US Army Corps of Engineers®
Portland District

WILLAMETTE VALLEY SYSTEM OPERATIONS AND MAINTENANCE

FINAL ENVIRONMENTAL IMPACT STATEMENT

APPENDIX E: FISH AND AQUATIC HABITAT ANALYSES

PART 1 – CHAPTER 1 THROUGH CHAPTER 4

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CHAPTER 1 - FISH BENEFIT WORKBOOK

Supporting Information for Biological Input Parameters Used for Modeling of the Willamette Valley System EIS Downstream Fish Passage Measures in the Fish Benefit Workbook (FBW)

1.1 - SPRING CHINOOK SALMON -

1.1.1 DETROIT & BIG CLIFF

<u>Assumptions</u>:

- Yearling stage begins in January
- Baseline includes spilling for temperature management, which is equivalent to the spring spill measure 714. It is assumed that these measures are identical.

No Action Alternative (NAA or Baseline) / Measure 714 (Use spillway to pass fish in the spring).

Run timing –

Schedules were developed separately for a) when reservoir fills sufficiently for surface spill (see Run timing **IF SPILL OCCURS**) and b) if no surface spill available (see Run timing **IF NO SPILL**) in a given year. This is based on the assumption that few fish would pass in the spring or summer in years when no surface spill is available under measure 714, and instead fish would pass in the fall via the turbines or RO as the reservoir is drafted. During the target spill period (June to October), most water years in the period of record fall into one of two categories: 75% of the days providing spill, or <30% of the days providing spill. The FBW will apply the spill run timing in years with 75% of the days providing spill, otherwise apply the non-spill year run timing for a given year in the period of record.

*Run timing **IF SPILL OCCURS** (reservoir fills above spillway crest for a portion of the run season):*

- Fry – applied Alden (2014) for baseline conditions. Assume fry distribute along reservoir shorelines upon entry in spring, and most become available to pass in June based on Monzyk et al (2010-2014) fry distribution data.
- Subyearlings - adjusted original Alden (2014) timing to reflect more spring passage. Assume most fry mature into subs stage and become more pelagic and widely distribute in reservoir in June. References in Hansen et al. 2017 (Khan et al. 2012, Romer et al. 2013, Beeman and Adams 2015) –indicate fish will use the spillway when it’s operated.
- Yearlings – Adjusted original Alden (2014) timing. Yearlings have been shown to migrate quickly through reservoirs. The Alden (2014) timing (which used CGR as a surrogate) was adjusted with upstream trap data for DET (Romer et al. 2016). Assumed yearlings are seeking to leave in winter and spring. Some yearlings will be available and pass with spill (Romer et al. 2013).

Run timing for ***IF NO SPILL.***

- Fry – Applied the Alden (2014) timing for fry.
- Subyearling - Applied the Alden (2014) run timing, which was also used in Detroit Configuration/Operation Plan 2.0 Reevaluation (USACE 2019).
- Yearling - Alden (2014) timing was adjusted with upstream trap data for DET (Romer et al. 2016). Alden (2014) used CGR screwtrap data as surrogate. Yearlings have been shown to migrate quickly through reservoir.

DPE (Dam Passage Efficiency) –

Applied USGS (Beeman et al. 2014b) data from Table 11, using averages of dam passage efficiencies from the spring and fall studies weighted by sample sizes. However, there are no studies of fish passage efficiency with Detroit reservoir drafted below 1450. The target elevation for measures 40 and 720 is 1375. Original proposed DPE values are currently 0.4 when the pool is between 1363 and 1424 ft and 0.27 when the pool is at 1341 to 1362. DPE values for Detroit Dam when the pool elevation is near the spillway crest and turbine penstocks is up to 0.77.

Table 1-1. Revised Dam Passage Efficiency inputs applied:

Pool Elevation	DPE	Note
1574	0.77	Max pool
1541	0.77	Spillway crest
1540	0.03	
1500	0.04	
1450	0.27	50' over top of penstock
1425	0.77	6' over top of penstock
1415	0.3	40' over top of RO
1375	0.77	25' over top of RO
1340	0.77	Upper RO

Note the DPE at elevation 1425 (6’ over the top of the penstocks) may be too high for Measures 40 and 720 considering that some adjustment may be needed to compensate for the fact that FBW is a daily model, yet the intent of the proposed operations when drafting below 50’ of depth over the penstocks is that turbines will only be operated during the daytime for 8 hrs.

Route effectiveness (RE)– Applied Alden (2014).

Alden rationale for their recommended RE values states “Data are based on Khan et al. 2012 and Beeman preliminary 2013. The values were set up such that at spill levels of greater than 30%, approximately 90 percent of the fish pass via the spillway. When the RO and Turbines (no spillway) is operating that analysis was based on Beaman wherein at a 70% turbine, 30% RO flow split; 88% of the fish passed the turbines 12% through the RO". The Alden RE estimates may be somewhat conservative for the spillway and RO. Beeman and Adams (2015) estimated spillway RE at 3.05 during the spring study period in 2013, when most fish passed at night over the spillway. The average spillway flow (552 cfs) to turbine flow (606 cfs) ratio was approximately 0.90 on during the night in this period. Turbine RE was estimated at 0.99 and regulating outlet RE was estimated at 1.62 during the fall study period, when most fish passed via the turbines. We did not revise inputs from the Alden 2014 recommendations however due to the lack of readily available information to estimate RE for different flow ratios using the Beeman and Adams results.

Route survival –

For turbines, Beeman and Adams (2015) estimated survival from the forebay Detroit Dam to Big Cliff forebay at 62.2% in the fall of 2013 when 120 of 122 fish that passed used the turbines. Turbine flows were generally greater than 1000 cfs. Therefore, a survival rate of 62.2% was applied for turbine passage at flows of 1000cfs for all life stages. Applied Alden (2014) for flows <1000cfs, which was based on Normandeau (2010) and utilized rainbow trout as a surrogate for subs/yearlings.

For regulating outlets (ROs), Applied Alden (2014) survival rates, which were based on Normandeau (2010) and utilized rainbow trout as a surrogate for subs/yearlings.

For spill, the high range of the Alden (2014) estimates was used. Normandeau (2010) data indicated higher survival. Survival estimates by Beeman and Adams (2015) was also considered. They modeled survival from the forebay Detroit Dam to Big Cliff forebay as 71.6% based on detections of acoustic tagged juvenile Chinook. However did not account for route of passage. Most of the fish passage events detected occurred during the period when surface spill was occurring and those fish with known routes of passage nearly all used the spillway.

