-0.1	0.4
190 *vs.* 280	0.282		81%	196	0.13	-0.1	0.4
190 *vs.* 290	0.1931		75%	133	0.16	-0.1	0.4
190 *vs.* ≥ 300	0.2423		79%	157	0.15	-0.1	0.4

Table C.29 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
200 *vs.* 210	0.1599		71%	244	0.04	0.0	0.1
200 *vs.* 220	0.2553		80%	68	-1.19	-3.3	0.9
200 *vs.* 230	0.4807		89%	1068	0.02	0.0	0.1
200 *vs.* 240	0.3335		84%	570	-0.08	-0.2	0.1
200 *vs.* 250	0.3301		84%	1003	-0.09	-0.3	0.1
200 *vs.* 260	0.1811		73%	440	0.03	0.0	0.1
200 *vs.* 270	0.2901		82%	709	0.03	0.0	0.1
200 *vs.* 280	0.1811		73%	434	0.03	0.0	0.1
200 *vs.* 290	0.0358	56%			0.06	0.0	0.1
200 *vs.* ≥ 300	0.2661		80%	199	0.05	0.0	0.1

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
210 *vs.* 220	0.244		80%	65	-1.23	-3.3	0.9
210 *vs.* 230	0.4818		89%	597	-0.02	-0.1	0.0
210 *vs.* 240	0.1489		70%	242	-0.12	-0.3	0.0
210 *vs.* 250	0.1606		71%	471	-0.13	-0.3	0.1
210 *vs.* 260	0.6553		93%	2066	-0.01	-0.1	0.0
210 *vs.* 270	0.7242		94%	4490	-0.01	-0.1	0.0
210 *vs.* 280	0.6553		93%	2011	-0.01	-0.1	0.0
210 *vs.* 290	0.4819		89%	566	0.02	0.0	0.1
210 *vs.* ≥ 300	0.8241		94%	3117	0.01	-0.1	0.1

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
220 *vs.* 230	0.25		80%	67	1.21	-0.9	3.3
220 *vs.* 240	0.2907		82%	81	1.11	-1.0	3.2
220 *vs.* 250	0.2939		82%	85	1.1	-1.0	3.2
220 *vs.* 260	0.2427		79%	64	1.22	-0.8	3.3
220 *vs.* 270	0.2432		79%	65	1.22	-0.8	3.3
220 *vs.* 280	0.2428		79%	64	1.22	-0.8	3.3
220 *vs.* 290	0.2354		79%	63	1.25	-0.8	3.3
220 *vs.* ≥ 300	0.2447		80%	66	1.24	-0.9	3.4

Table C.29 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
230 *vs.* 240	0.2279		78%	352	-0.1	-0.3	0.1
230 *vs.* 250	0.2346		78%	661	-0.11	-0.3	0.1
230 *vs.* 260	0.6553		93%	2445	0.01	0.0	0.1
230 *vs.* 270	0.7242		94%	4867	0.01	0.0	0.1
230 *vs.* 280	0.6553		93%	2390	0.01	0.0	0.1
230 *vs.* 290	0.1612		72%	165	0.04	0.0	0.1
230 *vs.* ≥ 300	0.505		90%	387	0.03	-0.1	0.1

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
240 *vs.* 250	0.9339		95%	111887	-0.01	-0.2	0.2
240 *vs.* 260	0.174		73%	286	0.11	0.0	0.3
240 *vs.* 270	0.184		74%	306	0.11	-0.1	0.3
240 *vs.* 280	0.174		73%	286	0.11	0.0	0.3
240 *vs.* 290	0.0926		61%	179	0.14	0.0	0.3
240 *vs.* ≥ 300	0.15		70%	214	0.13	0.0	0.3

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
250 *vs.* 260	0.1863		74%	551	0.12	-0.1	0.3
250 *vs.* 270	0.1944		75%	568	0.12	-0.1	0.3
250 *vs.* 280	0.1863		74%	550	0.12	-0.1	0.3
250 *vs.* 290	0.1057		64%	355	0.15	0.0	0.3
250 *vs.* ≥ 300	0.1575		71%	412	0.14	-0.1	0.3

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
260 *vs.* 270	1		95%	65535	0	0.0	0.0
260 *vs.* 280	1		95%	65535	0	0.0	0.0
260 *vs.* 290	0.1815		74%	258	0.03	0.0	0.1
260 *vs.* ≥ 300	0.6283		92%	780	0.02	-0.1	0.1

Table C.29 (contd)

270 *vs.* 280	1		95%	65535	0	0.0	0.0
270 *vs.* 290	0.2906		82%	527	0.03	0.0	0.1
270 *vs.* ≥ 300	0.6555		93%	1388	0.02	-0.1	0.1
280 *vs.* 290	0.1815		74%	252	0.03	0.0	0.1
280 *vs.* ≥ 300	0.6284		92%	766	0.02	-0.1	0.1
290 *vs.* ≥ 300	0.8239		94%	3357	-0.01	-0.1	0.1

Table C.30. BON All Tailrace Egress Time for Spill Discharge by 10 kcfs Bins and Grouped Years for STH

	2008, 2010 to 2012 for STH						
Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
≤ 70 *vs.* 80	0.0918		61%	133	-0.16	-0.3	0.0
≤ 70 *vs.* 90	0.0949		61%	934	-0.52	-1.1	0.1
≤ 70 *vs.* 100	0.2189		77%	10517	-0.37	-1.0	0.2
≤ 70 *vs.* 110	0.2173		77%	26	0.1	-0.1	0.3
≤ 70 *vs.* 120	0.9157		95%	46446	0.01	-0.2	0.2
≤ 70 *vs.* 130	0.2264		77%	93	0.1	-0.1	0.3
≤ 70 *vs.* 140	0.0488	50%			0.16	0.0	0.3
≤ 70 *vs.* 150	0.778		94%	11620	-0.03	-0.2	0.2
≤ 70 *vs.* 160	0.0925		61%	26	0.14	0.0	0.3
≤ 70 *vs.* 170	0.2964		83%	268	-0.38	-1.1	0.3
≤ 70 *vs.* 180	0.6593		93%	2733	0.05	-0.2	0.3
≤ 70 *vs.* 190	0.7625		94%	2587	-0.06	-0.5	0.3
≤ 70 *vs.* 200	0.8592		95%	15666	-0.04	-0.5	0.4
≤ 70 *vs.* 210	0.0141	72%			0.22	0.0	0.4
≤ 70 *vs.* 220	0.0274	65%			0.23	0.0	0.4
≤ 70 *vs.* 230	0.3552		86%	124	0.1	-0.1	0.3
≤ 70 *vs.* 240	0.0332	57%			0.18	0.0	0.3
≤ 70 *vs.* 250	0.0169	67%			0.2	0.0	0.4
≤ 70 *vs.* 260	0.0412	53%			0.17	0.0	0.3
≤ 70 *vs.* 270	0.8313		95%	16011	-0.05	-0.5	0.4
≤ 70 *vs.* 280	0.0227	63%			0.19	0.0	0.4
≤ 70 *vs.* 290	0.0415	53%			0.18	0.0	0.4
≤ 70 *vs.* ≥ 300	0.063		55%	10	0.2	0.0	0.4

Table C.30 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
80 *vs.* 90	0.2371		78%	1968	-0.36	-1.0	0.2
80 *vs.* 100	0.4755		89%	32716	-0.21	-0.8	0.4
80 *vs.* 110	0	100%			0.26	0.2	0.4
80 *vs.* 120	0.0167	67%			0.17	0.0	0.3
80 *vs.* 130	0	100%			0.26	0.2	0.4
80 *vs.* 140	0	100%			0.32	0.2	0.4
80 *vs.* 150	0.1315		67%	799	0.13	0.0	0.3
80 *vs.* 160	0	100%			0.3	0.2	0.4
80 *vs.* 170	0.5345		91%	830	-0.22	-0.9	0.5
80 *vs.* 180	0.0268	60%			0.21	0.0	0.4
80 *vs.* 190	0.5931		92%	1197	0.1	-0.3	0.5
80 *vs.* 200	0.5788		91%	1921	0.12	-0.3	0.5
80 *vs.* 210	0	100%			0.38	0.3	0.5
80 *vs.* 220	0	100%			0.39	0.3	0.5
80 *vs.* 230	0.0029	85%			0.26	0.1	0.4
80 *vs.* 240	0	100%			0.34	0.2	0.4
0 *vs.* 250	0	100%			0.36	0.3	0.5
80 *vs.* 260	0	100%			0.33	0.2	0.4
80 *vs.* 270	0.6263		92%	3525	0.11	-0.3	0.6
80 *vs.* 280	0	100%			0.35	0.2	0.5
80 *vs.* 290	0	100%			0.34	0.2	0.5
80 *vs.* ≥ 300	0	100%			0.36	0.2	0.5

