FISH PASSAGE CENTER

1827 NE 44th Ave., Suite 240, Portland, OR 97213

Phone: (503) 230-4099 Fax: (503) 230-7559

http://www.fpc.org/

e-mail us at fpcstaff@fpc.org

MEMORANDUM

TO: Val Wedman, GeoSense

FROM: Michele DeHart

DATE: March 9, 2012

RE: Comparison of fish mortality via spillways and turbines

Thank you for your recent request regarding the comparison of spill versus turbine mortality imposed on juvenile salmonids at a hydroelectric project. There is a significant body of information regarding individual experiments that address salmonid survival through turbines and spillways routes of passage at various projects. This memo does not attempt to provide you with a complete annotation of those references, but the Fish Passage Center Library houses a large number of these studies and you are welcome to use that resource. The most important points to note from the collective body of this research are:

- The highest rate of mortality at a hydroproject is generally associated with turbine passage.
- Spill is considered to be the safest route of passage at a project and is used to mitigate for turbine mortality.
- The benefits of spill extend beyond the at-project improvements in survival.

Hydroelectric Project Passage

When fish approach a hydroelectric project they can either enter the powerhouse or continue migrating downstream by passing over the spillway. Upon entering the powerhouse fish either pass through a turbine unit or are mechanically collected and bypassed downstream without passing through the turbines. Reviews of studies of downstream passage for salmon at hydroelectric projects in the Columbia River basin found higher mean mortality at turbines than for spillways or bypass systems. The potential mechanisms of mortality during turbine passage may include pressure changes, cavitation, shear, turbulence, strike, or grinding (Ham et al., 2005).

Employing the use of spill for juvenile migrants has long been used as an effective management tool for improving passage survival of migrating juvenile salmon at mainstem hydroelectric projects. Routing smolts through spillways at hydroelectric projects in the Columbia and Snake rivers is generally considered to be the safest passage strategy, when compared to the passage survival through bypass systems and turbine routes. Some juvenile mortality and injury is associated with all routes of dam passage, but turbines generally cause the highest direct mortality rates—generally ranging between 8 and 19 percent. Juveniles passing through project spillways, sluiceways and other surface routes generally suffer the lowest direct mortality rates, typically losses are 2% or less (Ferguson et al. 2005, NOAA Technical Memoranda NMFS-NWFSC-64).

When considering the benefits of spill passage it is important to recognize that the benefits of spill aren't completely captured in the point estimates of at-project passage survival. The benefits of spill extend from the improvement in forebay passage all the way through the tailrace of a project, and extend to the adult life stage.

Spill and Decreases in Delay associated with Project Passage

A significant rate of juvenile mortality (approximately 3-5%) can occur in project forebays, just upstream of the dams (Axel et al. 2003; Ferguson et al. 2005; Hockersmith 2007), where fish can be substantially delayed (median of 15-20 hours) before passing through the dam (Perry et al. 2007). Hansel et al., (1999) showed that in general, yearling chinook salmon and steelhead that arrived in the forebay when no spill occurred tended to delay. Yearling chinook salmon and steelhead that arrived at night, concurrent with spill, passed the dam more readily. Residence times of yearling chinook salmon were markedly reduced with respect to daytime spill, whereas steelhead residence times decreased only slightly in the presence of daytime spill. When daytime spill went from 0 to 30% yearling chinook salmon residence time dropped from 8.5 h to 0.8 h in 1999 and 9.0 h to 2.4 h in 2000, while yearling steelhead residence time decreased from 11.4 to 11.3 h in 1999 and 11.4 to 9.4 h in 2000. Data collected in 1999 and 2000 suggest that hatchery steelhead (>200 mm) may delay in the John Day Dam forebay longer than wild steelhead (<200 mm). (NOAA, 2000).