Re-regulation mortality, applied the same value as used by Corps (2015) of 15%. Beeman and Adams (2015) estimated juvenile Chinook survival from Detroit Dam tailrace downstream to Minto Dam as 0.67 to 0.74, or inversely a mortality of 0.26 to 0.33. We assume this estimate includes mortality occurring below Big Cliff Reservoir. Fischer et al. 2019 estimated mortality through Dexter Reservoir (which reregulates flows below Lookout Point Dam), at about 2%. Big Cliff Resevoir is smaller than Dexter. Oligher and Donaldson (1966) conducted Big Cliff Kaplan turbine unit tests to determine what effect various operating conditions would have on survival of fish passing through this type of turbine. Average survival from all tests in Oct. 1964 was 91.1 percent at 91 ft. head, 94.5 percent at 81 ft. head, and 89.7 percent at 71 ft. head. Average survival from all tests in May 1966 was 92.2 percent at 91 ft. head, 89.8 percent at 81 ft. head, and 90.6 percent at 71 ft. head. Therefore, we expect the 26%-33% mortality rate range is likely high since it also includes mortality occurring below Big Cliff. Therefore, we applied 15% reregulation mortality, as used previously in USACE (2015).

Measure 392+105: FSS with SWS –

Flow range determined in the Detroit Design Documentation Report (DDR) for the Floating Screen Structure (FSS) is 1,000 – 5,600 CFS, with all flow to the Selective Withdrawal Structure (SWS) going through FSS to avoid competing flow. Above 5,600 through the FSS we are not in NMFS fry criteria anymore and would want lower survival for fry → here we assume that above 5,600, water would be drawn in from a low-level inlet and assume no fish in that part of the water column.

Run timing -

- Fry - Applied the Alden (2014) timing for a floating structure.
- Subyearlings – Adjusted the Alden (2014) baseline timing with downstream passage from the Willamette Project Configuration/Operations Plan (USACE 2015, p 48, Appendix K). Assumed some fry would mature to subyearling stage in spring and be available to pass. Data indicates growth rates can be high in DET Reservoir; Breitenbush tributary data indicate by May-June fish would have grown >60 mm (Monzyk et al. 2015). Adjusted subyearling timing accordingly.
- Yearlings – same as baseline

Dam Passage Efficiency - above minimum conservation pool–

DPE within the pool elevation operating range of the FSS was estimated separately for each alternative. The method and results are described in Attachment A of this Chapter.

Table 1-2. Dam Passage Efficiency Values by Alternative:

Alternative	DPE within the FSS pool elevation operating range
1	0.569
2	*TBD – pending finalization of alternative and RES-SIM results*
3a and 3b	Not applicable
4	*TBD – pending finalization of alternative and RES-SIM results*

Dam Passage Efficiency, below minimum conservation pool - applied DPE values from Detroit (DET) baseline

Route Effectiveness –

Applied Alden (2014). Assumes no surface spill and all flow through the FSS.

Route survival –

98% for all life stages for the fish passage route (FSS). Other routes same as baseline. The FSS is assumed to have a passage survival of 98% for all target species collected, based on structures operating in the Northwest similar to the FSS concepts being considered for the WVS EIS (see USACE 2015 section 2.5.5).

Measure 40 – Deep fall drawdown to 10ft over the top of the upper RO's – Target start date 15 Nov and maintained for three weeks.

Run timing -

Same as baseline.

Dam Passage Efficiency –

Same as baseline.

Route effectiveness –

Same as baseline.

Route survival –

Same as baseline.

Measure 720: Spring delay refill with target elevation at 10' over the top of the upper RO's. May 1 to May 21 at target elevation.

Run timing –

- Fry – Same as Detroit (DET) FSS (measure 392)
- Subyearlings – Same as DET FSS (measure 392)
- Yearlings – Same as baseline

Dam Passage Efficiency –

Same as baseline.

Route Effectiveness –

Same as baseline.

Route Survival –

Same as baseline.

1.1.2 FOSTER

<u>Assumptions</u>:

- Yearling stage begins in January
- Baseline includes spilling for temperature management, which is equivalent to the spring spill measure 714. It is assumed that these measures are identical.

Baseline

Run timing –

Same as used in the Foster Downstream Fish Passage EDR (2016). Alden (2014) recommendation was based on fry data from Monzyk (2012) and for subyearling and yearling data from Wagner and Ingram (1973). Adjustments to Alden timing made considered data presented by Monzyk and Romer (2013 and 2014) above and below resevoir screwtrapping. We assume subs (>60 mm) are from those that entered the reservoir as fry, grew, and then move further from shore in May- June then emigrate.

Dam Passage Efficiency –

Applied data from Liss et al. (2020). Also see Alden (2014). Fry and sub-yearlings. Liss et al. did not include data for fry; assumed same for fry. Values at different elevations given the presence of a weir were taken from Liss et al. (2020) for the weir (SPE), low pool (min con), and the turbines. Liss et al. assumed low pool conditions when sub-yearlings pass. Therefore, we used the average DPE observed over 3 years.

Turbine passage was averaged from observations of passage from Liss et al. (2020) over low pool conditions (ie, calculated using FPE, Fish Passage Proportion). DPE was available for yearlings under high and low pool conditions. Therefore, DPE was taken to be the midpoint between low and high DPE values over 3 years and two pool elevations for yearlings using PNNL 2020.

Route Effectiveness –

Applied Alden (2014)

Route survival –

Applied averages of estimated survival for subs (CK0) and yearlings (CK1) for each route from Liss et al. (2020). Low and high pool survival estimates were available for yearling Chinook, and so the average across both pool elevations was applied.

Measure 392

Run timing -

Same as baseline.

Dam Passage Efficiency –

Measure 392 for Foster Dam is a concept of either further improving the fish weir operated in Spillbay 4 or constructing a dedicated fish collection and bypass pipe in the same vicinity as the fish weir, with either concept operating at about 600 cfs. Until further refinement of this concept, we assumed a DPE consistent with the highest DPE measured at the dam for steelhead to date of 0.76 as reported in Table 5.6 of Liss et al. (2020).

Route Effectiveness –

Applied Alden (2014)

Route survival –

For spillway and turbines, used same values as for baseline. For fish passage route, assumed 98%, where fish passage concept is either a modified overflow weir or a dedicated fish pipe (see USACE 2015 section 2.5.5).

1.1.3 GREEN PETER

Baseline:

- Not applicable – no fish outplanted above dam.

Measure 392: GPR FSS –

Run timing –

Same as DET timing for Measure 392.

Dam Passage Efficiency –

DPE within the pool elevation operating range of the FSS was estimated separately for each alternative. The method and results are described in Appendix A of this document. DPE values by Alternative when above minimum conservation pool:

Table 1-3. Dam Passage Efficiency by Alternative within the FSS.

Alternative	DPE within the FSS pool elevation operating range
1	0.544
2	TBD – pending finalization of alternative and RES-SIM results

Alternative	DPE within the FSS pool elevation operating range
3a and 3b	Not applicable
4	TBD – pending finalization of alternative and RES-SIM results

Below minimum conservation pool elevation, applied DPE values from baseline adjusted on depths to outlets for GPR.