Table C.30 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
90 *vs.* 100	0.7193		94%	75130	0.15	-0.7	1.0
90 *vs.* 110	0.0394	54%			0.62	0.0	1.2
90 *vs.* 120	0.0819		59%	912	0.53	-0.1	1.1
90 *vs.* 130	0.0396	54%			0.62	0.0	1.2
90 *vs.* 140	0.0239	62%			0.68	0.1	1.3
90 *vs.* 150	0.1122		65%	1091	0.49	-0.1	1.1
90 *vs.* 160	0.0287	59%			0.66	0.1	1.3
90 *vs.* 170	0.7615		94%	14732	0.14	-0.8	1.0
90 *vs.* 180	0.067		55%	796	0.57	0.0	1.2
90 *vs.* 190	0.1893		74%	1233	0.46	-0.2	1.1
90 *vs.* 200	0.1906		74%	1200	0.48	-0.2	1.2
90 *vs.* 210	0.0143	69%			0.74	0.1	1.3
90 *vs.* 220	0.0133	70%			0.75	0.2	1.3
90 *vs.* 230	0.0449	52%			0.62	0.0	1.2
90 *vs.* 240	0.0204	64%			0.7	0.1	1.3
90 *vs.* 250	0.017	67%			0.72	0.1	1.3
90 *vs.* 260	0.0222	63%			0.69	0.1	1.3
90 *vs.* 270	0.2071		76%	1318	0.47	-0.3	1.2
90 *vs.* 280	0.0186	65%			0.71	0.1	1.3
90 *vs.* 290	0.0208	64%			0.7	0.1	1.3
90 *vs.* ≥ 300	0.0184	66%			0.72	0.1	1.3

Table C.30 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
100 *vs.* 110	0.1054		63%	6518	0.47	-0.1	1.0
100 *vs.* 120	0.1967		75%	10000	0.38	-0.2	1.0
100 *vs.* 130	0.106		63%	6520	0.47	-0.1	1.0
100 *vs.* 140	0.0679		55%	5126	0.53	0.0	1.1
100 *vs.* 150	0.2545		79%	12541	0.34	-0.2	0.9
100 *vs.* 160	0.0795		58%	5536	0.51	-0.1	1.1
100 *vs.* 170	0.9824		95%	14761738	-0.01	-0.9	0.9
100 *vs.* 180	0.1628		71%	8199	0.42	-0.2	1.0
100 *vs.* 190	0.3639		85%	15071	0.31	-0.4	1.0
100 *vs.* 200	0.3568		85%	13443	0.33	-0.4	1.0
100 *vs.* 210	0.0425	53%			0.59	0.0	1.2
100 *vs.* 220	0.0397	54%			0.6	0.0	1.2
100 *vs.* 230	0.1153		65%	6522	0.47	-0.1	1.1
100 *vs.* 240	0.0586		53%	4760	0.55	0.0	1.1
100 *vs.* 250	0.05		50%	4432	0.57	0.0	1.1
100 *vs.* 260	0.0633		54%	4939	0.54	0.0	1.1
100 *vs.* 270	0.3794		86%	14441	0.32	-0.4	1.0
100 *vs.* 280	0.0542		51%	4592	0.56	0.0	1.1
100 *vs.* 290	0.0594		53%	4760	0.55	0.0	1.1
100 *vs.* ≥ 300	0.0529		51%	4432	0.57	0.0	1.1

Table C.30 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
110 *vs.* 120	0.0784		58%	565	-0.09	-0.2	0.0
110 *vs.* 130	1		95%	65535	0	0.0	0.0
110 *vs.* 140	0	99%			0.06	0.0	0.1
110 *vs.* 150	0.0668		55%	614	-0.13	-0.3	0.0
110 *vs.* 160	0.075		57%	263	0.04	0.0	0.1
110 *vs.* 170	0.1724		73%	162	-0.48	-1.2	0.2
110 *vs.* 180	0.5357		91%	2691	-0.05	-0.2	0.1
110 *vs.* 190	0.3762		86%	346	-0.16	-0.5	0.2
110 *vs.* 200	0.5063		90%	1255	-0.14	-0.6	0.3
110 *vs.* 210	0	100%			0.12	0.1	0.2
110 *vs.* 220	0.0001	98%			0.13	0.1	0.2
110 *vs.* 230	1		95%	65535	0	-0.1	0.1
110 *vs.* 240	0.0005	94%			0.08	0.0	0.1
110 *vs.* 250	0	99%			0.1	0.1	0.1
110 *vs.* 260	0.002	88%			0.07	0.0	0.1
110 *vs.* 270	0.4965		90%	1759	-0.15	-0.6	0.3
110 *vs.* 280	0.0001	98%			0.09	0.0	0.1
110 *vs.* 290	0.0124	71%			0.08	0.0	0.1
110 *vs.* ≥ 300	0.0521		51%	26	0.1	0.0	0.2

Table C.30 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
120 *vs.* 130	0.0953		62%	648	0.09	0.0	0.2
120 *vs.* 140	0.0035	84%			0.15	0.0	0.3
120 *vs.* 150	0.6421		93%	9215	-0.04	-0.2	0.1
120 *vs.* 160	0.0163	67%			0.13	0.0	0.2
120 *vs.* 170	0.271		81%	272	-0.39	-1.1	0.3
120 *vs.* 180	0.6718		93%	6935	0.04	-0.1	0.2
120 *vs.* 190	0.7082		93%	2694	-0.07	-0.4	0.3
120 *vs.* 200	0.817		94%	11550	-0.05	-0.5	0.4
120 *vs.* 210	0.0001	97%			0.21	0.1	0.3
120 *vs.* 220	0.0002	96%			0.22	0.1	0.3
120 *vs.* 230	0.2965		82%	679	0.09	-0.1	0.3
120 *vs.* 240	0.0018	88%			0.17	0.1	0.3
120 *vs.* 250	0.0005	94%			0.19	0.1	0.3
120 *vs.* 260	0.0032	84%			0.16	0.1	0.3
120 *vs.* 270	0.7904		94%	12179	-0.06	-0.5	0.4
120 *vs.* 280	0.0009	92%			0.18	0.1	0.3
120 *vs.* 290	0.0039	83%			0.17	0.1	0.3
120 *vs.* ≥ 300	0.0077	76%			0.19	0.1	0.3

Table C.30 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
130 *vs.* 140	0.0076	76%			0.06	0.0	0.1
130 *vs.* 150	0.0747		57%	654	-0.13	-0.3	0.0
130 *vs.* 160	0.1582		71%	687	0.04	0.0	0.1
130 *vs.* 170	0.172		72%	164	-0.48	-1.2	0.2
130 *vs.* 180	0.5447		91%	2956	-0.05	-0.2	0.1
130 *vs.* 190	0.3778		86%	371	-0.16	-0.5	0.2
130 *vs.* 200	0.5074		90%	1284	-0.14	-0.6	0.3
130 *vs.* 210	0	99%			0.12	0.1	0.2
130 *vs.* 220	0.0004	95%			0.13	0.1	0.2
130 *vs.* 230	1		95%	65535	0	-0.1	0.1
130 *vs.* 240	0.005	80%			0.08	0.0	0.1
130 *vs.* 250	0.0005	94%			0.1	0.0	0.2
130 *vs.* 260	0.0138	69%			0.07	0.0	0.1
130 *vs.* 270	0.4976		90%	1784	-0.15	-0.6	0.3
130 *vs.* 280	0.0016	89%			0.09	0.0	0.1
130 *vs.* 290	0.0273	60%			0.08	0.0	0.2
130 *vs.* ≥ 300	0.0645		54%	94	0.1	0.0	0.2

Table C.30 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
140 *vs.* 150	0.0075	76%			-0.19	-0.3	-0.1
140 *vs.* 160	0.3719		86%	1151	-0.02	-0.1	0.0
140 *vs.* 170	0.1246		67%	127	-0.54	-1.2	0.2
140 *vs.* 180	0.1735		73%	559	-0.11	-0.3	0.0
140 *vs.* 190	0.2238		77%	184	-0.22	-0.6	0.1
140 *vs.* 200	0.3424		84%	615	-0.2	-0.6	0.2
140 *vs.* 210	0.0079	76%			0.06	0.0	0.1
140 *vs.* 220	0.0281	59%			0.07	0.0	0.1
140 *vs.* 230	0.3972		87%	319	-0.06	-0.2	0.1
140 *vs.* 240	0.3721		86%	780	0.02	0.0	0.1
140 *vs.* 250	0.0747		57%	304	0.04	0.0	0.1
140 *vs.* 260	0.655		93%	5546	0.01	0.0	0.1
140 *vs.* 270	0.3412		84%	897	-0.21	-0.6	0.2
140 *vs.* 280	0.1807		73%	648	0.03	0.0	0.1
140 *vs.* 290	0.5278		90%	1033	0.02	0.0	0.1
140 *vs.* ≥ 300	0.4338		88%	184	0.04	-0.1	0.1

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
150 *vs.* 160	0.0201	64%			0.17	0.0	0.3
150 *vs.* 170	0.3276		84%	385	-0.35	-1.1	0.4
150 *vs.* 180	0.4522		88%	2640	0.08	-0.1	0.3
150 *vs.* 190	0.8767		95%	21112	-0.03	-0.4	0.4
150 *vs.* 200	0.964		95%	346619	-0.01	-0.4	0.4
150 *vs.* 210	0.0007	93%			0.25	0.1	0.4
150 *vs.* 220	0.0007	93%			0.26	0.1	0.4
150 *vs.* 230	0.1902		74%	670	0.13	-0.1	0.3
150 *vs.* 240	0.0042	82%			0.21	0.1	0.4
150 *vs.* 250	0.0017	88%			0.23	0.1	0.4
150 *vs.* 260	0.0063	78%			0.2	0.1	0.3
150 *vs.* 270	0.931		95%	124055	-0.02	-0.5	0.4
150 *vs.* 280	0.0027	85%			0.22	0.1	0.4
150 *vs.* 290	0.0062	78%			0.21	0.1	0.4
150 *vs.* ≥ 300	0.008	76%			0.23	0.1	0.4