Forebay delay increases juvenile fish exposure to fish and avian predators, and increases their exposure time to adverse water quality conditions (e.g. elevated total dissolved gas levels and high water temperatures). Spill is an effective tool in decreasing the amount of delay experienced by fish in forebays and tailraces of dams where predator populations and predation rates are highest. Beamesderfer and Rieman (1991) found that forebay populations of northern pikeminnow (*Ptychocheilus oregonensis*) and smallmouth bass (*Micropterus dolomieui*) were present in substantial numbers in the forebay of John Day Dam. Poe et al. (1991) reported that the diet of northern pikeminnow in the forebay of John Day Dam was 66% salmonid smolts. This suggests that delay of outmigrants in the forebay could reduce survival due to increased predation, and project operations such as daytime spill that decrease forebay residence time could increase survival. In addition, spill was also shown to be an important factor in reducing forebay delay in studies conducted by Snelling and Schreck (1994).

Dispersal of Predators

Spill establishes a large flow net with increased velocity that disperses predators from the forebay and tailrace areas thus reducing the potential for predator/prey interactions (Faler et al., 1988). The concept of developing spill patterns at FCRPS dams specifically for fish passage was first addressed systematically in the 1960s to facilitate adult salmon passage into the adult fish collection systems. Junge (1967) observed improved adult salmonid passage under intermediate to large spill volumes if four or five gates at each end of the spillway were at low volume settings. At large dams this resulted in a tapered spill pattern near each end and a flat spill pattern across the central portion of the spillway. At smaller dams this produced a "crowned" pattern across the entire spillway tailrace, with the highest discharge in the middle bays. The success of adult salmon passage was evaluated by comparing ladder passage counts associated with various spill patterns. The spill patterns developed that appeared best for adult passage conflict with what is thought today to be best for juvenile passage (high shoreline velocities), since Junge kept near-shore velocities low to facilitate adult migration and passage into fishway entrances located along shorelines (NOAA 2000). Smolt residence time in spillway tailraces is likely influenced by spill volume and pattern. High spill volume and water velocity push water and presumably juvenile salmonids out of the immediate tailrace, and help redistribute piscivorous predators (northern pikeminnow) away from the immediate spillway tailrace, reducing potential predation opportunities (Faler et al. 1988).

Shively et al. (1996) found that ambient river flow velocities of at least 1 m/s were necessary to keep northern pikeminnow from holding in areas near bypass outfalls, and that the degree by which water velocity eliminated northern pikeminnow holding increased as outfall distance from shore and water depth increased. Hansel et al. (1993) found that hydraulic cover such as eddies and backwaters at velocities below this threshold were preferred northern pikeminnow feeding habitats, particularly when near primary smolt outmigration paths. Spill patterns that facilitate rapid juvenile egress from the spillway stilling basin through the tailrace likely increase juvenile survival. Current spill patterns are developed to increase the survival of juvenile fish through tailraces, by emphasizing minimizing hydraulic cover and maintaining high water velocities near spillway shorelines. To not interfere with daytime adult passage, these juvenile spill patterns are often employed during nighttime hours only (COE, 1999; NOAA 2000).

Spillway Survival

Whitney et al. (1997) reviewed 13 estimates of spill mortality for salmonids (3 steelhead and 10 salmon) published through 1995 and concluded that 0 to 2% is the most likely mortality range for standard spillbays. They also pointed out that local conditions, such as back eddies or other situations that may favor the presence of predators, may lead to higher spill mortality. Some point estimates for mortality in spillbays with spill deflectors are higher than estimates for spillbays without deflectors.

A number of methodologies have been used to estimate spillway survival at lower Columbia River dams, including identification of test fish by fin clips (Holmes 1952), freeze brands (Johnsen and Dawley 1974, Raymond and Sims 1980), coded-wire tags and freeze brands

(Ledgerwood et al. 1990), balloon tags (Normandeau Associates Inc. et al. 1996a, b). At Bonneville Dam, Holmes (1952) estimated that subyearling chinook salmon survival through the spillway was 96 to 97%, depending on how the data were analyzed. Johnsen and Dawley (1974) compared the survival of subyearling chinook salmon passing through spillbays with and without flow deflectors, and found that relative survival was 87 and 96%, respectively, and that these differences were not statistically different. Ledgerwood et al. (1990) found that survival of subyearling chinook through spillbay 5 was not significantly different than for fish released downstream. Based on the balloon-tag methodology, the calculated survival probabilities for deflector and non-deflector spillways were both 1.0 at Bonneville Dam, however, fish passing through a spillbay without a spill deflector displayed a slightly higher injury rate (Normandeau et al. 1996a; NOAA 2000).