Route effectiveness –

Applied DET RE values due to similarity in dam configuration. Local data on RE for existing routes at GPR not available.

Route survival –

98% for fish passage route (see USACE 2015, section 2.5.5). Spillway, turbines and RO assumed the same as DET due to similar dam configuration.

Measure 714 and 721: Spring/summer spill

Run timing –

Applied DET baseline timing for years with and without spill.

Dam Passage Efficiency –

Data is not available for DPE of juvenile Chinook at Green Peter Dam. Applied DPE values from DET to GPR based on DPEs for similar depths to outlets at GPR. Assumed highest DPE when pool surface elevation ≤ depth over top of outlet.

Route effectiveness –

Applied DET RE values due to similarity in dam configuration. Local data on RE for existing routes at GPR not available.

Route survival –

Applied route survival from DET due to similarity in dam configuration. No site-specific data on juvenile downstream passage survival for spillway, turbines and ROs.

Measure 40 (deep fall drawdown)

Same as 714 and 721

Measure 720 (spring delay refill)

Same as 714 and 721

1.1.4 COUGAR

Assumptions:

- o Yearling stage begins in January

Baseline

Run Timing

- Fry – Applied Alden (2014)
- Subyearlings – Applied Alden (2014)
- Yearlings – Applied Alden (2014). Also see CGR 2.0 DDR, Romer et al. 2013 and Hansen et al. 2017.

Dam Passage Efficiency –

Applied DPE as used in CGR 2.0 DDR (USACE, 2020). DPE estimates developed based on passage rates reported in Beeman et al. 2013 and 2014. For diversion tunnel DPE, RO passage rates reported by Beeman et al. were applied for the diversion tunnel based on similar depths to the outlet except when very near or below the top of the diversion tunnel, in which case estimated DPE was based on passage rates observed by Nesbit et al. (2014) for Fall Creek Dam outlet works at low pool elevations. After modeling with initial assumptions, DPE input values were further reviewed to adjust assumptions to better reflect field data and the new operational scenarios included in the EIS (M40 and 720). Due to lack of data on Chinook passage when the pool elevation is very near the top of the RO, information on juvenile Chinook passage from Fall Creek Reservoir was applied considering that both outlets are located in close proximity to the bottom of the pool.

Table 1-4. Dam Passage Efficiency Values Applied by Elevation.

Pool elevation	Previous DPE	DPE	Revised 9/23 DPE
1690	0.1	0.135	0.135
1635			0.2
1571	0.2	0.2	0.3
1570	0.42	0.16	0.5
1532	0.42	0.33	0.6
1516	0.6	0.6	0.75
1500	0.7	0.7	0.8
1450	0.1	0.1	
1425	0.299	0.299	0.299
1400	0.5	0.5	0.5
1360	0.6	0.6	0.6

Pool elevation	Previous DPE	DPE	Revised 9/23 DPE
1337	0.7	0.7	0.7
1321	0.8	0.8	0.8
1310	0.95	0.95	0.95
1290	0.95	0.95	0.95

Route Effectiveness –

Applied Alden (2014). These values were derived from Beeman et al. (2013 and 2014a) data. The overall value from 2011 and 2012 were averaged to obtain RO effectiveness value of 91.45%. The estimate applies for flows ranging from 48% to 73%, as this was the range of flows the data was collected over. Values for flows above and below the range were shaped based on professional opinion. The use of professional opinion should have little effect as the project should operate within the published ranges very often. [*NOTE: Below 1571, the RO bypass gate is opened. Effectiveness in this case should be equivalent to the best Surface Flow Outlets, ~6.0 (ENSR 2007, Johnson et al. 2009.)*

Route Survival –

Fry: Applied Alden (2014).

Subs and yearlings: Adjusted USACE 2015 (see Appendix K) values down to 36% based upon the Beeman (2012) radio-telemetry work. 60% seems very high based on all available data, while Alden's 29% seems very low. CGR EDR explains why COP HI-Z tag data is likely estimated high due to premature inflation of tags, and that barotrauma sheer stress was high, and why that value should be adjusted downward. CGR EDR: "This, coupled with modeling of the chance of turbine strike at different fork lengths, indicate that the chances of yearling Chinook surviving turbine passage at Cougar Dam are certainly less than 50% and likely in the 30-40% range (Duncan 2010a, Carlson 2010)." Used 30% as low and 40% as high estimate bracket.

Measure 392: CGR FSS –

Run Timing -

- Fry – Applied Alden (2014)
- Subyearlings – Same as DET FSS timing for subyearlings.
- Yearlings – Revised from Alden (2014) in consideration of Romer et al. (2013-2016) above-reservoir screw trap data for CGR.

Dam Passage Efficiency –

DPE within the pool elevation operating range of the FSS was estimated separately for each alternative (see Appendix A).

Table 1-5. Dam Passage Efficiency values by Alternative for measure 392.

Alternative	DPE within the FSS pool elevation operating range
1	Not applicable
2	Not applicable
3a and 3b	Not applicable
4	*0.864*

Below the operating elevation range of the FSS (minimum conservation pool) - applied DPE values as used in the baseline.

Route Effectiveness –

Applied Alden (2014). Assumes no surface spill and all flow through the FSS when pool between min and max conservation elevations.

Route survival –

Fish passage route 98% for all life stages (see USACE 2015 section 2.5.5). Same as baseline for other routes.

Measure 40: Deeper fall drawdowns to 10 ft over top of upper RO's AND to diversion tunnel (1290') – target start 15 Nov for three weeks. Assumes RO structural improvements for fish passage survival.

Run Timing –

Fry – Same as baseline

Subyearlings – Same as baseline

Yearlings – Same as baseline

Dam Passage Efficiency –

Same as baseline.

Route Effectiveness –

Same as baseline.

Route Survival –

Used Nesbit (2014) survival data for diversion tunnel, and Alden (2014) parameter estimates for other routes.

Measure 720: Delay refill with pool held at 10 ft above top of upper RO's – target May 1 to May 21 at target elevation.

Run Timing –

- Fry – used Cougar head of reservoir data from Monzyk et al. (2011) and Romer et al. 2012-2016.
- Subyearlings – Same as DET FSS timing for subyearlings.
- Yearlings – Run timing revised from Alden (2014) in consideration of Romer et al. (2013-2016) above-reservoir screw trap data for CGR.

Dam Passage Efficiency –

Same as baseline.

Route Effectiveness –

Same as baseline.

Route Survival –

Same as baseline.

Measure 720: Spring drawdown to diversion tunnel (1290') target May 1 to May 21 at target elevation.