Table C.30 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
160 *vs.* 170	0.1403		69%	139	-0.52	-1.2	0.2
160 *vs.* 180	0.2762		81%	860	-0.09	-0.3	0.1
160 *vs.* 190	0.2714		81%	228	-0.2	-0.6	0.2
160 *vs.* 200	0.3947		87%	767	-0.18	-0.6	0.2
160 *vs.* 210	0.0055	80%			0.08	0.0	0.1
160 *vs.* 220	0.0141	70%			0.09	0.0	0.2
160 *vs.* 230	0.5837		92%	840	-0.04	-0.2	0.1
160 *vs.* 240	0.1593		71%	316	0.04	0.0	0.1
160 *vs.* 250	0.0351	56%			0.06	0.0	0.1
160 *vs.* 260	0.2899		82%	831	0.03	0.0	0.1
160 *vs.* 270	0.3907		86%	1104	-0.19	-0.6	0.2
160 *vs.* 280	0.0784		58%	311	0.05	0.0	0.1
160 *vs.* 290	0.2692		81%	380	0.04	0.0	0.1
160 *vs.* ≥ 300	0.2677		81%	136	0.06	0.0	0.2

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
170 *vs.* 180	0.2327		78%	236	0.43	-0.3	1.1
170 *vs.* 190	0.4189		88%	454	0.32	-0.5	1.1
170 *vs.* 200	0.4067		87%	536	0.34	-0.5	1.1
170 *vs.* 210	0.0924		61%	106	0.6	-0.1	1.3
170 *vs.* 220	0.0896		61%	103	0.61	-0.1	1.3
170 *vs.* 230	0.1836		74%	169	0.48	-0.2	1.2
170 *vs.* 240	0.1136		65%	120	0.56	-0.1	1.3
170 *vs.* 250	0.1002		63%	112	0.58	-0.1	1.3
170 *vs.* 260	0.1185		66%	124	0.55	-0.1	1.2
170 *vs.* 270	0.4261		88%	705	0.33	-0.5	1.1
170 *vs.* 280	0.1057		64%	116	0.57	-0.1	1.3
170 *vs.* 290	0.1151		65%	121	0.56	-0.1	1.3
170 *vs.* ≥ 300	0.108		64%	115	0.58	-0.1	1.3

Table C.30 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
180 *vs.* 190	0.5773		91%	1274	-0.11	-0.5	0.3
180 *vs.* 200	0.6892		93%	3842	-0.09	-0.5	0.4
180 *vs.* 210	0.041	53%			0.17	0.0	0.3
180 *vs.* 220	0.037	55%			0.18	0.0	0.3
180 *vs.* 230	0.6388		93%	3071	0.05	-0.2	0.3
180 *vs.* 240	0.1166		65%	405	0.13	0.0	0.3
180 *vs.* 250	0.0702		56%	311	0.15	0.0	0.3
180 *vs.* 260	0.1468		70%	490	0.12	0.0	0.3
180 *vs.* 270	0.6696		93%	4610	-0.1	-0.6	0.4
180 *vs.* 280	0.0907		61%	362	0.14	0.0	0.3
180 *vs.* 290	0.13		67%	411	0.13	0.0	0.3
180 *vs.* ≥ 300	0.1141		65%	304	0.15	0.0	0.3

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
190 *vs.* 200	0.9425		95%	83786	0.02	-0.5	0.6
190 *vs.* 210	0.128		68%	116	0.28	-0.1	0.6
190 *vs.* 220	0.1201		67%	109	0.29	-0.1	0.7
190 *vs.* 230	0.4108		87%	390	0.16	-0.2	0.5
190 *vs.* 240	0.1885		74%	157	0.24	-0.1	0.6
190 *vs.* 250	0.1533		70%	135	0.26	-0.1	0.6
190 *vs.* 260	0.2059		76%	174	0.23	-0.1	0.6
190 *vs.* 270	0.972		95%	484729	0.01	-0.6	0.6
190 *vs.* 280	0.1692		72%	148	0.25	-0.1	0.6
190 *vs.* 290	0.1927		75%	160	0.24	-0.1	0.6
190 *vs.* ≥ 300	0.1717		73%	137	0.26	-0.1	0.6

Table C.30 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
200 *vs.* 210	0.221		77%	368	0.26	-0.2	0.7
200 *vs.* 220	0.207		76%	342	0.27	-0.2	0.7
200 *vs.* 230	0.5286		91%	1315	0.14	-0.3	0.6
200 *vs.* 240	0.299		82%	513	0.22	-0.2	0.6
200 *vs.* 250	0.2568		80%	432	0.24	-0.2	0.7
200 *vs.* 260	0.3207		83%	565	0.21	-0.2	0.6
200 *vs.* 270	0.9738		95%	640870	-0.01	-0.6	0.6
200 *vs.* 280	0.2768		81%	471	0.23	-0.2	0.6
200 *vs.* 290	0.302		83%	516	0.22	-0.2	0.6
200 *vs.* ≥ 300	0.2697		81%	435	0.24	-0.2	0.7

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
210 *vs.* 220	0.7837		94%	1246	0.01	-0.1	0.1
210 *vs.* 230	0.1063		64%	78	-0.12	-0.3	0.0
210 *vs.* 240	0.1614		72%	156	-0.04	-0.1	0.0
210 *vs.* 250	0.4808		89%	1052	-0.02	-0.1	0.0
210 *vs.* 260	0.0791		58%	196	-0.05	-0.1	0.0
210 *vs.* 270	0.224		77%	547	-0.27	-0.7	0.2
210 *vs.* 280	0.2904		82%	576	-0.03	-0.1	0.0
210 *vs.* 290	0.2718		81%	221	-0.04	-0.1	0.0
210 *vs.* ≥ 300	0.7132		94%	600	-0.02	-0.1	0.1

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
220 *vs.* 230	0.0978		63%	67	-0.13	-0.3	0.0
220 *vs.* 240	0.1706		73%	94	-0.05	-0.1	0.0
220 *vs.* 250	0.4071		87%	450	-0.03	-0.1	0.0
220 *vs.* 260	0.0984		62%	132	-0.06	-0.1	0.0
220 *vs.* 270	0.21		76%	509	-0.28	-0.7	0.2
220 *vs.* 280	0.2691		81%	314	-0.04	-0.1	0.0
220 *vs.* 290	0.2449		80%	136	-0.05	-0.1	0.0
220 *vs.* ≥ 300	0.6155		93%	269	-0.03	-0.2	0.1

Table C.30 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
230 *vs.* 240	0.2751		81%	189	0.08	-0.1	0.2
230 *vs.* 250	0.1718		73%	137	0.1	0.0	0.2
230 *vs.* 260	0.3378		84%	293	0.07	-0.1	0.2
230 *vs.* 270	0.517		90%	1812	-0.15	-0.6	0.3
230 *vs.* 280	0.2181		77%	181	0.09	-0.1	0.2
230 *vs.* 290	0.2975		82%	206	0.08	-0.1	0.2
230 *vs.* ≥ 300	0.2536		80%	124	0.1	-0.1	0.3

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
240 *vs.* 250	0.4805		89%	1327	0.02	0.0	0.1
240 *vs.* 260	0.7241		94%	5997	-0.01	-0.1	0.0
240 *vs.* 270	0.2994		82%	753	-0.23	-0.7	0.2
240 *vs.* 280	0.7241		94%	6279	0.01	0.0	0.1
240 *vs.* 290	1		95%	65535	0	-0.1	0.1
240 *vs.* ≥ 300	0.7116		94%	859	0.02	-0.1	0.1

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
250 *vs.* 260	0.2899		82%	859	-0.03	-0.1	0.0
250 *vs.* 270	0.259		80%	638	-0.25	-0.7	0.2
250 *vs.* 280	0.724		94%	8006	-0.01	-0.1	0.0
250 *vs.* 290	0.5799		92%	1581	-0.02	-0.1	0.1
250 *vs.* ≥ 300	1		95%	65535	0	-0.1	0.1

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
260 *vs.* 270	0.3203		83%	824	-0.22	-0.7	0.2
260 *vs.* 280	0.4801		89%	2174	0.02	0.0	0.1
260 *vs.* 290	0.7818		94%	7011	0.01	-0.1	0.1
260 *vs.* ≥ 300	0.5784		91%	648	0.03	-0.1	0.1

Table C.30 (contd)

Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
270 *vs.* 280	0.2784		81%	693	0.24	-0.2	0.7
270 *vs.* 290	0.302		82%	756	0.23	-0.2	0.7
270 *vs.* ≥ 300	0.2703		81%	640	0.25	-0.2	0.7
280 *vs.* 290	0.7818		94%	7293	-0.01	-0.1	0.1
280 *vs.* ≥ 300	0.8529		95%	6109	0.01	-0.1	0.1
290 *vs.* ≥ 300	0.7332		94%	1130	0.02	-0.1	0.1

Table C.31. BON All Tailrace Egress Time for Spill Discharge by 10 kcfs Bins and Grouped Years for CH0

Bins	2008, 2010, 2012 for CH0						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
90 *vs.* 100	0.0018	88%			0.07	0.0	0.1
90 *vs.* 110	0	100%			0.17	0.1	0.2
90 *vs.* 120	0	100%			0.18	0.1	0.2
90 *vs.* 130	0	100%			0.2	0.1	0.3
90 *vs.* 140	0	100%			0.25	0.2	0.3
90 *vs.* 150	0.0001	97%			0.21	0.1	0.3
90 *vs.* 160	0	100%			0.28	0.2	0.3
90 *vs.* 170	0	100%			0.27	0.2	0.3
90 *vs.* 180	0.5081		90%	4867	-0.53	-2.1	1.0
90 *vs.* 190	0	100%			0.27	0.2	0.3
90 *vs.* 200	0	100%			0.31	0.3	0.4
90 *vs.* 210	0	100%			0.25	0.2	0.3
90 *vs.* 220	0	100%			0.31	0.3	0.4
90 *vs.* ≤ 80	0.2173		77%	207	-0.09	-0.2	0.1
90 *vs.* ≥ 230	0	100%			0.31	0.3	0.4