Survival to Adult Life Stage

There has been a growing body of research indicating that both freshwater and marine factors are important in determining survival to adulthood of Chinook salmon and steelhead. This is particularly true in river systems where the freshwater habitat is highly influenced by anthropogenic factors (Schaller and Petrosky 2007; Petrosky and Schaller 2010). Haeseker et al., 2012, identified spill as having measureable on survival during juvenile out-migration, andon survival during the ocean-adult period for both Chinook salmon and steelhead.

References:

Axel, G. A, E. E. Hockersmith, M. B. Eppard, B. P. Sandford, S. G. Smith, and D. B. Dey. 2003. Passage behavior and survival of hatchery yearling Chinook salmon passing Ice Harbor and McNary Dams during a low flow year, 2001. Report to the U.S. Army Corps of Engineers, Contract W68SBV92844866.

Beamesderfer, R. C., and B. E. Rieman. 1991. Abundance and distribution of northern squawfish, walleyes, and smallmouth bass in John Day Reservoir, Columbia River. Trans. Am. Fish. Soc.120:439-447.

Faler, M. P., L. Miller, and K. Welke. 1988. Effects of variation in flow on distribution of northern squawfish in the Columbia River below McNary Dam. N. Am. J. Fish. Manage. 8:30-35.

Ferguson, J.W., G.M. Matthews, R.L. McComas, R.F. Absolon, D.A. Brege, M.H. Gessel and L.G. Gilbreath. 2005. Passage of Adult and juvenile salmonids through Columbia River power system dams. U.S. Dept. of Commer., NOAA Tech Memo. NMFS-NWFSC-64, 160p.

Haeseker, S. L., J. A. McCann, J. Tuomikoski and B.Chockley, 2012. Assessing Freshwater and Marine Environmental Influences on Life-Stage-Specific Survival Rates of Snake River Spring–Summer Chinook Salmon and Steelhead, Transactions of the American Fisheries Society, 141:1, 121-138.

Ham, K. D., J. J. Anderson, J. A. Vucelick. September 2005 Effect of Multiple Turbine Passage on Juvenile Snake River Salmonid Survival. U.S. Department of Energy, Contract DE-AC05-76RL01830.

Hansel, H. C., N. S. Adams, T. D. Counihan, B. D. Liedtke, M. S. Novick, J. M. Plumb and T. P. Poe. 1999. Estimates of fish and spill passage efficiency for radio-tagged juvenile steelhead and yearling chinook salmon at John Day Dam, 1999. Annual report of research to U.S. Army Corps of Engineers, Portland District, Portland, OR. (Available from U.S. Geological Survey, Biological Resources Division, 5501A Cook-Underwood Rd., Cook, WA 98605.)

Hansel, H. C., R. S. Shively, G. S. Holmberg, T. P. King, T. L. Martinelli, and M. B. Sheer. 1993. Movements and distribution of radio-tagged northern squawfish near The Dalles and John Day dams. *In* T. Poe (editor), Significance of selective predation and development of prey protection measures for juvenile salmonids in the Columbia and Snake River reservoirs. Report to Bonneville Power Administration, Contract DE-AI79-88BP91964, 42 p. plus Appendix.

Hockersmith, E. E., G. A. Axel, D. A. Ogden, B. J. Burke, K. E. Frick, B. P. Sandford, and R. F. Absolon. 2008. Passage behavior and survival for radio-tagged yearling Chinook salmon and juvenile steelhead at Lower Monumental Dam, 2006. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Northwestern Division, Walla Walla, Washington. (Available from the Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097).

Holmes, H. B. 1952. Loss of salmon fingerlings in passing Bonneville Dam as determined by marking experiments. Unpublished manuscript, U.S. Bureau of Commercial Fisheries Report to U.S. Army Corps of Engineers, North Pacific Division, Portland, OR, 52 p. (Available from U.S. Fish and Wildlife Service, Vancouver, WA.)