Run Timing –

- Fry – used Cougar head of reservoir data from Monzyk et al. 2011, and Romer et al. 2012-2016. Notes: Most fry emigrate into CGR Reservoir during April and May. RES-SIM models of a 1290 delay refill indicates the reservoir elevation will be much higher than 1290 during these months in several years. Fry will therefore distribute along the reservoir shoreline (Monzyk et al. 2011-2015), and then many will pass once the reservoir is less than about 20 feet over the diversion tunnel.
- Subyearlings – Same as DET FSS timing for subyearlings. Notes: Fry mature into the parr stage and become pelagic in June (Monzyk et al. 2011-2015). We expect some will pass when the reservoir is within 50ft of depth over the DT, and most will pass once the reservoir is within 25 of the top DT, based on radio-telemetry study at Fall Creek Dam (Nesbit et al. 2014).
- Yearlings – Run timing revised from Alden (2014) in consideration of Monzyk et al. 2011 and Romer et al. (2012-2016) above-reservoir screw trap data for CGR.

Dam Passage Efficiency –

Same as baseline.

Route Effectiveness –

Same as baseline.

Route Survival –

Same as baseline.

1.1.5 HILLS CREEK

Assumptions:

- The spillway will not be used under the NAA and Measure 392.
- Measures 714 and 479 assume spillway modified to improve fish survival and feasibility for long-term use.
- Yearling stage begins in January.

Baseline

Run Timing -

- Fry – Applied Alden (2014) for CGR baseline run timing
- Subyearlings – Applied Alden (2014) for CGR baseline run timing
- Yearlings – Revised run timing applied in the COP for HCR (USACE 2015, Appendix K) based on the assumption that the yearling stage begins in January.

Dam Passage Efficiency –

Applied DPE from CGR for similar depths to outlets using data from Beeman et al. (2013; see Table 9). Assumes no surface spill is occurring since the spillway at HCR is not used (i.e. designed only for emergency use).

Route Effectiveness –

Same as CGR for each route, due to similarity in dam configuration.

Route Survival –

Used Alden 2014 (based on CGR RO survival estimates). Assumes no surface spill. Alden estimates could be high, considering RO configuration at HCR would be expected to result in higher injury and mortality. Life cycle model sensitivity analysis will further assess the parameters estimates and influence on the model results.

Measure 714 –

Use a modified spillway to pass fish in the spring –From May 1 until July 1 (or as long as hydrology supports during the conservation season), operate the spillway 24 hrs/day as the primary outlet, with turbines and ROs as secondary. This measure assumes structural modifications to the spillway to make it feasible to operate, and safer for fish to pass over.

Run timing -

- Fry – Same as baseline
- Subyearlings – Used similar approach as for DET, measure 714: If 'no spill': same as HCR baseline. If spill: used DET spill timing for baseline/measure 714.
- Yearlings – Same as HCR baseline

Dam Passage Efficiency –

Updated baseline DPE estimates to include operation of a modified spillway. Adjusted DET DPE down for above spillway crest at high pool due to the fact that at HCR the max pool is higher above crest than DET max pool over the DET spillway crest (i.e fish must sound to greater depths when at HCR max pool).

Route Effectiveness –

Spillway same as DET since this measure assumes modifications to the spillway. Other routes same as CGR for each route, due to similarity in dam configuration.

Route Survival -

Spillway – Assumed spillway will be newly designed with fish survival in mind; anticipate slightly higher survival than DET. Used the high end of the DET range, as reported for sensor fish/balloon tag data (Normandeau, 2010); 48 hr survival was 64 – 84% at different gate openings. [Data also reported in Hansen et al. (2017) data synthesis.]

RO and turbines – Utilized Alden (2014)

Measure 479: Modify Existing Outlets –

Re-design spillway gates and channel to allow for low-flow releases when lake is above spillway crest. This would provide more normative temperatures during the summer through the release of warmer water during the summer and saving cooler deeper water for the fall. Won't change total flow, but less hydropower. Hit 1495 by Feb 26 on current rule curve.

Run Timing –

Same as for measure 714 (spring spill).

Dam Passage Efficiency –

Same as for measure 714 (spring spill).

Route Effectiveness –

Same as for measure 714 (spring spill).

Route Survival -

Same as for measure 714 (spring spill).

Measure 392: Floating screen structure

Run Timing –

Same as for DET Measure 392.

Dam Passage Efficiency –

Fish passage within the FSS – DPE within the pool elevation operating range of the FSS was estimated separately for each alternative. The method and results are described in Appendix A of this document.

Table 1-6. Hills Creek DPE values by Alternative.

Alternative	DPE within the FSS pool elevation operating range
1	Not applicable
2	Not applicable
3a and 3b	Not applicable
4	0.791

Below minimum conservation pool - applied DPE values from baseline

Route Effectiveness –

RE for FSS from CGR Measure 392, other routes same as baseline

Route Survival –

FSS 98% for all life stages, other routes same as baseline.

Measure 304: Augment flows by tapping the power pool

Run Timing –

Same as HCR Baseline.

Dam Passage Efficiency –

Same as HCR Baseline.

Route Effectiveness –

Same as HCR Baseline.

Route Survival –

Same as HCR Baseline.

Measure 40: Deep fall drawdown to 10 ft above the top of the RO by NOV15 –

Target start date 15 Nov and maintained for three weeks. Assumed not to affect run timing of yearlings.

Run Timing -

- Fry – same as Baseline.
- Subyearlings – same as DET baseline ‘no spill” timing, which has peak passage in Nov. when reservoir elevation low.
- Yearlings – same as HCR Baseline. This measure would end before Jan.

Dam Passage Efficiency –

Same as HCR Baseline.

Route Effectiveness –

Same as HCR Baseline.

Route Survival –

Same as HCR Baseline.

Measure 720: Delay refill to 10 ft above the top of the RO May 1 to May 21

Run timing -

- Fry – same as baseline.
- Subyearlings – same as DET Measure 392.
- Yearlings – same as DET Measure 392.

Dam Passage Efficiency –

Same as HCR Baseline.

Route Effectiveness –

Same as HCR Baseline.

Route Survival –

Same as HCR Baseline.

1.1.6 LOOKOUT POINT & DEXTER

<u>Assumptions</u>:

- Yearling stage begins in January.

Baseline

Run Timing –

Same as DET baseline, all life stages.

Dam Passage Efficiency –

Based on DPE values used for DET, adjusted for outlet elevations at Lookout Point (LOP). Also considered Fischer et al. (2019) estimated DPE was 31% for October released fish and 58% for December-released fish, when forebay surface elevations in October were about 850ft, and ranged from 822 to 837 ft in December.