	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
100 *vs.* 110	0	100%			0.1	0.1	0.1
100 *vs.* 120	0	100%			0.11	0.1	0.1
100 *vs.* 130	0	100%			0.13	0.1	0.2
100 *vs.* 140	0	100%			0.18	0.2	0.2
100 *vs.* 150	0.0061	78%			0.14	0.0	0.2
100 *vs.* 160	0	100%			0.21	0.2	0.2
100 *vs.* 170	0	100%			0.2	0.2	0.2
100 *vs.* 180	0.4535		88%	3791	-0.6	-2.2	1.0
100 *vs.* 190	0	100%			0.2	0.2	0.2
100 *vs.* 200	0	100%			0.24	0.2	0.3
100 *vs.* 210	0	99%			0.18	0.1	0.3
100 *vs.* 220	0	100%			0.24	0.2	0.3
100 *vs.* ≤ 80	0.0239	62%			-0.16	-0.3	0.0
100 *vs.* ≥ 230	0	100%			0.24	0.2	0.3

Table C.31 (contd)

	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
110 *vs.* 120	0.4798		89%	4749	0.01	0.0	0.0
110 *vs.* 130	0.1801		73%	2411	0.03	0.0	0.1
110 *vs.* 140	0	100%			0.08	0.1	0.1
110 *vs.* 150	0.4329		88%	12971	0.04	-0.1	0.1
110 *vs.* 160	0	100%			0.11	0.1	0.1
110 *vs.* 170	0	100%			0.1	0.1	0.1
110 *vs.* 180	0.3821		86%	2791	-0.7	-2.3	0.9
110 *vs.* 190	0	99%			0.1	0.1	0.1
110 *vs.* 200	0	100%			0.14	0.1	0.2
110 *vs.* 210	0.0533		51%	271	0.08	0.0	0.2
110 *vs.* 220	0	100%			0.14	0.1	0.2
110 *vs.* ≤ 80	0.0003	96%			-0.26	-0.4	-0.1
110 *vs.* ≥ 230	0	100%			0.14	0.1	0.2

	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
120 *vs.* 130	0.3713		85%	5925	0.02	0.0	0.1
120 *vs.* 140	0	100%			0.07	0.1	0.1
120 *vs.* 150	0.5564		91%	23277	0.03	-0.1	0.1
120 *vs.* 160	0	100%			0.1	0.1	0.1
120 *vs.* 170	0	100%			0.09	0.1	0.1
120 *vs.* 180	0.3752		86%	2709	-0.71	-2.3	0.9
120 *vs.* 190	0.0001	98%			0.09	0.0	0.1
120 *vs.* 200	0	100%			0.13	0.1	0.2
120 *vs.* 210	0.0901		60%	394	0.07	0.0	0.2
120 *vs.* 220	0	100%			0.13	0.1	0.2
120 *vs.* ≤ 80	0.0002	97%			-0.27	-0.4	-0.1
120 *vs.* ≥ 230	0	100%			0.13	0.1	0.2

Table C.31 (contd)

	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
130 *vs.* 140	0.0126	70%			0.05	0.0	0.1
130 *vs.* 150	0.8527		95%	226380	0.01	-0.1	0.1
130 *vs.* 160	0.0001	98%			0.08	0.0	0.1
130 *vs.* 170	0.0005	94%			0.07	0.0	0.1
130 *vs.* 180	0.3619		85%	2564	-0.73	-2.3	0.8
130 *vs.* 190	0.0136	70%			0.07	0.0	0.1
130 *vs.* 200	0	100%			0.11	0.1	0.2
130 *vs.* 210	0.2639		80%	1448	0.05	0.0	0.1
130 *vs.* 220	0.0001	97%			0.11	0.1	0.2
130 *vs.* ≤ 80	0.0001	98%			-0.29	-0.4	-0.1
130 *vs.* ≥ 230	0.0001	97%			0.11	0.1	0.2

	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
140 *vs.* 150	0.4239		87%	12884	-0.04	-0.1	0.1
140 *vs.* 160	0	100%			0.03	0.0	0.0
140 *vs.* 170	0	100%			0.02	0.0	0.0
140 *vs.* 180	0.33		84%	2246	-0.78	-2.4	0.8
140 *vs.* 190	0.3179		83%	774	0.02	0.0	0.1
140 *vs.* 200	0	100%			0.06	0.0	0.1
140 *vs.* 210	1		95%	65535	0	-0.1	0.1
140 *vs.* 220	0.0028	85%			0.06	0.0	0.1
140 *vs.* ≤ 80	0	100%			-0.34	-0.5	-0.2
140 *vs.* ≥ 230	0.0029	85%			0.06	0.0	0.1

Table C.31 (contd)

	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
150 *vs.* 160	0.1617		71%	4206	0.07	0.0	0.2
150 *vs.* 170	0.2303		78%	5725	0.06	0.0	0.2
150 *vs.* 180	0.3561		85%	2528	-0.74	-2.3	0.8
150 *vs.* 190	0.2654		80%	5814	0.06	0.0	0.2
150 *vs.* 200	0.0501		50%	2074	0.1	0.0	0.2
150 *vs.* 210	0.5323		90%	13877	0.04	-0.1	0.2
150 *vs.* 220	0.0635		54%	2138	0.1	0.0	0.2
150 *vs.* ≤ 80	0.0005	94%			-0.3	-0.5	-0.1
150 *vs.* ≥ 230	0.0636		54%	2087	0.1	0.0	0.2

	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
160 *vs.* 170	0	100%			-0.01	0.0	0.0
160 *vs.* 180	0.3116		83%	2080	-0.81	-2.4	0.8
160 *vs.* 190	0.6172		92%	3085	-0.01	0.0	0.0
160 *vs.* 200	0.0028	85%			0.03	0.0	0.0
160 *vs.* 210	0.4535		88%	1763	-0.03	-0.1	0.0
160 *vs.* 220	0.1339		68%	846	0.03	0.0	0.1
160 *vs.* ≤ 80	0	100%			-0.37	-0.5	-0.2
160 *vs.* ≥ 230	0.134		68%	274	0.03	0.0	0.1

	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
170 *vs.* 180	0.3176		83%	2132	-0.8	-2.4	0.8
170 *vs.* 190	1		95%	65535	0	0.0	0.0
170 *vs.* 200	0.0001	98%			0.04	0.0	0.1
170 *vs.* 210	0.6172		92%	3967	-0.02	-0.1	0.1
170 *vs.* 220	0.0458	51%			0.04	0.0	0.1
170 *vs.* ≤ 80	0	100%			-0.36	-0.5	-0.2
170 *vs.* ≥ 230	0.0459	51%			0.04	0.0	0.1

Table C.31 (contd)

	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
180 *vs.* 190	0.3181		83%	2139	0.8	-0.8	2.4
180 *vs.* 200	0.2944		82%	1939	0.84	-0.7	2.4
180 *vs.* 210	0.3308		84%	2252	0.78	-0.8	2.4
180 *vs.* 220	0.2944		82%	1938	0.84	-0.7	2.4
180 *vs.* ≤ 80	0.5842		92%	7084	0.44	-1.1	2.0
180 *vs.* ≥ 230	0.2946		82%	1941	0.84	-0.7	2.4

	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
190 *vs.* 200	0.0749		57%	268	0.04	0.0	0.1
190 *vs.* 210	0.6552		93%	4767	-0.02	-0.1	0.1
190 *vs.* 220	0.1582		71%	672	0.04	0.0	0.1
190 *vs.* ≤ 80	0	100%			-0.36	-0.5	-0.2
190 *vs.* ≥ 230	0.1591		71%	350	0.04	0.0	0.1

	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
200 *vs.* 210	0.1468		70%	476	-0.06	-0.1	0.0
200 *vs.* 220	1		95%	65535	0	0.0	0.0
200 *vs.* ≤ 80	0	100%			-0.4	-0.5	-0.3
200 *vs.* ≥ 230	1		95%	65535	0	0.0	0.0

	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
210 *vs.* 220	0.1805		73%	655	0.06	0.0	0.1
210 *vs.* ≤ 80	0	99%			-0.34	-0.5	-0.2
210 *vs.* ≥ 230	0.1812		73%	513	0.06	0.0	0.1
220 *vs.* ≤ 80	0	100%			-0.4	-0.5	-0.3
220 *vs.* ≥ 230	1		95%	65535	0	-0.1	0.1
≤ 80 *vs.* ≥ 230	0	100%			0.4	0.3	0.5

Table C.32. BON All Tailrace Egress Time for Spill Discharge by 20 kcfs Bins and Grouped Years for CH1

Bins	2008, 2010 to 2012 for CH1						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
≤ 60 *vs.* 80	0.6539		93%	23889	-0.21	-1.1	0.7
≤ 60 *vs.* 100	0.2079		76%	2233	0.22	-0.1	0.6
≤ 60 *vs.* 120	0.0051	80%			0.45	0.1	0.8
≤ 60 *vs.* 140	0.0023	86%			0.49	0.2	0.8
≤ 60 *vs.* 160	0.8415		95%	28449	0.09	-0.8	1.0
≤ 60 *vs.* 180	0.0023	87%			0.5	0.2	0.8
≤ 60 *vs.* 200	0.0015	90%			0.52	0.2	0.8
≤ 60 *vs.* 220	0.3069		83%	317	0.28	-0.3	0.8
≤ 60 *vs.* 240	0.0146	69%			0.43	0.1	0.8
≤ 60 *vs.* 260	0.0009	92%			0.54	0.2	0.9
≤ 60 *vs.* 280	0.0009	92%			0.54	0.2	0.9
≤ 60 *vs.* ≥ 300	0.0018	91%			0.56	0.2	0.9

