Baker Hydroelectric Project Imminent Flood Reservoir Drawdown

Why Drawing Down the Reservoirs In Advance of a Skagit Basin Flood Reduces Flood Risk, Improves Salmon Survival, and Increases Power Generation

Chal A. Martin, P.E.
Public Works Director
City of Burlington

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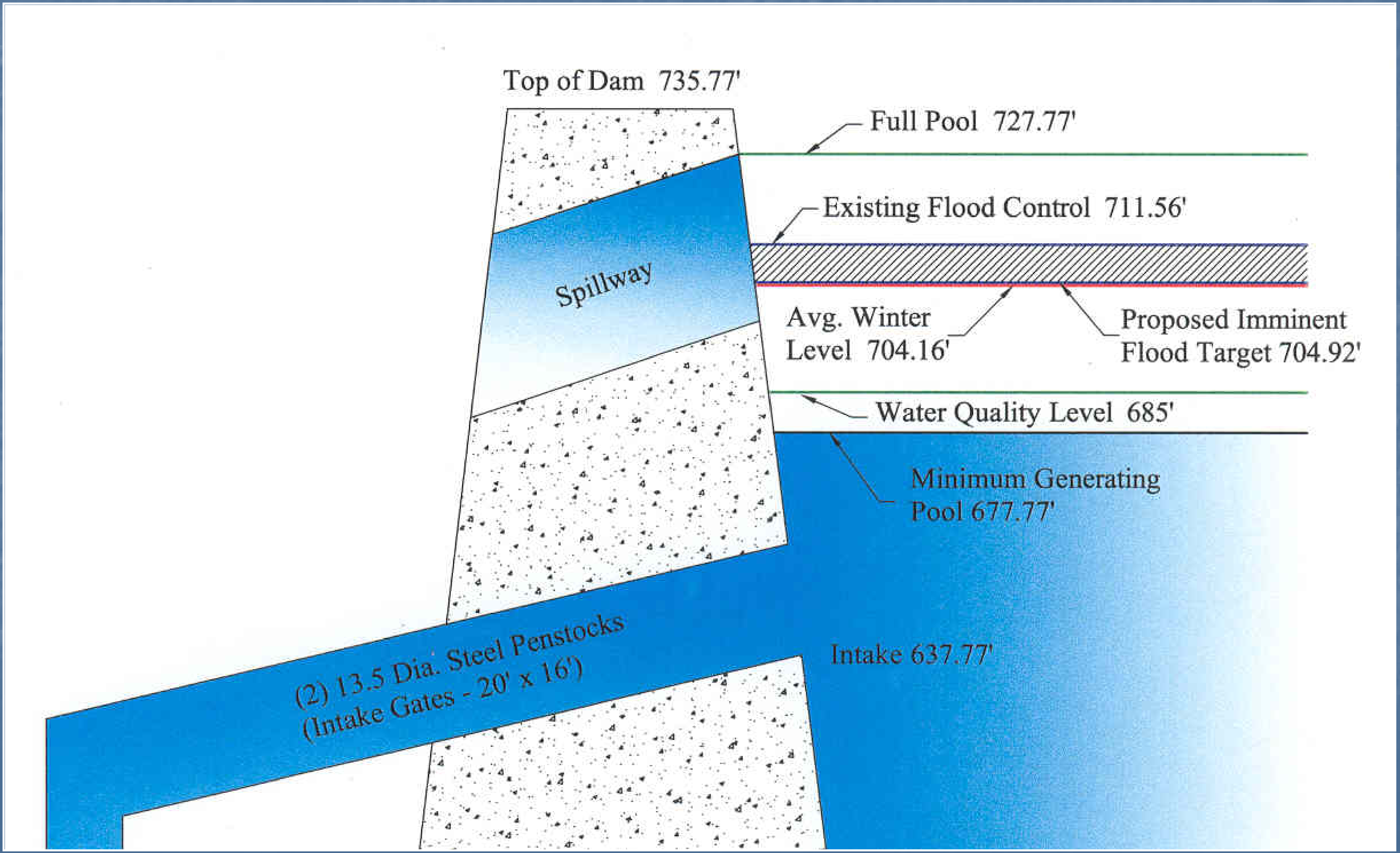
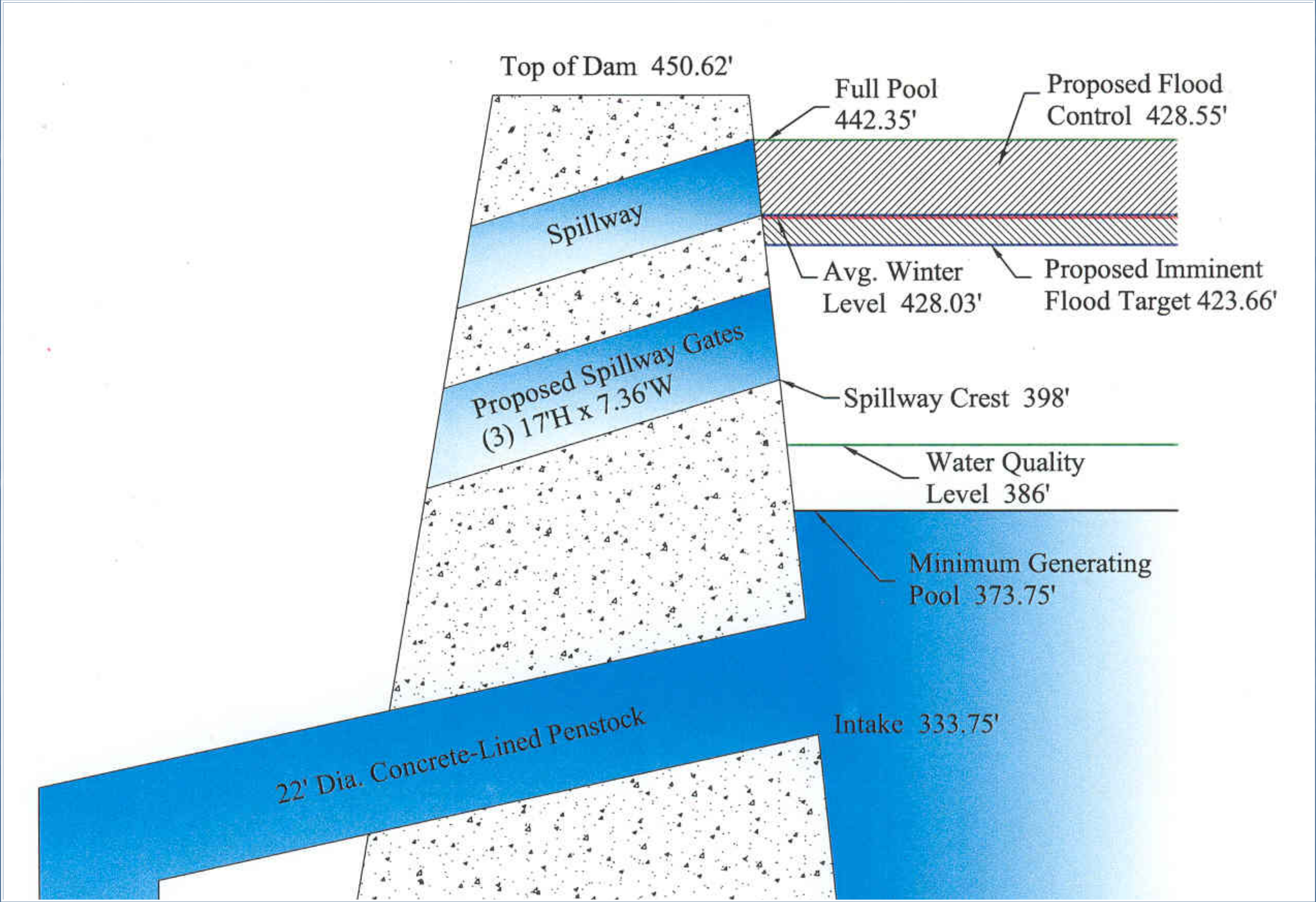
Goals of Advance Reservoir Drawdown in the Baker System