Table 1-7. Revised DPEs inputs applied

Pool elevation	DPE	Note
934	0.77	Max pool
926	0.77	
887.5	0.77	Spillway crest
887	0.10	
825	0.58	Min cons.
819	0.58	Min power
780	0.30	Below power pool; 44' over top of RO
761	0.77	25' over top of RO
724	0.77	RO invert

Route Effectiveness –

Applied Alden (2014).

Route Survival –

RO survival rates assumed are the same as for DET baseline, all lifestages, since no data is available for LOP RO survival. For turbines at lower flows, also used DET data since recent PNNL acoustic telemetry studies estimated survival only for moderate to high flows levels (Fischer et al. 2019). For higher flows, used Fischer et al. (2019), who estimated survival of turbine-passed fish to the Lookout Point tailwaters at 77.9% (SE = 3.9) for October released fish (n = 134) and 82.3% (SE = 3.4) for December-released fish (n = 331). Survival of turbine-passed fish (n = 83) to the Lookout Point tailrace was 78.4% (SE = 4.7) for February-released fish. For spillway survival, also used Fischer et al. (2019), who estimated survival of pooled February and April-released fish passing via Spill Bay 3 on April 29, 2018 (n = 66) was 98.7% (SE = 5.5).

Reregulation Reservoir and Dam Passage Mortality for Dexter- for all life stages, applied 26%. Fischer et al. (2019) estimated survival of Chinook subs and yearlings, from the Lookout Point tailwaters to Dexter Dam forebay ranged from 88.5% (SE=4.3) to 93.0% (SE = 6.8) to 88.5% (SE=4.3) among the study release groups. Survival for fish passing Dexter Dam was not estimated. For fish released in October and December, the joint probability of migration and survival from Lookout Point tailrace to the Corvallis array was 0.435 and 0.443, respectively. However, since this estimate includes survival within a significant river reach downstream of Dexter Dam, we considered passage survival data from Big Cliff Dam (the reregulation dam below Detroit Dam which also has Kaplan turbines). Beeman and Adams (2015) estimated juvenile Chinook survival from Detroit Dam tailrace downstream to Minto Dam as 0.67 to 0.74. Considering the Beeman and Adams mortality estimate would be somewhat lower if it was for just Big Cliff Dam, and the very low mortality estimated in Dexter Reservoir by Fischer (2019), we applied a re-regulation mortality estimate of 26%.

PNNL survival estimate summary (Tables from Fischer et al. 2019)

Table 4.2. Sample Sizes (N) and Estimated ViRDCt Survival Probabilities ($\hat{S}$) from Lookout Point to the Lookout Point Immediate Tailrace Array (LPT array) and to Dexter for Acoustic-Tagged CH0 Released into the Lookout Point Reservoir in October and December 2017. Detection probabilities (p) of each detection array (LPT and Dexter) are also shown. Virtual release groups (V_1) were formed by release month and route of passage at Lookout Point. Standard errors (SEs) of survival estimates are shown in parentheses. All detection probability SEs were ≤0.01. Superscripts indicate the model that was used to estimate survival.

		Lookout Point to Immediate Tailrace		Lookout Point to Dexter	
V_1 group	N	$\hat{S}$ (SE)	p	$\hat{S}$ (SE)	p
Oct turbines	134	0.779 (0.039)[a]	0.99	0.724 (0.039)[b]	1.00
Dec turbines	331	0.823 (0.024)[c]	1.00	0.727 (0.025)[d]	1.00

(a) Reduced ViRDCt model
(b) CJS model
(c) Tag life-adjusted ViRDCt model
(d) Tag life-adjusted CJS model

Table 5.2. Sample Sizes (N) and Estimated ViRDCt Survival Probabilities ($\hat{S}$) from Lookout Point Passage to the Lookout Point Immediate Tailrace (LPT Array) and to Dexter for Acoustic-Tagged CH1 Released into the Lookout Point Reservoir in February and April 2018. Detection probabilities (p) of each detection array (LPT and Dexter) are also shown. Virtual release groups (V_1) were formed by month of release and route of passage at Lookout Point. Standard errors (SEs) of survival estimates are shown in parentheses. All detection probability SEs were ≤0.01. Superscripts indicate the model used to estimate survival.

		Lookout Point to Immediate Tailrace		Lookout Point to Dexter	
V_1 Group	N	$\hat{S}$ (SE)	p	$\hat{S}$ (SE)	p
February turbines	83	0.784 (0.047)[a]	1.00	0.699 (0.050)[b]	1.00
April turbines	11	0.654 (0.189)[e]	1.00	0.441 (0.143)[a]	1.00
Feb & April spillway	66	0.987 (0.055)[c]	1.00	0.884 (0.070)[c]	1.00
Spill and April Pooled	77	0.942 (0.057)[c]	1.00	0.822 (0.047)[c]	1.00

(a) Reduced ViRDCt model
(b) CJS model
(c) Tag life-adjusted ViRDCt model
(e) Full ViRDCt model

Measure 392 + 105: Structure (FSS) with SWS – Assumes design concept from DET scaled to LOP turbine capacity.

Run Timing –

Fry – Same as baseline.
Subyearlings – Same as DET measure 392.
Yearlings – Same as DET measure 392.

Dam Passage Efficiency –

Dam Passage Efficiency within the pool elevation operating range of the FSS was estimated separately for each alternative. The method and results are described in Appendix A of this document.

Table 1-8. Dam Passage Efficiency values by Alternative

Alternative	DPE within the FSS pool elevation operating range
1	0.824
2	0.824
3a and 3b	Not applicable
4	*0.964*

Note: Below minimum conservation pool - applied DPE values from baseline

Route Effectiveness –

Same as DET measure 392.

Route Survival –

Fish passage: 98% for all life stages. Other routes same as baseline.

Measure 166: Use lowest ROs in fall and winter drawdowns to reduce water temperatures below dams

Run Timing –

Same as LOP baseline.

Dam Passage Efficiency –

Same as LOP baseline.

Route Effectiveness –

Same as LOP baseline.

Route Survival –

Same as LOP baseline.

Measure 714 and 721: Use spillway to pass fish in the spring

Run Timing –

Same as LOP baseline.

Dam Passage Efficiency –

Same as LOP baseline.

Route Effectiveness –

Same as LOP baseline.

Route Survival –

Same as LOP baseline.

Measure 40: Deep fall drawdown to 10' over the top of the RO - on 15 Nov. (Anytime from 15 Oct – 15 Dec.)

Run timing –

Same as LOP baseline.

Dam Passage Efficiency –

Same as LOP baseline.

Route Effectiveness –

Same as LOP baseline.

Route Survival –

Same as LOP baseline.

Measure 720 – Spring drawdown to lowest outlet for downstream passage – June 1-22.