	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
80 *vs.* 100	0.3345		84%	6231	0.43	-0.4	1.3
80 *vs.* 120	0.1339		68%	2408	0.66	-0.2	1.5
80 *vs.* 140	0.1119		64%	2141	0.7	-0.2	1.6
80 *vs.* 160	0.622		92%	14158	0.3	-0.9	1.5
80 *vs.* 180	0.1073		64%	2083	0.71	-0.2	1.6
80 *vs.* 200	0.0976		62%	1970	0.73	-0.1	1.6
80 *vs.* 220	0.3195		83%	4458	0.49	-0.5	1.5
80 *vs.* 240	0.1512		70%	2580	0.64	-0.2	1.5
80 *vs.* 260	0.0887		60%	1866	0.75	-0.1	1.6
80 *vs.* 280	0.0887		60%	1866	0.75	-0.1	1.6
80 *vs.* ≥ 300	0.0818		59%	1772	0.77	-0.1	1.6

Table C.32 (contd)

	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
100 *vs.* 120	0.001	91%			0.23	0.1	0.4
100 *vs.* 140	0.0001	97%			0.27	0.1	0.4
100 *vs.* 160	0.7602		94%	19460	-0.13	-1.0	0.7
100 *vs.* 180	0.0001	97%			0.28	0.1	0.4
100 *vs.* 200	0	99%			0.3	0.2	0.4
100 *vs.* 220	0.795		94%	34707	0.06	-0.4	0.5
100 *vs.* 240	0.034	56%			0.21	0.0	0.4
100 *vs.* 260	0	99%			0.32	0.2	0.5
100 *vs.* 280	0	99%			0.32	0.2	0.5
100 *vs.* ≥ 300	0	99%			0.34	0.2	0.5

	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
120 *vs.* 140	0	100%			0.04	0.0	0.0
120 *vs.* 160	0.3917		86%	1736	-0.36	-1.2	0.5
120 *vs.* 180	0.0127	70%			0.05	0.0	0.1
120 *vs.* 200	0	100%			0.07	0.1	0.1
120 *vs.* 220	0.44		88%	713	-0.17	-0.6	0.3
120 *vs.* 240	0.7752		94%	18127	-0.02	-0.2	0.1
120 *vs.* 260	0	100%			0.09	0.1	0.1
120 *vs.* 280	0	100%			0.09	0.1	0.1
120 *vs.* ≥ 300	0.0062	78%			0.11	0.0	0.2

	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
140 *vs.* 160	0.3413		84%	1407	-0.4	-1.2	0.4
140 *vs.* 180	0.6173		92%	4538	0.01	0.0	0.0
140 *vs.* 200	0.0028	85%			0.03	0.0	0.0
140 *vs.* 220	0.3403		84%	468	-0.21	-0.6	0.2
140 *vs.* 240	0.3917		86%	2016	-0.06	-0.2	0.1
140 *vs.* 260	0	100%			0.05	0.0	0.1
140 *vs.* 280	0	100%			0.05	0.0	0.1
140 *vs.* ≥ 300	0.0808		59%	43	0.07	0.0	0.1

Table C.32 (contd)

	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
160 *vs.* 180	0.3303		84%	1346	0.41	-0.4	1.2
160 *vs.* 200	0.3069		83%	1223	0.43	-0.4	1.3
160 *vs.* 220	0.689		93%	6844	0.19	-0.7	1.1
160 *vs.* 240	0.4251		88%	2015	0.34	-0.5	1.2
160 *vs.* 260	0.2847		81%	1114	0.45	-0.4	1.3
160 *vs.* 280	0.2849		81%	1115	0.45	-0.4	1.3
160 *vs.* ≥ 300	0.2668		80%	1028	0.47	-0.4	1.3

	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
180 *vs.* 200	0.3719		86%	1380	0.02	0.0	0.1
180 *vs.* 220	0.3205		83%	438	-0.22	-0.7	0.2
180 *vs.* 240	0.337		84%	1578	-0.07	-0.2	0.1
180 *vs.* 260	0.0744		57%	406	0.04	0.0	0.1
180 *vs.* 280	0.0746		57%	368	0.04	0.0	0.1
180 *vs.* ≥ 300	0.1816		74%	184	0.06	0.0	0.1

	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
200 *vs.* 220	0.2773		81%	362	-0.24	-0.7	0.2
200 *vs.* 240	0.2041		76%	911	-0.09	-0.2	0.0
200 *vs.* 260	0.1581		71%	726	0.02	0.0	0.0
200 *vs.* 280	0.1584		71%	573	0.02	0.0	0.0
200 *vs.* ≥ 300	0.3337		84%	189	0.04	0.0	0.1

	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
220 *vs.* 240	0.5165		90%	1244	0.15	-0.3	0.6
220 *vs.* 260	0.2387		78%	309	0.26	-0.2	0.7
220 *vs.* 280	0.239		78%	309	0.26	-0.2	0.7
220 *vs.* ≥ 300	0.2148		77%	272	0.28	-0.2	0.7

Table C.32 (contd)

	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
240 *vs.* 260	0.1205		66%	617	0.11	0.0	0.2
240 *vs.* 280	0.1207		66%	612	0.11	0.0	0.2
240 *vs.* ≥ 300	0.1084		64%	445	0.13	0.0	0.3
260 *vs.* 280	1		95%	65535	0	0.0	0.0
260 *vs.* ≥ 300	0.628		92%	993	0.02	-0.1	0.1
280 *vs.* ≥ 300	0.6282		92%	841	0.02	-0.1	0.1

Table C.33. BON All Tailrace Egress Time for Spill Discharge by 20 kcfs Bins and Grouped Years for STH

60 kcfs Bins	2008, 2010 to 2012 for STH						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
≤ 60 *vs.* 80	0.0575		52%	972	-0.41	-0.8	0.0
≤ 60 *vs.* 100	0.2274		77%	11381	-0.34	-0.9	0.2
≤ 60 *vs.* 120	0.4829		89%	973	0.06	-0.1	0.2
≤ 60 *vs.* 140	0.6549		93%	3533	0.04	-0.1	0.2
≤ 60 *vs.* 160	1		95%	65535	0	-0.3	0.3
≤ 60 *vs.* 180	0.851		95%	16434	0.02	-0.2	0.2
≤ 60 *vs.* 200	0.9112		95%	47083	0.02	-0.3	0.4
≤ 60 *vs.* 220	0.2023		76%	68	0.13	-0.1	0.3
≤ 60 *vs.* 240	0.0196	65%			0.19	0.0	0.3
≤ 60 *vs.* 260	0.5852		92%	3843	0.07	-0.2	0.3
≤ 60 *vs.* 280	0.0195	65%			0.19	0.0	0.3
≤ 60 *vs.* ≥ 300	0.063		55%	10	0.2	0.0	0.4

80 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
80 *vs.* 100	0.835		95%	301625	0.07	-0.6	0.7
80 *vs.* 120	0.0203	64%			0.47	0.1	0.9
80 *vs.* 140	0.0276	60%			0.45	0.0	0.9
80 *vs.* 160	0.0672		55%	1037	0.41	0.0	0.8
80 *vs.* 180	0.0428	53%			0.43	0.0	0.8
80 *vs.* 200	0.0937		61%	982	0.43	-0.1	0.9
80 *vs.* 220	0.01	73%			0.54	0.1	1.0
80 *vs.* 240	0.0028	85%			0.6	0.2	1.0
80 *vs.* 260	0.0321	57%			0.48	0.0	0.9
80 *vs.* 280	0.0028	85%			0.6	0.2	1.0
80 *vs.* ≥ 300	0.0032	84%			0.61	0.2	1.0

Table C.33 (contd)

100 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
100 *vs.* 120	0.141		69%	8242	0.4	-0.1	0.9
100 *vs.* 140	0.164		71%	9147	0.38	-0.2	0.9
100 *vs.* 160	0.2378		78%	11475	0.34	-0.2	0.9
100 *vs.* 180	0.1969		75%	10199	0.36	-0.2	0.9
100 *vs.* 200	0.2515		79%	10291	0.36	-0.3	1.0
100 *vs.* 220	0.0894		60%	5959	0.47	-0.1	1.0
100 *vs.* 240	0.0499	50%			0.53	0.0	1.1
100 *vs.* 260	0.1546		70%	7935	0.41	-0.2	1.0
100 *vs.* 280	0.0499	50%			0.53	0.0	1.1
100 *vs.* ≥ 300	0.0494	50%			0.54	0.0	1.1

120 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
120 *vs.* 140	0.6893		93%	22072	-0.02	-0.1	0.1
120 *vs.* 160	0.5657		91%	4014	-0.06	-0.3	0.1
120 *vs.* 180	0.5996		92%	6069	-0.04	-0.2	0.1
120 *vs.* 200	0.806		94%	13559	-0.04	-0.4	0.3
120 *vs.* 220	0.2972		82%	875	0.07	-0.1	0.2
120 *vs.* 240	0	98%			0.13	0.1	0.2
120 *vs.* 260	0.9237		95%	219181	0.01	-0.2	0.2
120 *vs.* 280	0	98%			0.13	0.1	0.2
120 *vs.* ≥ 300	0.0167	67%			0.14	0.0	0.3