- Achieve <u>zero outflow</u> from Baker System during 24 hours of Skagit Flood Peak
- Reduce 100-year flood peak by 13,000 – 18,000 cfs (about 1.5 feet of Skagit River depth)
- Storage needed: 140,000 acre-feet
  - Same as "reservoir target elevations" outlined in license (see reservoir schematics following)

Upper Baker Dam



Lower Baker Dam



How will advance drawdown work?

- Long range forecast indicates flood-producing storm is 5-7 days out
- Skagit County consults with emergency managers and Baker Aquatic Resource Group
  - Review reservoir levels, seriousness of possible storm, salmon spawning activity
  - Most times, precedent conditions will not immediately indicate drawdown is necessary
  - Initial decision to increase outflow can be changed based on updated forecast
  - Review and adapt outflow every 12-24 hours

How often and how long?

- How often:
  - 2-3 times per decade
- How long:
  - 5 days
  - Total of maybe 15 days per decade

Maximum Baker Outflow Necessary to Achieve Reservoir Target Elevations in Advance of a Skagit Flood

Date	Storage IPP* (acre-ft)	Storage SAA 106 Aquatics 1 (acre-ft)	Storage Aquatics 1 Plus 1/2 Buffer** (acre-ft)	Outflow SAA 106 Aquatics 1 (cfs)	Outflow Average 5-Day Outflow Needed at Baker To Achieve 140,000 AF*** (cfs)	Outflow Exceeding SAA 106 Aquatics 1 (cfs)	Corresponding Skagit Rise
1-Oct	115,000	0	13,000	3,200	15,000	11,800	14 inches
15-Oct	115,000	25,000	38,000	3,200	12,500	9,300	11 inches
1-Nov	115,000	50,000	63,000	3,600	10,000	6,400	8 inches
15-Nov	115,000	74,000	87,000	3,600	7,600	3,000	4 inches
1-Dec	no req't	74,000	87,000	3,600	7,600	3,000	4 inches
15-Dec	no req't	74,000	87,000	3,600	7,600	3,000	4 inches
1-Jan	no req't	74,000	87,000	5,600	7,600	2,000	2 inches

Notes:

1) Storage needed to capture Baker basin inflow for Skagit 100-year event is 140,000 AF (297 square miles)
2) Storage needed to capture Ross basin inflow for Skagit 100-year event is 150,000 AF (999 square miles)
3) Even though the Projects' flood control rule curves do not require maximum hard storage until late November, large Skagit floods occur in October. The Skagit flood of record occurred Oct 14-22, 2003
4) Downstream communities' flood control goal is to reduce Projects' outflow to zero 12 hours before/after Skagit flood peak at Concrete (see Skagit Project water control manual, page 7-8)

* IPP (Interim Protection Plan) will sunset in 2013

**Approximate storage represented by 1/2 of the Upper Baker operating buffer is 13,000 Acre-Feet

***Assumes average basin inflow during the imminent flood drawdown period is 2,300 cfs

Puget Sound Salmon Recovery Plan, Skagit Annex, p. 182

The greatest impact on egg-to-fry survival is flooding during egg incubation. Severe floods (15-20 year events) reduce survival by 75-80% when compared to 1 year flooding events. Ten year events reduce survival by 33%. In the Skagit, flood events are increasing in frequency and magnitude, which has serious impacts on survival. Flood events are especially severe in the Lower Skagit where the full brunt of a flood must be absorbed.

The Promise of Advance Reservoir Drawdown for Increased Fish Survival

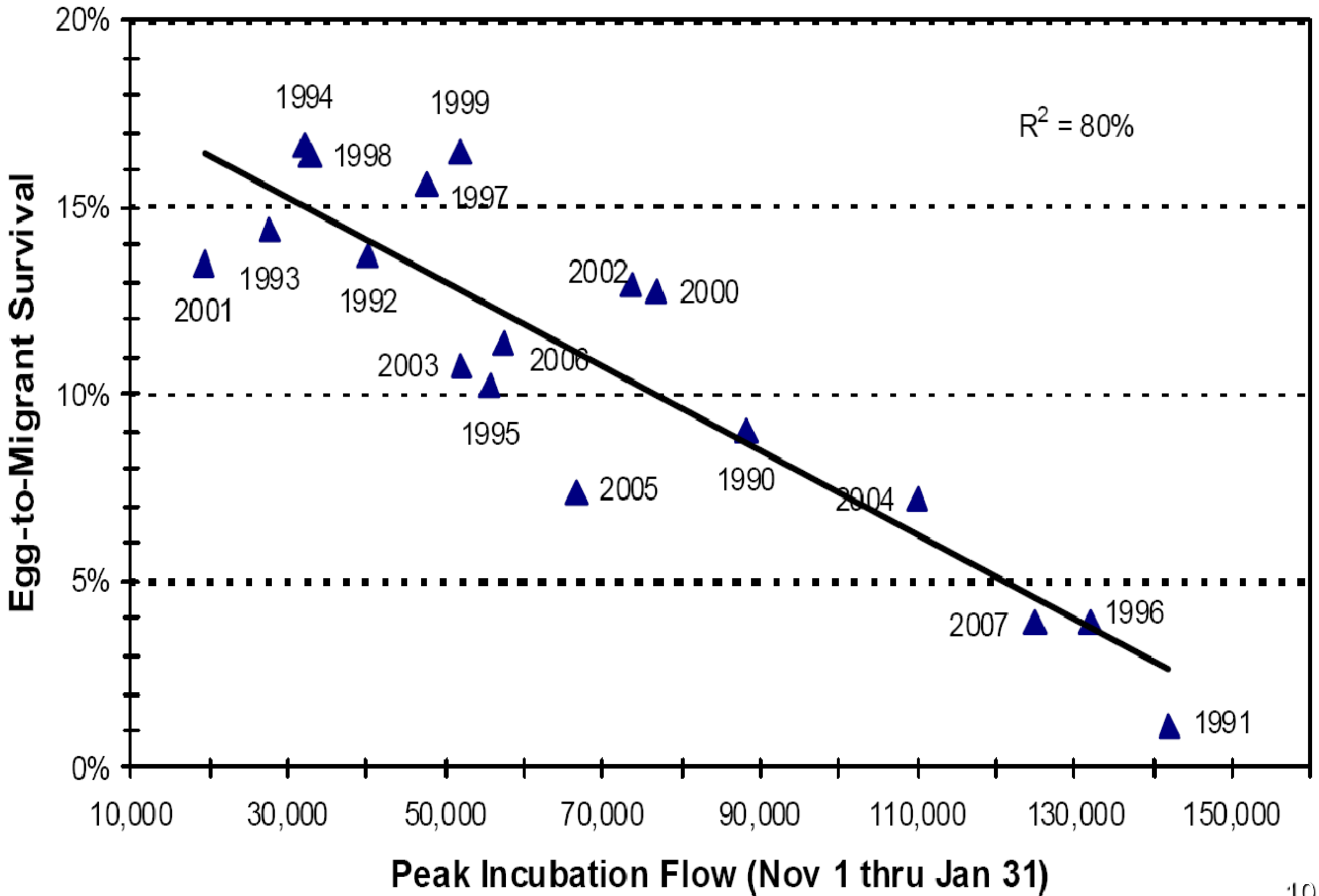
On the front side of the flood, advance reservoir drawdown has a minor negative impact on spawning fish:

- Higher artificial water level may fool fish into spawning in areas that may later be dewatered
- Therefore, dessiccation of redds will be higher during the 5 days of advance drawdown (example assumes 100% mortality, although actual mortality would be expected to be much less)
- Spawning periods are about 60 days

On the back side of the flood, reservoir drawdown has a major positive impact on spawning fish:

- Reduced peak flow dislodges fewer redds, significantly increasing egg-to-migrant survival

Egg-to-Migrant Survival (Kinsel et al, 2008)



How Egg-to-Migrant Survival Increases with Imminent Flood Drawdown Protocol

For this example:

- 1,200 spawning females*
- 5,500 eggs per female**
- Spawning period is 60 days***
- At peak Skagit 24-hour flow of 135,000 cfs, egg-to-migrant survival is 3.5%****
- At peak Skagit 24-hour flow of 120,000 cfs, egg-to-migrant survival is 5.0%****

*Email communication with Wendy Cole and Brett Barkdull, WDFW, 7 November 2011, 2:34 p.m.

**2007 Skagit River Annual Salmon Production Evaluation, Annual Report., Table 14, page 28. Washington Department of Fish and Wildlife, December 2008 .

***Puget Sound Salmon Recovery Plan. Shared Strategy for Puget Sound. Figure 2.4, page 42. January 19, 2007.

**** 2007 Skagit River Annual Salmon Production Evaluation, Annual Report. Figure 13, page 44. Washington Department of Fish and Wildlife, December 2008 .

How Egg-to-Migrant Survival Increases with Imminent Flood Drawdown Protocol

Condition with <u>no</u> advance drawdown:

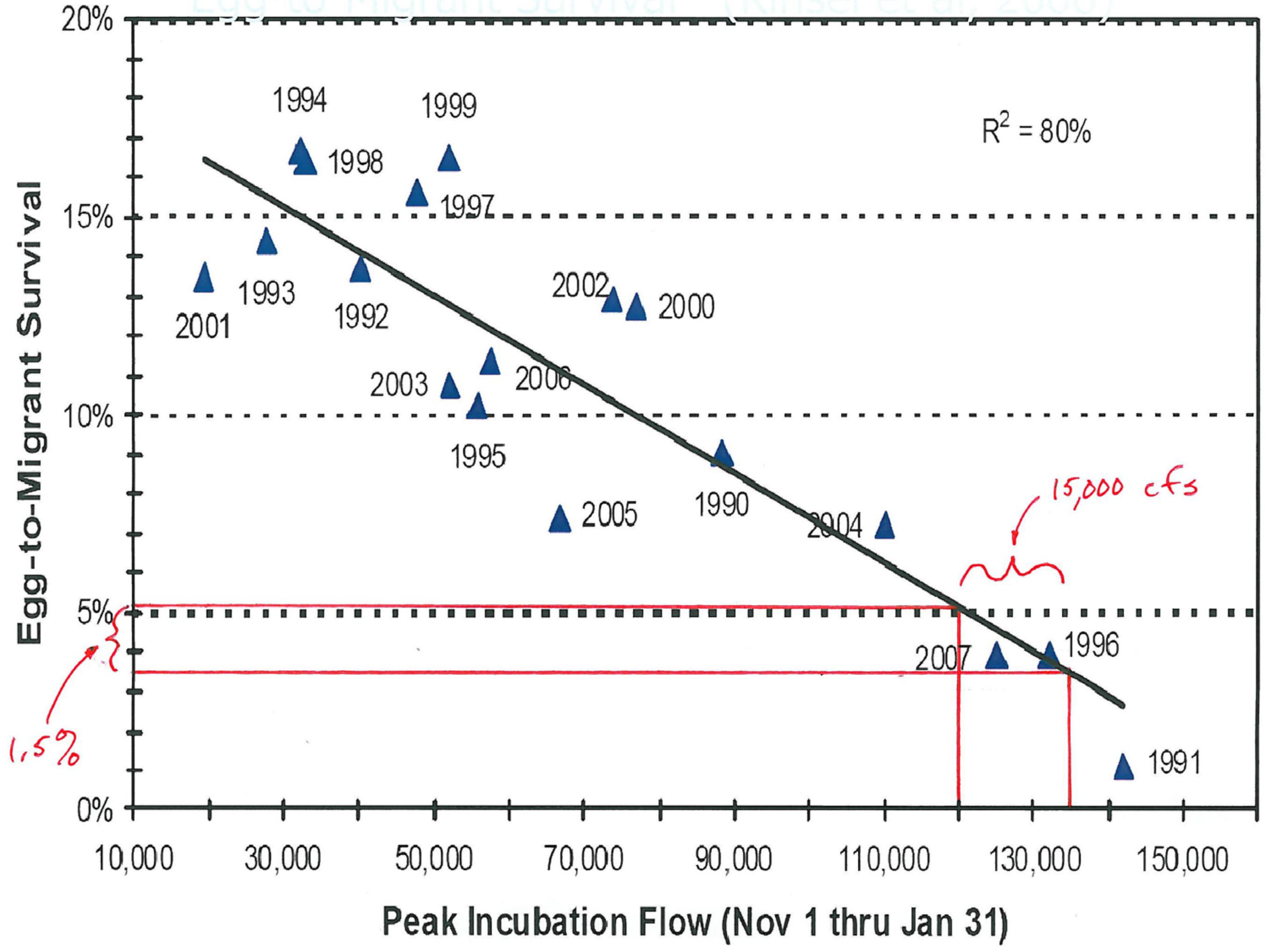
- 1,200 spawning females at 5,500 eggs/female = 6,600,000 eggs
- Baker reservoirs are filled, so system passes inflow of 15,000 cfs at Skagit flood peak
- With peak 1-day flow of 135,000 cfs, egg-to-migrant survival = 3.5%, resulting in (.035)(6,600,000) = 231,000 outmigrants

Condition <u>with</u> advance drawdown:

- 6,600,000 eggs reduced by 5 spawning days over a 60-day spawning period, (55/60)(6,600,000) = 6,050,000 eggs (assuming 5 days continuous drawdown)
- Baker reservoirs have enough capacity to absorb all Baker inflow for 24 hours surrounding the Skagit flood peak, resulting in 15,000 cfs reduction in Skagit peak one-day flow
- In this case, egg-to-migrant survival is increased to 5% (based on 15,000 cfs peak flow reduction), resulting in (.05)(6,050,000) = 302,500 outmigrants

Result: Increase of 71,500 outmigrants

- 31% increase



20%
15%
10%
5%
0%
Egg-to-Migrant Survival
R^2 = 80%
1994
1999
1998
1997
1993
1992
2001
2002
2000
2003
2006
1995
1990
2005
2004
2007
1996
1991
15,000 cfs
1.5%
10,000
30,000
50,000
70,000
90,000
110,000
130,000
150,000
Peak Incubation Flow (Nov 1 thru Jan 31)

Power Generation is Improved*

- POWER = (Density of Water) X (Height) X (Flow Rate) X (Gravity Constant) X (Efficiency)
- If, for Lower Baker Dam only, imminent flood drawdown protocols enable an average reservoir elevation 10 feet higher, then power generation could increase by 3.9%**

*Estimate for Lower Baker only. Similar power increases may be possible for Upper Baker.

**Assume average LB reservoir elevation increases to 438 feet from 428 feet. Hydraulic head increases from 258' to 268' (438'-170'(powerhouse elevation)), or 81.68 meters from 78.63 meters. Full pool elevation of LB is 442.35' NAVD.