Run Timing -

- Fry – Same as LOP baseline. Reservoir is smaller in spring, but assume fry remain along shorelines until June (see Monzyk and Romer 2011-2015).
- Subyearlings – New. Assume majority of subs passing in June, when recruitment to the subyearling stage (>50mm size obtained, and more pelagically distributed) primarily occurs per Monzyk et al. 2010-2015).
- Yearlings – Same as LOP baseline.

Dam Passage Efficiency –

Same as LOP baseline.

Route Effectiveness –

Same as LOP baseline.

Route Survival –

Same as LOP baseline.

SPRING CHINOOK REFERENCES

Alden. 2014. Willamette River Fish Benefit Workbook Parameterization: Chinook. Memorandum to Robert Wertheimer and Richard Piaskowski, U.S. Army Corps of Engineers. Prepared by Kevin Malone, Isaac Willig, Shari Dunlop, 01 April 2014.

Beeman, J.W., Hansel, H.C., Hansen, A.C., Evans, S.D., Haner, P.V., Hatton, T.W., Kofoot, E.E., Sprando, J.M., and Smith, C.D., 2013, Behavior and Dam Passage of Juvenile Chinook Salmon at Cougar Reservoir and Dam, Oregon, March 2012–February 2013.

Beeman, J.W., Hansel, H.C., Hansen, A.C., Evans, S.D., Haner, P.V., Hatton, T.W., Kofoot, E.E., Sprando, J.M., and Smith, C.D., 2014a, Behavior and dam passage of juvenile Chinook salmon at Cougar Reservoir and Dam, Oregon, March 2012–February 2013: U.S. Geological Survey Open-File Report 2014-1177, 52 p., http://dx.doi.org/10.3133/ofr20141177

Beeman, J.W., Hansel, H. C., Hansen, A.C., Evans, S.D., Haner, P.V., Hatton, T.W., Kofoot, E.E., Sprando, J.M., and Smith, C.D., 2014b, Behavior and dam passage of juvenile Chinook salmon and juvenile steelhead at Detroit Reservoir and Dam, Oregon, March 2012–February 2013: U.S. Geological Survey Open-File Report 2014-1144, 62 p., http://dx.doi.org/10.3133/ofr20141144.

Beeman, J.W. and N.S. Adams, eds. 2015. In-reservoir behavior, dam passage, and downstream migration of juvenile Chinook salmon and juvenile steelhead from Detroit Reservoir and Dam to Portland, Oregon, February 2013–February 2014. U.S. Geological Survey Open-File Report 2015-1090. http://dx.doi.org/10.3133/ofr20151090.

Fischer, ES, JS Hughes, CA Grieshaber, SA Liss, SE Blackburn, RA Harnish, KD Ham, T Fu and G Johnson. 2019. *Passage and Survival of Chinook Salmon at Lookout Point Dam, Fall 2017 and Spring 2018*. PNNL-28171. Final report prepared for the U.S. Army Corps of Engineers, Portland, Oregon, by Pacific Northwest National Laboratory, Richland, Washington.

Hansen, A.C., T.J. Kock, and G.S. Hansen. 2017. Synthesis of downstream fish passage information at projects owned by the U.S. Army Corps of Engineers in the Willamette River Basin, Oregon. U.S. Geological Survey Open File Report 2017-1101, https://doi.org/10.3133/ofr20171101.

Johnson, G.E., M.C. Richmond, J.B. Hedgepeth, G.R. Ploskey, M.G. Anderson, Z. Deng and six others. 2009. Smolt Responses to Hydrodynamic Conditions in Forebay Flow Nets of Surface Flow Outlets, 2007. Pacific Northwest National Laboratory, Richland, WA. Report to the U.S. Army Corps of Engineers, Portland, Oregon. Contract DE-AC05-76

Johnson, M.A., T.A. Friesen, P.M. Olmsted, and J.R. Brandt. 2016. Migration survival, growth and fate of hatchery juvenile Chinook salmon released above and below dams in the Willamette River Basin. Oregon Department of Fish and Wildlife. Report to U.S. Army Corps of Engineers, Portland District.

Khan, F., I.M. Royer, G.E. Johnson, and K.D. Ham. 2012. Hydroacoustic evaluation of juvenile salmonid passage and distribution at Detroit Dam, 2011. Pacific Northwest National Laboratory, Richland, Washington. Report to the U.S. Army Corps of Engineers, Portland District. Contract DE-AC05-76RL01830.

Kock, T.J., Verretto, N.E., Ackerman, N.K., Perry, R.W., Beeman, J.W., Garello, M.C. and Fielding, S.D. (2019), Assessment of Operational and Structural Factors Influencing Performance of Fish Collectors in Forebays of High-Head Dams. Trans Am Fish Soc, 148: 464-479. https://doi.org/10.1002/tafs.10146.

Liss, SA, KR Znotinas, JS Hughes, BJ Bellgraph, CR Vernon, RA Harnish, ES Fischer, and SE Blackburn. 2020. *Evaluation of Foster Dam Juvenile Fish Passage, 2018.* PNNL-29587. Final report submitted by the Pacific Northwest National Laboratory to the U.S. Army Corps of Engineers, Portland, Oregon.

Monzyk, F.R., J.D. Romer, R. Emig, and T.A. Friesen. 2011, 2012, 2013, 2014, and 2015. Life-History Characteristics of Juvenile Spring Chinook Salmon Rearing in Willamette Valley Reservoirs. Oregon Department of Fish and Wildlife, Corvallis. Reports to U.S. Army Corps of Engineers, Portland District.

Monzyk, F.R., J.D. Romer, R. Emig, and T.A. Friesen. 2011. Pilot Head-of-Reservoir Juvenile Salmonid Monitoring. Oregon Department of Fish and Wildlife, Corvallis. Reports to U.S. Army Corps of Engineers, Portland District.

Nesbit, MG, GA Axel**,** BP Sandford, BJ Burke, KE Frick, and JJ La. 2014. Passage Behavior and Survival of Juvenile Spring Chinook Salmon at Fall Creek Dam, 2012. Fish Ecology Division, Northwest Fisheries Science Center National Marine Fisheries Service National Oceanic and Atmospheric Administration. Report to the U.S. Army Corps of Engineers Portland District, Contract JPL 13-05-FCR. February 2014.

Normandeau Associates, Inc. 2010. Estimates of direct survival and injury of rainbow trout (*Oncorhynchus mykiss*) passing spillway, turbine, and regulating outlet at Detroit Dam, Oregon. Report to the U.S. Army Corps of Engineers, Portland District. Contract W912EF-08-D-0005-DT01.

Oligher, R.C., I.J. Donaldson. 1966. Fish Passage Through Turbines Tests at Big Cliff Hydroelectric Plant. Progress Report No. 6. U.S. Army Engineer District, Walla Walla Corps of Engineers.