140 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
140 *vs.* 160	0.7105		93%	10375	-0.04	-0.3	0.2
140 *vs.* 180	0.8042		94%	29650	-0.02	-0.2	0.1
140 *vs.* 200	0.9035		95%	59622	-0.02	-0.3	0.3
140 *vs.* 220	0.2126		76%	795	0.09	-0.1	0.2
140 *vs.* 240	0.0003	95%			0.15	0.1	0.2
140 *vs.* 260	0.7807		94%	26744	0.03	-0.2	0.2
140 *vs.* 280	0.0003	95%			0.15	0.1	0.2
140 *vs.* ≥ 300	0.0128	70%			0.16	0.0	0.3

Table C.33 (contd)

160 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
160 *vs.* 180	0.87		95%	43813	0.02	-0.2	0.3
160 *vs.* 200	0.9157		95%	74006	0.02	-0.4	0.4
160 *vs.* 220	0.2665		80%	719	0.13	-0.1	0.4
160 *vs.* 240	0.0596		53%	313	0.19	0.0	0.4
160 *vs.* 260	0.6209		92%	6071	0.07	-0.2	0.3
160 *vs.* 280	0.0596		53%	313	0.19	0.0	0.4
160 *vs.* ≥ 300	0.0757		57%	285	0.2	0.0	0.4

180 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
180 *vs.* 200	1		95%	65535	0	-0.3	0.3
180 *vs.* 220	0.2343		78%	608	0.11	-0.1	0.3
180 *vs.* 240	0.0168	67%			0.17	0.0	0.3
180 *vs.* 260	0.6823		93%	9997	0.05	-0.2	0.3
180 *vs.* 280	0.0167	67%			0.17	0.0	0.3
180 *vs.* ≥ 300	0.0379	55%			0.18	0.0	0.3

200 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
200 *vs.* 220	0.521		90%	1614	0.11	-0.2	0.4
200 *vs.* 240	0.2899		82%	643	0.17	-0.1	0.5
200 *vs.* 260	0.7912		94%	14813	0.05	-0.3	0.4
200 *vs.* 280	0.2899		82%	643	0.17	-0.1	0.5
200 *vs.* ≥ 300	0.2856		82%	581	0.18	-0.2	0.5

220 kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
220 *vs.* 240	0.3251		84%	299	0.06	-0.1	0.2
220 *vs.* 260	0.6073		92%	5445	-0.06	-0.3	0.2
220 *vs.* 280	0.3251		84%	302	0.06	-0.1	0.2
220 *vs.* ≥ 300	0.3756		86%	234	0.07	-0.1	0.2

Table C.33 (contd)

kcfs Bins	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
240 *vs.* 260	0.2332		78%	1302	-0.12	-0.3	0.1
240 *vs.* 280	1		95%	65535	0	0.0	0.0
240 *vs.* ≥ 300	0.8447		95%	2914	0.01	-0.1	0.1
260 *vs.* 280	0.2331		78%	1303	0.12	-0.1	0.3
260 *vs.* ≥ 300	0.2461		79%	1115	0.13	-0.1	0.4
280 *vs.* ≥ 300	0.8447		95%	3022	0.01	-0.1	0.1

Table C.34. BON All Tailrace Egress Time for Spill Discharge by 20 kcfs Bins and Grouped Years for CH0

Bins	2008, 2010, 2012 for CH0						
	P value	Power	Type II Error	N 80% Power	Point Est	CI LB	CI UB
100 *vs.* 120	0	100%			0.11	0.1	0.2
100 *vs.* 140	0.0016	88%			0.13	0.0	0.2
100 *vs.* 160	0	100%			0.19	0.2	0.2
100 *vs.* 180	0.4873		89%	6012	-0.41	-1.6	0.7
100 *vs.* 200	0	100%			0.19	0.1	0.2
100 *vs.* ≤ 80	0.0001	98%			-0.09	-0.1	0.0
100 *vs.* ≥ 220	0	100%			0.22	0.2	0.2
120 *vs.* 140	0.6548		93%	50745	0.02	-0.1	0.1
120 *vs.* 160	0.0001	98%			0.08	0.0	0.1
120 *vs.* 180	0.3785		86%	3747	-0.52	-1.7	0.6
120 *vs.* 200	0.0047	81%			0.08	0.0	0.1
120 *vs.* ≤ 80	0	100%			-0.2	-0.3	-0.1
120 *vs.* ≥ 220	0	100%			0.11	0.1	0.2
140 *vs.* 160	0.1337		68%	4699	0.06	0.0	0.1
140 *vs.* 180	0.3613		85%	3520	-0.54	-1.7	0.6
140 *vs.* 200	0.1799		73%	4942	0.06	0.0	0.1
140 *vs.* ≤ 80	0	100%			-0.22	-0.3	-0.1
140 *vs.* ≥ 220	0.0292	59%			0.09	0.0	0.2
160 *vs.* 180	0.3093		83%	2804	-0.6	-1.8	0.6
160 *vs.* 200	1		95%	65535	0	0.0	0.0
160 *vs.* ≤ 80	0	100%			-0.28	-0.3	-0.2
160 *vs.* ≥ 220	0.0027	85%			0.03	0.0	0.0
180 *vs.* 200	0.3098		83%	2812	0.6	-0.6	1.8
180 *vs.* ≤ 80	0.588		92%	9884	0.32	-0.8	1.5
180 *vs.* ≥ 220	0.2861		81%	2548	0.63	-0.5	1.8
200 *vs.* ≤ 80	0	100%			-0.28	-0.3	-0.2
200 *vs.* ≥ 220	0.1802		73%	1243	0.03	0.0	0.1
≤ 80 *vs.* ≥ 220	0	100%			0.31	0.3	0.4

Appendix D

Bonneville Dam Operations and Passage Survival Estimates by Tailwater Elevation and Discharge

Appendix D

Bonneville Dam Operations and Passage Survival Estimates by Tailwater Elevation and Discharge

The following tables provide the survival estimates, standard errors (SEs) and sample sizes (N) for CH1, STH, and CH0 passing 1, B2, and the BON spillway relative to the tailwater elevation as described in detail in Sections 3.0, 4.0, and 5.0.

Table D.1. BON Percent Operation Time for Tailrace Elevation Bins

Bins	2010–2012		2008–2012		2008, 2010–2012	
	B1		B2		Spillway	
	Spring	Summer	Spring	Summer	Spring	Summer
	% Ops	% Ops	% Ops	% Ops	% Ops	% Ops
5 m	4.9%	8.7%	13.9%	22.6%	17.2%	19.8%
6 m	8.7%	13.8%	21.2%	16.1%	16.3%	10.3%
7 m	22.8%	37.0%	20.7%	18.5%	18.3%	32.5%
8 m	31.1%	33.6%	21.4%	33.9%	21.4%	35.4%
9 m	32.5%	6.9%	22.8%	8.9%	26.8%	2.0%

Table D.2. BON B1 Passage Survival Estimates by Tailrace Elevation Bins for Each Species-Run

	2010–2012						2010–2012		
	CH1			STH			CH0		
Bins	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
5 m	0.9868	0.0260	92	0.8605	0.0446	84	0.8939	0.0305	103
6 m	1.0052	0.0152	165	0.9480	0.0161	232	0.9811	0.0132	132
7 m	0.9643	0.0080	623	0.9392	0.0092	700	0.9604	0.0088	568
8 m	0.9635	0.0067	862	0.9462	0.0077	916	0.9517	0.0077	815
9 m	0.9652	0.0134	708	0.9318	0.0129	777	0.9483	0.0170	172
Total			2450			2709			1790

Table D.3. BON B2 Passage Survival Estimates by Tailrace Elevation Bins for Each Species-Run

	2008–2012								
	CH1			STH			CH0		
Bins	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
5 m	0.9515	0.0120	390	0.8960	0.0162	404	0.9102	0.0158	338
6 m	0.9510	0.0106	556	0.8955	0.0170	367	0.9440	0.0139	280
7 m	0.9577	0.0102	490	0.9846	0.0105	243	0.9454	0.0118	398
8 m	0.9598	0.0091	534	0.8953	0.0217	216	0.9522	0.0060	1375
9 m	0.9167	0.0222	264	0.9144	0.0322	106	0.9663	0.0104	315
Total			2234			1336			2706

Table D.4. BON Spillway Survival Estimates by Tailrace Elevation Bins for Each Species-Run

Bins	2008, 2010–2012						2008, 2010, 2012		
	CH1			STH			CH0		
	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
5 m	0.9328	0.0076	1197	0.9466	0.0086	884	0.9050	0.0094	996
6 m	0.9535	0.0070	1678	0.9538	0.0076	1380	0.9210	0.0106	683
7 m	0.9302	0.0068	1518	0.9311	0.0072	1365	0.9508	0.0046	2478
8 m	0.9351	0.0063	1886	0.9308	0.0064	1954	0.9672	0.0029	4031
9 m	0.9542	0.0094	2397	0.9534	0.0076	2490	0.9709	0.0083	410
Total			8676			8073			8598

Table D.5. BON Spillway Survival Estimates by 10 kcfs Spillway Discharge Bins for Each Species-Run