Questions / Discussion

Further Discussion / Background / Issues

1. Research assumes one-day flows, not peak flows. Therefore, to be effective, the shutdown would need to be for 24 hours.
   - Answer: Yes
2. Is 140,000 acre-feet enough to absorb 24 hours of Baker inflow?
   - Will depend. However, this is what was agreed to in the relicensing negotiations
3. Example assumes 13,000 – 18,000 cfs savings, but that is for a 100-year event and the Kinsel chart only goes to 1-day flows of 162,000 cfs
   - Answer:
     1. 1) COE 1-day, 100-year regulated flow = 178,000 cfs at Concrete*
     2. 2) COE 1-day, 50-year regulated flow = 153,000 cfs at Concrete*
     3. 3) PI Engineering 1 day, 100-year regulated flow = 151,000 cfs at Concrete**
     4. 4) PI Engineering 1 day, 50-year regulated flow = 133,000 cfs at Concrete**
     5. Baker hydrology is independent of Skagit basin hydrology. 140,000 cfs still needed in "smaller" Skagit events (i.e., 50-year floods) to ensure Baker can be shut down for 24 hours, due to variability in main storm energy, even in smaller-than-100-year Skagit flood
4. Answer above begs question: would it be appropriate for Puget to always operate system to shut down outflow in the 24 hours, even for relatively small Skagit flood event?
   - Answer: we believe the science indicates Yes.
5. "Flood events are natural processes that also form and maintain rearing habitats important to salmon capacity and productivity. Actions that seek to eliminate flood events only would likely also have adverse impacts to juvenile rearing life stages of salmon."***
   - Answer: there may be methods to analyze this assertion. We are skeptical that peak flow reduction in the range discussed would reduce habitat-forming processes to the point that the positive benefit of increased egg-to-migrant survival would be supplanted by the negative impact of "not as much" habitat-forming process.

*COE Hydrology Summary, 1 May 2008, Table 22. Regulated peak flows reduced by 1.179

**PI Engineering Hydrology Summary, October 2008, Table 9

***Beamer, et al., "Linking Watershed Conditions to Egg-to-Fry Survival of Skagit Chinook Salmon, An Appendix to the Skagit River System Cooperative Chinook Recovery Plan." Draft Version 2.0, November 2005, p. 6.

Puget Sound Salmon Recovery Plan, Figure 2.9, p. 49.