Romer, J.D., F.R. Monzyk, R. Emig, and T.A. Friesen. 2012, 2013, 2014, 2015, 2016 and 2017. Juvenile salmonid outmigration monitoring at Willamette Valley Project reservoirs. Oregon Department of Fish and Wildlife, Corvallis. Report to U.S. Army Corps of Engineers, Portland District.

U.S. Army Corps of Engineers (USACE). 2015. Willamette Valley Configuration/Operation Plan, Phase II Report. U.S. Army Corps of Engineers, Portland District.

U.S. Army Corps of Engineers (USACE). 2017a. Cougar Dam Downstream Fish Passage Engineering Documentation Report. January 2017. U.S. Army Corps of Engineers, Portland District.

U.S. Army Corps of Engineers (USACE). 2017b. Detroit and Big Cliff Long-Term Temperature Control and Downstream Fish Passage; North Santiam River. Willamette Biological Opinion Engineering Documentation Report. July 2017. U.S. Army Corps of Engineers, Portland District.

U.S. Army Corps of Engineers (USACE). 2017. DRAFT Cougar Downstream Fish Passage Alternatives Reevaluation. October 2020. U.S. Army Corps of Engineers, Portland District.

U.S. Army Corps of Engineers (USACE). 2019. Detroit Configuration/Operation Plan 2.0 Reevaluation. Report completed 17 July 2019.

1.1.7 CHINOOK ATTACHMENT A

Fish Benefits Workbook (FBW) Dam Passage Efficiency (DPE) Calculations for Floating Screen Structures, Willamette Valley System EIS and ESA consultation fish effects analysis.

Floating screen structures (FSS) are dynamic in that they can accommodate varying elevations while taking advantage of available outflows. The FSS design includes two screened flumes or barrels that can accommodate a wider range of inflows better than a single flume design. Data on the fish collection efficiency of these and similar structures is limited but growing. For spring Chinook salmon, a target species for passage at Willamette dams, a wide range of collection rates have been observed among floating surface collectors operating in the Pacific Northwest (Kock et al. 2019). Some of these differences would be attributable to differences in designs and local conditions, making comparisons difficult among existing surface collectors. Kock et al. (2019) used a hierarchical log-linear regression to identify which design aspects most successfully predicted dam passage efficiency. They are: effective forebay size at a distance 500 meters from the dam face (ha), entrance size (m^2), collector inflow (m^3/s), and the presence of nets that improve fish guidance or efficiency (See Table 1-9 adapted from Kock et al. 2019). While this model is heavily focused on physical attributes of dam configuration and proposed engineering design dimensions for a collector, it is important to recognize that the collectors discussed in the EIS and the BA have yet to be successfully implemented and there is considerable risk and uncertainty about the realized effectiveness of these structures. Under modeled and simulated conditions, these collectors are expected to perform reasonably, but real time management or unobserved conditions could impact the effectiveness of proposed collectors, particularly in cases where the predictor variables represent the highest extremes of the functional relationships described in Kock et al. (2019). For this reason, dam passage efficiency should be interpreted in the lens of perfect information and actual results may vary.

Table 1-9. Coefficients for each significant predictor of fish collection efficiency. *

Variable	Coefficient estimate	SE	t-value	P-value
Intercept (Chinook Salmon)	-0.923	0.356	NA	NA
Coho Salmon	0.876	0.371	2.361	0.023
Sockeye Salmon	0.631	0.383	1.647	0.107
Steelhead	1.474	0.539	2.737	0.009
Lead nets	0.848	0.313	2.705	0.009
Inflow	0.492	0.068	7.188	<0.001
Effective forebay area	-1.086	0.183	-5.945	<0.001
Entrance area	0.991	0.233	4.254	<0.001
Effective forebay area x entrance area	2.112	0.362	5.835	<0.001

Notes: * Adapted Table 7 from Kock et al. 2019.

** Table 7 Coefficient estimates, SEs, and tests of significance for the effect of each predictor variable on fish collection efficiency (FCE) from Kock et al. 20

Forebay size for application of the Kock et al. regression model was estimated following the methods described by Kock et al. (2019). An FSS has been designed for Detroit and for Cougar; however, FSS's are also measures proposed for several other projects for the Willamette Systems EIS. The most relevant information about what inflows and entrance sizes may be reasonably expected comes from the design plans for Detroit and Cougar.

Forebay Size

Similar to Kock et al. (2019), effective forebay size was calculated as the water surface area from the face of the dam to the area 500m from the dam face. This was calculated for each project of interest:

Table 1-10. Effective forebay size for several Willamette Systems projects

Project	Size	Unit
Hills Creek	55.4	Ha
Green Peter	20.9	Ha
Cougar	27.6	Ha
Foster	47.9	Ha
Detroit	24.2	Ha
Lookout Point	35.4	Ha

Inflow and Entrance Specifications

We used Detroit and Cougar and scaled the designs and operations to the projects for which they were most similar.

Minimum and maximum flows through the FSS for DET and CGR were based on design flow ranges as documented in the DDRs. The FSS inflow operating range for a Hills Creek Dam FSS were assumed from the Cougar Dam FSS design, given the similarity in dam configuration and turbine capacity. Total FSS inflow capacity for GRP and LOP were determined by scaling based on the DET design flow. This was accomplished by dividing the DET total design flow by the DET turbine capacity, and then multiplying the result with the total turbine capacity flow at GRP and LOP. Due to the frequency at which flows can be less than 1000 cfs from GRP Dam, it was assumed that pumped flow would be used to supplement the FSS inflows up to 1000 cfs for the minimum FSS operating range at GRP.

Table 1-11. Detroit specifications. *

Project	Max total turbine capacity at min con	FSS V-screen design flow	Scaler (design flow / turbine capacity)
DET	4960	4600 (double barrel)	0.927

Note: * Green Peter and Lookout Point do not currently have an FSS design. Therefore, proposed FSS's at these locations were scaled to the Detroit FSS based on turbine capacity.

Table 1-12. Proposed Green Peter and Lookout FSS specifications *

Project	Max total turbine capacity at min con	DET FSS Scaler	Estimated Double V-screen design flow	Total V-screen design flow assumed for EIS
LOP	8100	.927	7509	6000
GPR	4420	.927	4097	4000

Note: * Proposed FSS specifications for Green Peter and Lookout scaled to the Detroit FSS design.

Adjusted down design flow, based on Kock et al. 2019 model of FSC fish guidance efficiency indicating efficiency would be high assuming a double V-screen designed of 6000 cfs.

Min con = Minimum Conservation Pool.