10 kcfs Bins	2008, 2010–2012						2008, 2010, 2012		
	CH1			STH			CH0		
	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
≤ 90	0.9404	0.0089	808	0.9361	0.0051	603	0.9141	0.008	1279
100	0.9330	0.0047	3279	0.9317	0.0203	2755	0.9268	0.009	873
110	0.9491	0.0167	175	0.9396	0.0138	158	0.9476	0.0102	536
120	0.9481	0.0119	356	0.9449	0.0147	333	0.9358	0.0113	495
130	0.9643	0.0151	311	0.9159	0.0171	321	0.9538	0.0072	937
140	0.9127	0.0204	193	0.9297	0.0125	269	0.9795	0.0077	457
150	0.9603	0.0091	507	0.9351	0.0233	469	0.9783	0.0045	1192
160	0.9372	0.0221	141	0.9689	0.0220	118	0.9593	0.0069	870
170	0.9685	0.0205	137	0.9390	0.0173	121	0.9539	0.0074	868
180	0.9308	0.0203	218	0.9428	0.0250	283	0.9712	0.0098	303
190	0.9365	0.0212	214	0.9411	0.0243	259	0.9900	0.0099	100
200	0.9588	0.0202	241	0.9269	0.0476	211	0.9684	0.0122	214
210	0.9165	0.0302	154	0.9995	0.0540	134	0.9845	0.0109	129
220	0.9793	0.0218	184	0.9413	0.0373	178	0.9729	0.0102	256
230	0.9515	0.0370	134	1.0006	0.0233	122	0.9775	0.0157	89
240	0.9541	0.0281	235	0.9922	0.0176	245			
250	1.0002	0.0223	286	0.9869	0.0184	273			
260	0.9553	0.0272	269	0.9463	0.0215	310			
270	0.9530	0.0257	261	0.9530	0.0182	303			
280	0.9752	0.0262	363	0.9593	0.0109	418			
≥ 290	0.8563	0.0431	209	0.8448	0.0391	190			
Total			8675			8073			8598

Table D.6. BON Spillway Percent Operation Time for 10 kcfs Spillway Discharge Bins for Each Species-Run

10 kcfs Bins	2008, 2010–2012 Spring % OPS	2008, 2010, 2012 Summer % OPS
≤ 90	9.15	30.10
100	35.71	15.08
110	2.57	6.51
120	3.66	7.50
130	4.28	10.82
140	3.90	5.56
150	10.28	8.49
160	1.38	5.27
170	2.98	6.17
180	2.69	1.63
190	2.68	0.37
200	4.52	1.03
210	1.38	0.47
220	1.32	0.79
230	0.67	0.20
240	0.98	
250	1.16	
260	1.21	
270	1.10	
280	2.72	
≥ 290	5.66	

Table D.7. BON Spillway Percent Operation Time for Spillway Discharge by 20 kcfs Bins for Each Species-Run

20 kcfs Bins	2008, 2010–2012 Spring % OPS	2008, 2010, 2012 Summer % OPS
≤ 80	9.15	30.10
100	38.28	21.59
120	7.94	18.32
140	14.17	14.05
160	4.37	11.44
180	5.37	2.01
200	5.89	1.50
220	2.00	0.99
240	2.14	
260	2.31	
≥ 280	8.37	

Appendix E

The Dalles Dam Spillway Survival Estimates by Bay and Spill Discharge

Appendix E

The Dalles Dam Spillway Survival Estimates by Bay and Spill Discharge

The following tables provide the survival estimates, standard errors (SEs) and sample sizes (N) for CH1, STH, and CH0 passing The Dalles Dam spillway during different years, by spillbay, and across groups of spillbays as described in detail in Section 6.0.

Table E.1. TDA CH1 Spillway Passage Survival Estimates by Bay for Individual Years

	2010			2011			2012		
Bay	**Estimate**	**SE**	**N**	**Estimate**	**SE**	**N**	**Estimate**	**SE**	**N**
1	0.9494	0.0247	79	0.9529	0.0153	191	0.9396	0.0155	243
2	0.9120	0.0253	125	0.9322	0.0164	236	0.9247	0.0143	343
3	0.9553	0.0201	109	0.9385	0.0154	244	0.9782	0.0078	357
4	0.9518	0.0181	143	0.9366	0.0149	268	0.9655	0.0093	397
5	0.8693	0.0273	153	0.9669	0.0108	272	0.9712	0.0079	467
6	0.9213	0.0192	200	0.9675	0.0107	277	0.9491	0.0104	448
7	0.9340	0.0171	212	0.9639	0.0107	305	0.9527	0.0095	517
8	0.9312	0.0096	694	0.9622	0.0077	608	0.9654	0.0064	848
Total			1715			2401			3620

Table E.2. TDA STH Spillway Passage Survival Estimates by Bay for Individual Years

	2010			2011			2012		
Bay	**Estimate**	**SE**	**N**	**Estimate**	**SE**	**N**	**Estimate**	**SE**	**N**
1	0.9518	0.0235	83	0.9620	0.0124	237	0.9563	0.0130	261
2	0.9586	0.0165	145	0.9517	0.0131	269	0.9598	0.0113	313
3	0.9403	0.0195	149	0.9846	0.0077	259	0.9617	0.0111	307
4	0.9726	0.0123	180	0.9815	0.0082	270	0.9802	0.0078	337
5	0.9333	0.0204	150	0.9469	0.0143	245	0.9755	0.0084	352
6	0.9461	0.016	202	0.9775	0.0084	311	0.9665	0.0084	467
7	0.9195	0.0177	236	0.9639	0.0102	332	0.9677	0.0077	545
8	0.9280	0.0101	651	0.9678	0.0063	777	0.9715	0.0047	1312
Total			1796			2700			3894

Table E.3. TDA CH0 Spillway Passage Survival Estimates by Bay for Individual Years

Bay	2010			2012		
	Estimate	**SE**	**N**	**Estimate**	**SE**	**N**
1	0.9023	0.0250	148	0.9542	0.0129	262
2	0.9316	0.0200	168	0.9590	0.0090	486
3	0.9351	0.0198	179	0.9582	0.0084	571
4	0.9059	0.0235	169	0.9647	0.0075	618
5	0.9123	0.0212	187	0.9567	0.0080	646
6	0.9134	0.0205	199	0.9532	0.0080	702
7	0.9260	0.0186	215	0.9538	0.0082	649
8	0.9120	0.0137	455	0.9469	0.0068	1106
Total			1720			5040

Table E.4. TDA Spillway Passage Survival Estimates by Bay for Combined Years for Each Species-Run

Bay	2010–2012						2010 and 2012		
	CH1			**STH**			**CH0**		
	Estimate	**SE**	**N**	**Estimate**	**SE**	**N**	**Estimate**	**SE**	**N**
1	0.9463	0.0100	513	0.9578	0.0084	581	0.9352	0.0123	410
2	0.9251	0.0100	704	0.9568	0.0076	727	0.9519	0.0084	654
3	0.9611	0.0073	710	0.9656	0.0069	715	0.9520	0.0079	750
4	0.9536	0.0075	808	0.9790	0.0052	787	0.9516	0.0078	787
5	0.9526	0.0072	892	0.9578	0.0074	747	0.9465	0.0078	833
6	0.9486	0.0073	925	0.9661	0.0059	980	0.9441	0.0077	901
7	0.9525	0.0067	1034	0.9565	0.0062	1113	0.9464	0.0077	864
8	0.9535	0.0046	2150	0.9603	0.0038	2740	0.9365	0.0062	1561
Total			7736			8390			6760

Table E.5. TDA Spillway Passage Survival Estimates by Bay Group (Inside of Spill Wall vs. Outside of Spill Wall) for Each Species-Run.

Bays	2011–2012						2012		
	CH1			**STH**			**CH0**		
	Estimate	**SE**	**N**	**Estimate**	**SE**	**N**	**Estimate**	**SE**	**N**
1–8	0.9568	0.0026	6021	0.9683	0.0022	6594	0.9549	0.0029	5040
9–23	0.9486	0.0102	487	0.9802	0.0056	666	0.9650	0.0156	141
Total			6508			7260			5181

Table E.6. TDA Spillway Passage Survival Estimates by Bay Group (Outside of Spill Wall) for Each Species-Run

	2011–2012						2012		
	CH1			STH			CH0		
Bays	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
9–12	0.9472	0.0133	304	0.9813	0.0069	435	0.9453	0.0270	72
13–23	0.9508	0.0160	183	0.9784	0.0096	231	0.9855	0.0144	69
Total			487			666			141

Table E.7. TDA Spillway Passage Survival Estimates for Spillbays 9–23 by Year for CH1 and STH

	CH1			STH		
Years	Estimate	SE	N	Estimate	SE	N
2011	0.9488	0.0111	391	0.9816	0.0058	544
2012	0.9465	0.0254	96	0.9715	0.0164	122
Total			487			666

Table E.8. TDA Spillway Passage Survival Estimates by 10 kcfs Spill Discharge Bins for Each Species-Run

	2010–2012						2010 and 2012		
	CH1			STH			CH0		
10 kcfs Bins	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
≤ 70	0.9364	0.0086	816	0.9548	0.0075	769	0.8305	0.0225	298
80	0.9448	0.0083	773	0.9485	0.0092	581	0.8933	0.0162	412
90	0.9430	0.0104	502	0.9349	0.0110	507	0.9362	0.0146	314
100	0.9439	0.0060	1488	0.9616	0.0049	1546	0.9429	0.0191	153
110	0.9542	0.0070	890	0.9583	0.0061	1071	0.9598	0.0092	466
120	0.9532	0.0067	996	0.9614	0.0057	1158	0.9505	0.0069	986
130	0.9540	0.0088	563	0.9484	0.0091	599	0.9535	0.0043	2436
140	0.9476	0.0161	191	0.9695	0.0116	224	0.9704	0.0072	562
150	0.9675	0.0097	335	0.9839	0.006	436	0.9671	0.0145	152
≥ 160	0.9634	0.0057	1181	0.9815	0.0038	1497	0.9565	0.0065	981
Total			7735			8388			6760

Appendix F

Bonneville Dam and The Dalles Dam Tailrace Egress Time

Appendix F

Bonneville Dam and The Dalles Dam Tailrace Egress Time

The following tables provide the median, mean, minimum (min), maximum (max), standard errors (SEs) and sample size (N) tailrace egress time metrics for CH1, STH, and CH0 passing B1, B2, and the BON spillway and TDA spillway during different years, treatments, and discharge volumes as described in detail in Sections 3.0–6.0.