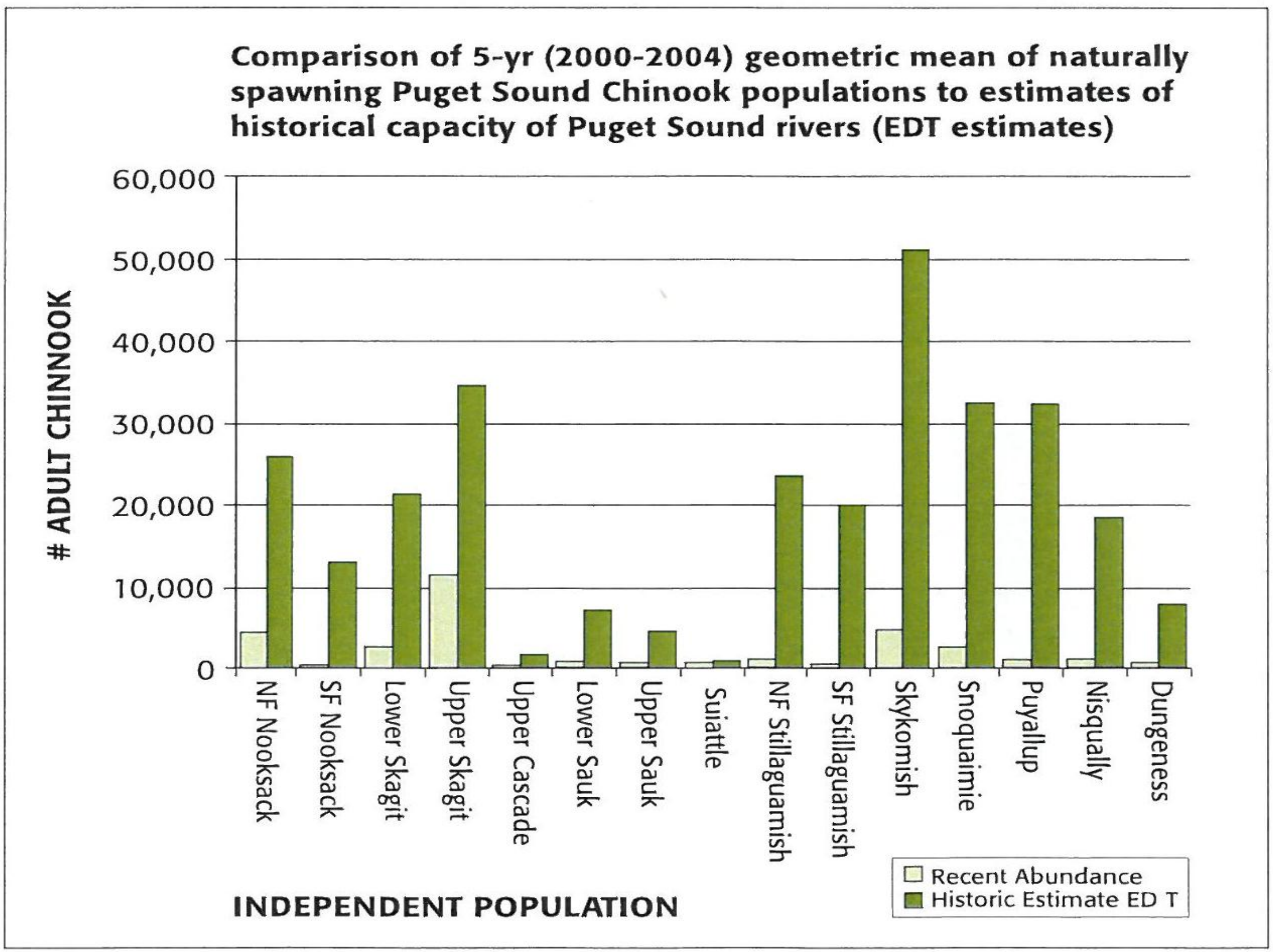


Figure 2.9 is a sampling of historical estimates for the 15 Puget Sound chinook populations for which EDT analysis was available.

Puget Sound Salmon Recovery Plan, Figure 2.8, p. 48.

	1986-1990			1994-1998			2000-2004	
Populations	Geometric Mean	% Hatchery Contribution	Productivity	Geometric Mean	% Hatchery Contribution	Productivity	Geometric Mean	% Hatchery Contribution
North + Middle Fork Nooksack	140	21%	1.29	263	67%	0.45	4,232	94%
South Fork Nooksack	243	7%	0.60	181	35%	1.20	303	46%
Lower Skagit	2,732	1%	0.59	974	1%	3.15	2,597	2%
Upper Skagit	8,020	2%	0.69	6,388	1%	1.60	12,116	4%
Upper Cascade	226	0%	0.88	241	0%	1.34	355	1%
Lower Sauk	888	0%	0.61	330	0%	2.35	825	0%
Upper Sauk	720	0%	0.57	245	0%	1.35	413	0%
Suiattle	687	0%	0.40	365	0%	1.20	409	0%
North Fork Stillaguamish	699	0%	0.92	862	35%	0.94	1,176	31%
South Fork Stillaguamish	257	0%	1.31	246	0%	1.22	205	0%
Skykomish	3,204	14%	0.52	3,172	52%	0.82	4,759	39%
Snoqualmie	907	12%	1.23	1,012	33%	1.68	2,446	14%
Sammamish	388	41%	0.28	145	74%	2.72	243	69%
Cedar	733	9%	0.51	391	17%	0.97	412	21%
Green/Duwamish	7,966	62%	0.50	7,060	71%	1.00	13,172	34%
White	73	56%	7.51	452	82%	1.49	1,417	28%
Puyallup	1,509	15%	1.86	1,657	40%	0.67	1,353	31%
Nisqually	602	3%	4.22	753	21%	1.38	1,295	25%
Skokomish	1,630	69%	0.48	866	69%	0.34	1,479	80%
Mid Hood Canal	87	26%	1.41	182	26%	1.31	202	46%
Dungeness	185	83%	0.12	101	83%	0.70	532	83%
Elwha Nat Spawners	2,055	34%	0.46	512	61%	1.03	847	54%
Elwha Nat+Hat Spawners	3,887	34%	0.67	1,679	61%	1.27	2,384	54%

Table Notes: Data from TRT A&P Tables 4/15/05.
No estimates of productivity are included for 2000-2004 period, since returns from those spawning (brood) years are not complete. The1986-1990 period represents the first 5 year period for which escapement data is available for all populations. The 1994-1998 period is the 5 years prior to listing (in March 1999). The 2000-2004 period is the last 5 years for which we have escapement data (most recent 5 years).