Iwamoto, R. N., W. D. Muir, B. P. Sandford, K. W. McIntyre, D. A. Frost, J. G. Williams, S. G. Smith, and J. R. Skalski. 1994. Survival estimates for the passage of juvenile chinook salmon through Snake River dams and reservoirs, 1993. Report to Bonneville Power Administration, Portland, Oregon, Contract DE-AI79-93BP10891,126 p. plus Appendixes. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Johnsen, R. C., and E. M. Dawley. 1974. The effect of spillway flow deflectors at Bonneville Dam on total gas supersaturation and survival of juvenile salmon. Report to U.S. Army Corps of Engineers, Contract DACW-57-74-F-0122, 19 p. (Available from the Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Junge, C. 1967. Standardization of spill patterns at Ice Harbor Dam. Oregon Fish Commission, Report to U.S. Army Corps of Engineers, Contract DACW68-67-C0108, 24 p.

Ledgerwood, R. D., E. M. Dawley, L. G. Gilbreath, P. J. Bentley, B. P. Sandford, and M. H. Schiewe. 1990. Relative survival of subyearling chinook salmon that have passed Bonneville Dam via the spillway or the second powerhouse turbines or bypass system in 1989, with comparisons to 1987 and 1988. Report to U.S. Army Corps of Engineers, Contract E85890024/E86890097, 64 p. plus Appendixes. (Available from the Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Muir, W. D., S. G. Smith, J. G. Williams, and B. P. Sanford. 2001. Survival of juvenile salmonids passing through bypass systems, turbines, and spillways with and without flow deflectors at Snake River dams. North American Journal of Fisheries Management 21:135-146.

Muir, W. D., R. N. Iwamoto, C. R. Pasley, B. P. Sandford, P. A. Ocker, and T. E. Ruehle. 1995. Relative survival of juvenile chinook salmon after passage through spillways and the tailrace at Lower Monumental Dam, 1994. Report to U.S. Army Corps of Engineers, Contract E86940101, 28 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Muir, W. D., S. G. Smith, K. W. McIntyre, and B. P. Sandford. 1998. Project survival of juvenile salmonids passing through the bypass system, turbines, and spillways with and without flow deflectors at Little Goose Dam, 1997. Report to U.S. Army Corps of Engineers, Contract E86970085, 47 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Muir, W. D., S. G. Smith, E. E. Hockersmith, S. Achord, R. F. Absolon, P. A. Ocker, B. M. Eppard, T. E. Ruehle, J. G. Williams, R. N. Iwamoto, and J. R. Skalski. 1996. Survival estimates for the passage of yearling chinook salmon and steelhead through Snake River dams and reservoirs, 1995. Report to Bonneville Power Administration, Portland, OR, Contract DEAI79-

93BP10891, and U.S. Army Corps of Engineers, Walla Walla, WA, Project E86940119, 150 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

National Oceanic and Atmospheric Administration Northwest Fisheries Science Center. 2000. Passage of Juvenile and Adult Salmonids Past Columbia and Snake River Dams, White Paper. April 2000.

National Oceanic and Atmospheric Administration, National Marine Fisheries Service, 2000 Biological Opinion on the Federal Columbia River Power System. December 2000.

Normandeau Associates Inc., J. R. Skalski, and Mid-Columbia Consulting Inc. 1996a. Draft report on potential effects of spillway flow deflectors on fish condition and survival at the Bonneville Dam, Columbia River. Report to the U.S. Army Corps of Engineers, Contract DACW57-95- C-0086, 51 p. plus Appendixes (Available from U.S. Army Corps of Engineers, Portland, OR 97208.)

Normandeau Associates Inc., J. R. Skalski, and Mid-Columbia Consulting Inc. 1996b. Potential effects of modified spillbay configurations on fish condition and survival at The Dalles Dam, Columbia River. Report to U.S. Army Corps of Engineers, Contract DACW57-95-C-0086, 59 p. plus Appendixes (Available from U.S. Army Corps of Engineers, Portland, OR 97208.)

Perry, R.W., M.S. Novick, A.C. Braatz, T. J. Kock, A.C. Pope, D.J. Shurtleff, S.N. Lampson, R.K. Burns, N. S. Adams and D.W. Rondorf, 2007. Survival and migration behavior of juvenile salmonids at Little Goose Dam, 2005. Final report of research by the U.S. Geological Survey to the U.S. Army Corps of Engineers, Walla Walla District, Contract Number W68SBV50568470, Walla Walla, WA.