Table F.1. BON CH1 Tailrace Egress Time by Operation Condition

2010–2012							
	Treatment	**Min**	**Max**	**Mean**	**SE**	**Median**	**N**
B1	Q1	0.27	280.27	6.40	2.10	0.46	234
	Q2	0.28	102.24	3.36	1.15	0.44	136
	Q3	0.23	110.46	2.43	0.82	0.38	189
	Q4	0.24	273.35	3.55	0.57	0.37	860
	BOR	0.24	281.36	5.90	1.67	0.37	286
	ABOP	0.21	200.41	4.23	0.70	0.30	485
	Total						2190
2008–2012							
B2	Q1	0.28	18.53	0.77	0.04	0.65	514
	Q2	0.25	15.53	0.86	0.06	0.65	350
	Q3	0.29	8.61	0.92	0.12	0.61	111
	Q4	0.25	3.41	0.65	0.03	0.55	141
	OG	0.45	5.75	1.12	0.58	0.51	9
	Total						1125

Table F.2. BON STH Tailrace Egress Time by Operation Condition

2010–2012							
	Treatment	**Min**	**Max**	**Mean**	**SE**	**Median**	**N**
B1	Q1	0.25	254.90	8.51	1.69	0.60	301
	Q2	0.25	589.93	9.84	4.57	0.57	146
	Q3	0.26	225.21	7.75	2.10	0.63	146
	Q4	0.24	419.08	17.14	1.39	0.52	1013
	BOR	0.25	404.61	23.96	3.49	0.58	282
	ABOP	0.20	415.51	15.11	2.21	0.42	476
	Total						2364
2008–2012							
B2	Q1	0.26	48.20	1.16	0.16	0.72	381
	Q2	0.22	24.13	1.16	0.14	0.71	257
	Q3	0.21	70.55	1.67	0.89	0.68	79
	Q4	0.22	5.19	0.89	0.10	0.71	57
	Total						774

Table F.3. BON CH0 Tailrace Egress Time by Operation Condition

2010 and 2012							
	Treatment	**Min**	**Max**	**Mean**	**SE**	**Median**	**N**
B1	Q1	0.29	68.26	2.17	1.45	0.46	47
	Q2	0.32	31.24	1.22	0.56	0.44	56
	Q3	0.25	44.93	1.67	0.53	0.39	116
	Q4	0.24	622.50	3.81	0.68	0.40	1148
	BOR	0.27	127.56	4.33	0.68	0.40	363
	ABOP	*	*	*	*	*	*
	Total						1730
2008–2010, 2012							
B2	Q1	0.29	6.15	0.83	0.06	0.73	111
	Q2	0.22	8.03	0.85	0.05	0.71	272
	Q3	0.21	530.52	2.82	2.01	0.67	263
	Q4	0.19	13.90	0.78	0.03	0.64	911
	Total						1557

Table F.4. BON CH1 Tailrace Egress Time by 10 kcfs Spill Discharge Bins

2008, 2010–2012						
10 kcfs Bins	**Min**	**Max**	**Mean**	**SE**	**Median**	**N**
≤ 70	0.38	3.07	0.83	0.16	0.53	18
80	0.33	306.51	1.76	1.13	0.51	271
90	0.32	5.28	0.58	0.02	0.46	418
100	0.19	157.14	0.61	0.07	0.41	2571
110	0.29	26.45	0.63	0.18	0.39	142
120	0.26	1.18	0.40	0.01	0.37	264
130	0.26	1.27	0.37	0.01	0.35	250
140	0.26	0.73	0.36	0.01	0.34	124
150	0.23	1.08	0.33	0.00	0.32	285
160	0.24	0.51	0.32	0.00	0.31	113
170	0.25	68.85	1.71	1.40	0.30	49
180	0.23	0.52	0.30	0.00	0.30	116
190	0.22	3.77	0.42	0.12	0.30	28
200	0.20	1.18	0.32	0.02	0.28	91
210	0.13	0.60	0.28	0.02	0.26	31
220	0.22	11.68	1.51	1.04	0.26	11
230	0.01	0.61	0.30	0.02	0.26	43
240	0.01	4.09	0.40	0.08	0.27	66
250	0.02	11.04	0.41	0.09	0.28	122
260	0.01	0.94	0.29	0.01	0.27	136
270	0.02	2.11	0.29	0.02	0.27	110
280	0.01	1.14	0.29	0.01	0.28	129
290	0.01	0.61	0.26	0.02	0.26	39
≥ 300	0.01	0.70	0.27	0.04	0.28	16
Total						5443

Table F.5. BON STH Tailrace Egress Time by 10 kcfs Spill Discharge Bins

2008, 2010–2012						
10 kcfs Bins	**Min**	**Max**	**Mean**	**SE**	**Median**	**N**
≤ 70	0.39	0.65	0.50	0.08	0.47	3
80	0.35	7.76	0.66	0.05	0.47	163
90	0.31	91.65	1.02	0.30	0.43	355
100	0.28	614.65	0.87	0.29	0.41	2179
110	0.29	0.95	0.40	0.01	0.38	118
120	0.27	10.18	0.49	0.05	0.36	227
130	0.26	4.97	0.40	0.02	0.35	245
140	0.25	1.05	0.34	0.01	0.32	170
150	0.23	12.13	0.53	0.07	0.31	266
160	0.25	1.78	0.36	0.02	0.31	103
170	0.22	13.22	0.88	0.35	0.31	38
180	0.11	9.45	0.45	0.08	0.30	131
190	0.22	6.35	0.56	0.18	0.29	34
200	0.05	14.68	0.54	0.21	0.29	70
210	0.19	0.53	0.28	0.02	0.25	21
220	0.19	0.38	0.27	0.03	0.23	7
230	0.10	1.81	0.40	0.07	0.31	26
240	0.11	0.98	0.32	0.02	0.28	56
250	0.01	1.32	0.30	0.02	0.29	111
260	0.02	2.15	0.33	0.02	0.29	133
270	0.03	22.94	0.55	0.22	0.31	103
280	0.01	1.73	0.31	0.02	0.29	142
290	0.03	0.70	0.32	0.03	0.29	39
≥ 300	0.01	0.53	0.30	0.05	0.33	8
Total						4748

Table F.6. BON CH0 Tailrace Egress Time by 10 kcfs Spill Discharge Bins

2008, 2010, 2012						
10 kcfs Bins	**Min**	**Max**	**Mean**	**SE**	**Median**	**N**
≤ 80	0.40	1.30	0.69	0.07	0.54	19
90	0.34	4.48	0.60	0.02	0.51	297
100	0.31	5.79	0.53	0.01	0.45	705
110	0.31	2.18	0.43	0.01	0.41	173
120	0.27	4.87	0.42	0.01	0.38	430
130	0.26	15.92	0.40	0.02	0.36	646
140	0.26	0.88	0.35	0.00	0.34	297
150	0.23	50.35	0.39	0.05	0.32	1049
160	0.23	1.02	0.32	0.00	0.31	702
170	0.23	1.07	0.33	0.00	0.30	631
180	0.22	217.95	1.13	0.80	0.30	271
190	0.23	1.34	0.33	0.02	0.28	98
200	0.21	0.82	0.29	0.01	0.28	149
210	0.21	4.13	0.35	0.04	0.28	126
220	0.19	4.40	0.29	0.02	0.26	242
≥ 230	0.19	1.06	0.29	0.02	0.25	78
Total						5913

Table F.7. TDA CH1 Tailrace Egress Time by 24 kcfs Spill Discharge Bins

2008, 2010–2012						
24 kcfs Bins	**Min**	**Max**	**Mean**	**SE**	**Median**	**N**
≤ 48	0.28	153.02	1.69	0.83	0.47	210
72	0	367.24	1.14	0.35	0.36	1233
96	0	475.07	2.14	0.69	0.27	858
120	0.01	156.4	0.9	0.34	0.21	663
144	0.1	120.33	0.49	0.26	0.16	464
≥ 168	0.11	0.44	0.16	0	0.14	227
Total						3655

Table F.8. TDA STH Tailrace Egress Time by 24 kcfs Spill Discharge Bins

2008, 2010–2012						
24 kcfs Bins	**Min**	**Max**	**Mean**	**SE**	**Median**	**N**
≤ 48	0.27	201.79	1.63	1.05	0.42	192
72	0	24.1	0.44	0.03	0.33	1060
96	0	52.84	0.43	0.08	0.25	1006
120	0	55.83	0.31	0.07	0.20	838
144	0.1	3.81	0.21	0.01	0.15	610
≥ 168	0.1	0.78	0.16	0	0.14	338
Total						4044

Table F.9. TDA CH0 Tailrace Egress Time by 24 kcfs Spill Discharge Bins

2008, 2010, 2012						
24 kcfs Bins	**Min**	**Max**	**Mean**	**SE**	**Median**	**N**
≤ 48	0.26	194.7	5.98	5.39	0.42	36
72	0.16	65.88	0.73	0.15	0.35	560
96	0.11	145.41	0.8	0.29	0.30	586
120	0.12	324.61	0.57	0.13	0.22	3436
144	0.11	324.19	0.84	0.42	0.19	870
168	0.11	449.89	1.82	0.98	0.17	648
216	0.17	324.49	18.26	12.55	0.24	36
240	0.15	0.48	0.24	0.01	0.23	84
≥ 312	0.12	0.54	0.18	0	0.16	168
Total						6424

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