Figure 2.8 Geometric mean (5 yr periods) of natural spawning abundance, % hatchery contribution to natural spawners, and productivity (return spawners from parent spawners) for Puget Sound Chinook populations.

Puget Sound Salmon Recovery Plan, Figure 2.4, p. 42.

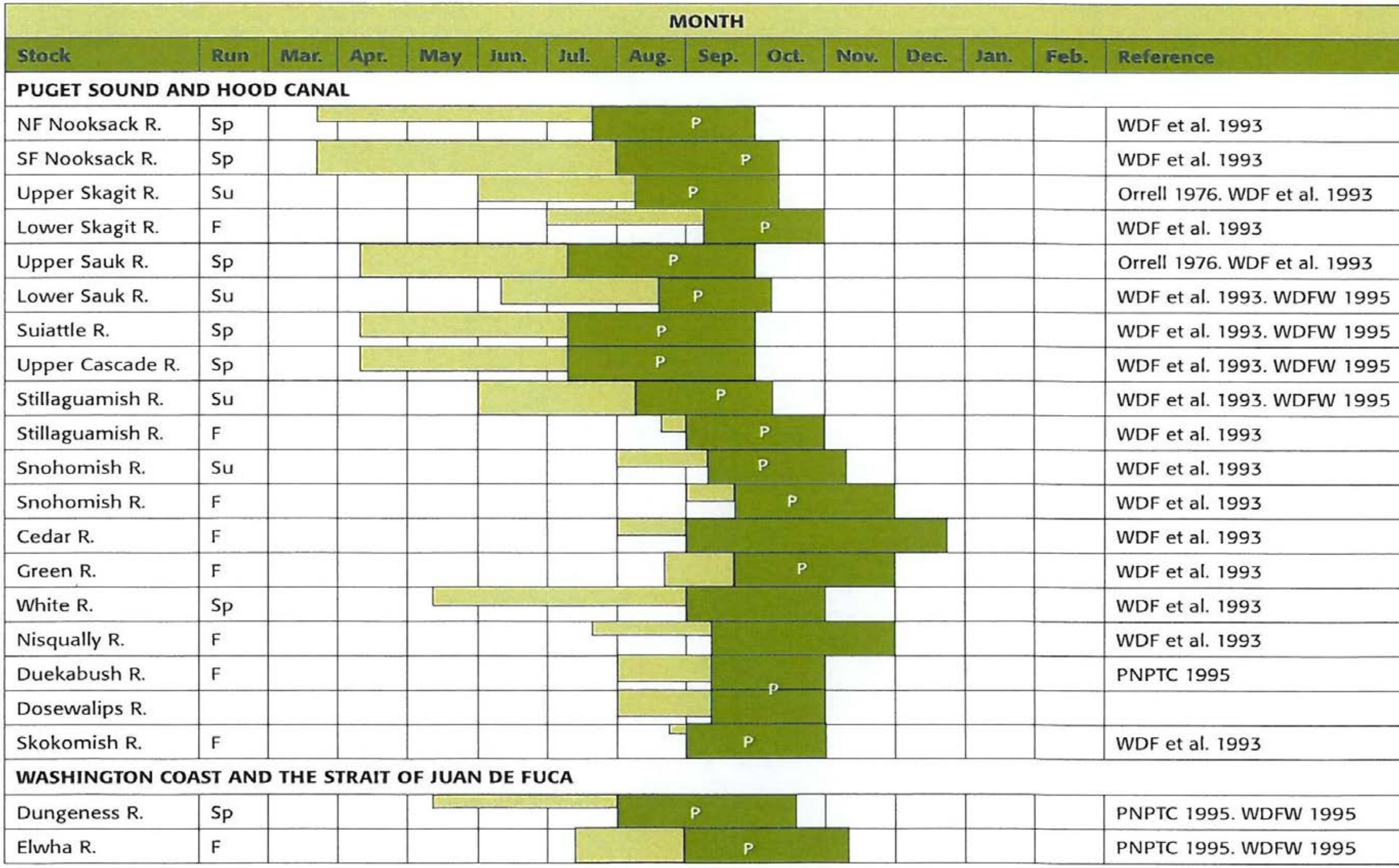


Figure 2.4 Freshwater migration and spawning timing for selected Chinook salmon from the Puget Sound. Run designations as characterized in the BRT Status Review, (Myers et al. 1998): Sp-spring; Su-summer; F-fall. Spring run designations for White and Dungeness Rivers stocks have been reclassified by local management agencies, but "Sp" labels have been retained for historical consistency. Due to variability in spawning times within a stock, some fish may still be entering freshwater during the spawning time intervals.

Freshwater Migration Timing
Spawning Timing