Petrosky, C. E., and H. A. Schaller. 2010. Influence of river conditions during seaward migration and ocean conditions on survival rates of Snake River Chinook salmon and steelhead. Ecology of Freshwater Fish 19:520–536.

Poe, T. P., H. C. Hansel, S. Vigg, D. E. Palmer, and L. A. Prendergast. 1991. Feeding of predaceous fishes on out-migrating juvenile salmonids in John Day Reservoir, Columbia River. Trans. Am. Fish. Soc. 120:40S-420.

Raymond, H. L., and C. W. Sims. 1980. Assessment of smolt migration and passage enhancement studies for 1979. Report to U.S. Army Corps of Engineers, 48 p. (Available from the Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Schaller, H. A., and C. E. Petrosky. 2007. Assessing hydrosystem influence on delayed mortality of Snake River stream-type Chinook salmon. North American Journal of Fisheries Management 27:810–824.

Snelling, J. C., and C. B. Schreck. 1994. Movement, Distribution, and Behavior of Juvenile Salmonids Passing through Columbia and Snake River Dams (draft). Bonneville Power Administration. 82-003. Portland.

Shively, R. S., T. P. Poe, M. B. Sheer, and R. Peters. 1996. Criteria for reducing predation by northern squawfish near juvenile salmonid bypass outfalls at Columbia River dams. Regul. Rivers Res. & Manage. 12: 493-500.

U.S. Army Corps of Engineers (COE). 1999. Fish Passage Plan for Corps of Engineers Projects. Northwestern Division, Portland, OR, 270 p. plus Appendixes. (Available from U.S. Army Corps of Engineers, Portland, OR.)

Whitney, R. R., L. Calvin, M. Erho, and C. Coutant. 1997. Downstream passage for salmon at hydroelectric projects in the Columbia River Basin: development, installation, and evaluation. U.S. Department of Energy, Northwest Power Planning Council, Portland, Oregon. Report 97-15. 101 p.

FISH PASSAGE CENTER
1827 NE 44th Ave, Suite 240, Portland, OR 97213
Phone: (503) 230-4099 Fax: (503) 230-7559
http://www.fpc.org
e-mail us at fpcstaff@fpc.org

DATA REQUEST FORM

Request Taken By: M. Filardo **Date:** 2/27/12

Data Requested By:
Name: MV Wedman **Phone:**
Address: **Fax:**
Email: wedmanfamily@gmail.com

Data Requested:
comparison of fish mortality spillway v. turbine
see attached email.

Data Format: Hardcopy ☐ Text ☑ Excel ☐

Delivery: Mail ☐ Email ☑ Fax ☐ Phone ☐

Comments:

Data Compiled By: M. Filardo **Date:** 3/9/12

Request # 15

G:\STAFF\DOCUMENT\FORMS\Templates\data request form template.doc

Margaret Filardo

From: Petrosky,Charlie <charlie.petrosky@idfg.idaho.gov>
Sent: Monday, February 27, 2012 7:01 AM
To: MVWedman
Cc: Michele Dehart; Margaret Filardo
Subject: RE: fish mortality on spillways

Val,
I am directing your inquiry to the Fish Passage Center in Portland, Oregon (copied on email). They should be able to direct you to a large volume of literature on spillway vs. turbine passage, and any technical memos that synthesize these studies. Hope this helps.

Charlie Petrosky
ESA Anadromous Coordinator
Idaho Department of Fish and Game
P.O. Box 25, 600 S. Walnut St.
Bosie, ID 83707
208-334-3791
charlie.petrosky@idfg.idaho.gov

-----Original Message-----
From: MVWedman [mailto:wedmanfamily@gmail.com]
Sent: Monday, February 27, 2012 6:50 AM
To: Petrosky,Charlie
Subject: fish mortality on spillways

Good Morning,

I was given your name by Dmitri Vidergar. I am an intern for a company who acts as an agent for dam construction/retrofitting. We are looking to make a comparison on fish mortality over spillways vs. through turbines. Do you have any information that might help in this regard, or do you know of someone you could direct me to? Any information you might have would be greatly appreciated.

Thank you,
Val Wedman
GeoSense