Table 1-13. Minimum and maximum flows through each FSS structure by project *

Project	Minimum FSS flow *	Maximum FSS flow *	Notes
Detroit FSS[1]	1000	5600	Per Detroit DDR
Cougar FSS[2]	300	1000	Per Cougar DDR
Green Peter FSS	1000	4000	Based on DET FSS scaler * GPR turbine capacity (See table above)
Lookout Pt FSS	1350 (equivalent to cavitation limit for DEX)	6000	Based on DET FSS scaler * LOP turbine capacity, adjusted based on Kock et al. FSC model (see table above)
Hills Creek FSS	300	1000	Assumed from CGR DDR

Notes: 1 Detroit FSS: There are two entrances in the FSS, capable of handling flow ranges from 1,000 cfs to 5,600 cfs. The design flow rate for fish collection operations is 4,500 cfs, with each channel operating at a flow of 2,250 cfs. Future provisions for pumped attraction flow will accommodate 1,000 cfs to drive flow through the FSS and continue attracting and collecting fish from the forebay. – per Final DDR.

2 Cougar FSS: There are two entrances on the Dual Entrance Angled FSS, with the starboard collection channel sized to pass 400 cubic feet per second (cfs) and the port collection channel sized to pass 600 cfs. Including two entrances instead of only one allows for better control of hydraulic conditions over the full range of design flows (300 to 1,000 cfs). – per 90% DDR.

* Flows are in cubic feet per second (cfs).

We applied these scalers at other projects of interest. Entrance size for a conceptual FSS at Hills Creek Dam was assumed from the Cougar Dam FSS design given the similarity in dam configuration and turbine capacity. These scaled relationships provided the most likely dimensions for an FSS at each project of interest based on available information (Table 4). Due to the frequency at which flows can be less than 1000 cfs from Green Peter Dam, it was assumed that pumped flow would be used to supplement the FSS inflows up to 1000 cfs for the minimum FSS operating range at GRP.

Table 1-14. Estimated dimensions of FSS entrances, minimum, and maximum outflow capacities. *

Project	Entrance area	Maximum FSS flow	Minimum FSS Flow
DET FSS	1776	5600	1000
GPR FSS	1268	4000	1000
LOP FSS	1902	6000	1350
CGR FSS	1938	1000	300
HCR FSS	1938	1000	300

Note: * Dimension estimates are based on turbine capacities and the relationship between entrance size and inflows.

Dimensions are indicated in Imperial units (square feet) but were converted to Metric for use in the log regression.

* Flows are in cubic feet per second (cfs).

It is important to note that entrance area is given for two flumes operating. When the FSS is operated at minimum inflow, only one barrel may operate. At these times, it was assumed that the entrance area is reduced by half. To investigate what flows were most likely at each project, we examined Res-Sim output for the period of record during peak fish passage times: April 1 – July 1 and September 1 to December 1. We developed a frequency distribution by binning dam discharge by 100 cfs increments. If the most frequently occurring flow was less than two times the minimum flow at a given project, we assumed single barrel operation and reduced the entrance size by half.

FCE Calculator

Once we had calculated the dimensions of each potential collector, we used these in the log-linear regression model from Kock et al. We adapted a spreadsheet "FCE Calculator" which captures the regression coefficients and log transformations to predict DPE.

Logistic regression equation for factors affecting FCE (from Kock et al. 2019)

$$lp = c_1 + c_2 \cdot I_{coho} + c_3 \cdot I_{sockeye} + c_4 \cdot I_{steelhead} + c_5 \cdot L + c_6 \cdot F + c_7 \cdot A + c_8 \cdot E + c_9 \cdot A \cdot E$$

$$FCE = \frac{\exp(lp)}{1 + \exp(lp)}$$

Figure 1-1. Logistic regression equation used to predict DPE *(indicated as FCE, here)*.

The spreadsheet calculator allows the user to input their own values into the regression. These values are standardized per Kock et al. using the mean and standard error from their hierarchical analysis. Since data do not currently exist for collectors in the Willamette, we used the mean and standard deviation of multiple collectors evaluated in Kock et al. (see Supplement 3 in Kock et al. 2019) to approximate a standardized estimate (ie, $\frac{x-\bar{x}}{sd}$). These standardized inputs are then log transformed and imputed to the log regression equation for each proposed collector. The regression result (*lp*) must be untransformed from log space to provide DPE, here indicated as *FCE* in the reference text. All inputs were converted to Metric prior to analysis.

Table 1-15. Example of FCE calculator run. *

Variables	Coefficient	To Equation	Input Values
c_1 (Chinook salmon) =	-0.923	1	1
c_2 (coho salmon) =	0.876	0	0
c_3 (sockeye salmon) =	0.631	0	0
c_4 (steelhead) =	1.474	0	0
c_5 Lead nets =	0.848	0	0
c_6 Inflow =	0.492	1.392	28.316847
c_7 Effective forebay area =	-1.086	0.567	24.2
c_8 Entrance area =	0.991	-0.408	82.497864
c_9 Effective forebay area x entrance area =	2.112	-2.273	n/a

Notes: Users may input data into the white cells. Blue cells carry user inputs, log transform, standardize, and pass to the logistic regression (red cells). Lp is the log transformed DPE whereas FCE is the untransformed result.

lp = 0.279; FCE = 0.569

Calculation and justification for inflows through each collector

The FCE calculator was used to predict DPE for each structure where an FSS is proposed in Alternatives 1 and 4. Although the model is informative in that it can integrate information from very different collector types based on specific design features common to all collectors, the model assumes constant inflow through the collector. There are two main reasons that we expect variable inflows through proposed collectors: 1) The USACE conducts power peaking at several projects (Green Peter, Lookout Point, and Detroit dams) where hourly outflows change dramatically over the course of 24 hours, and 2) available water in a given year does not necessarily support the hypothesis that the collector would run at optimal capacity at all times.

To evaluate what flows might be expected, we examined the frequency of the daily average outflows predicted by Res-Sim and binned by 100 cfs intervals, under alternatives 1 and 4. As expected, the most frequently occurring outflows were substantially less than the optimal capacity assumed for each collector. In some cases, the flows were below the capacity needed to run even one barrel of an FSS. In these cases, we assumed supplemental pumps would be required to increase the inflow to minimum operating capacity (one barrel); however, at power peaking projects, the daily average may not accurately reflect hours of the day when inflows could also be quite high.

We used hourly outflow information from DBQuery to determine hourly outflow pattens in a deficit, sufficient, and adequate year type. Each year was then divided into different fish passage seasons: spring (April 1-July 1) and fall (September 1-December 1). We calculated the quantiles for hourly outflows (Table 1-16) and plotted the median hourly outflow by season (Figure 1-2).

Table 1-16. Detroit Abundant Year (2011) Spring and Fall Hourly Outflow Quantiles. *

Season	0%	25%	50%	75%	100%
Spring	0	0	1.97	2.075	4.38
Fall	0	0	1.95	2.14	5.21

Note: * Quantiles for hourly outflows at Detroit in an abundant year type (2011) in the spring and fall.

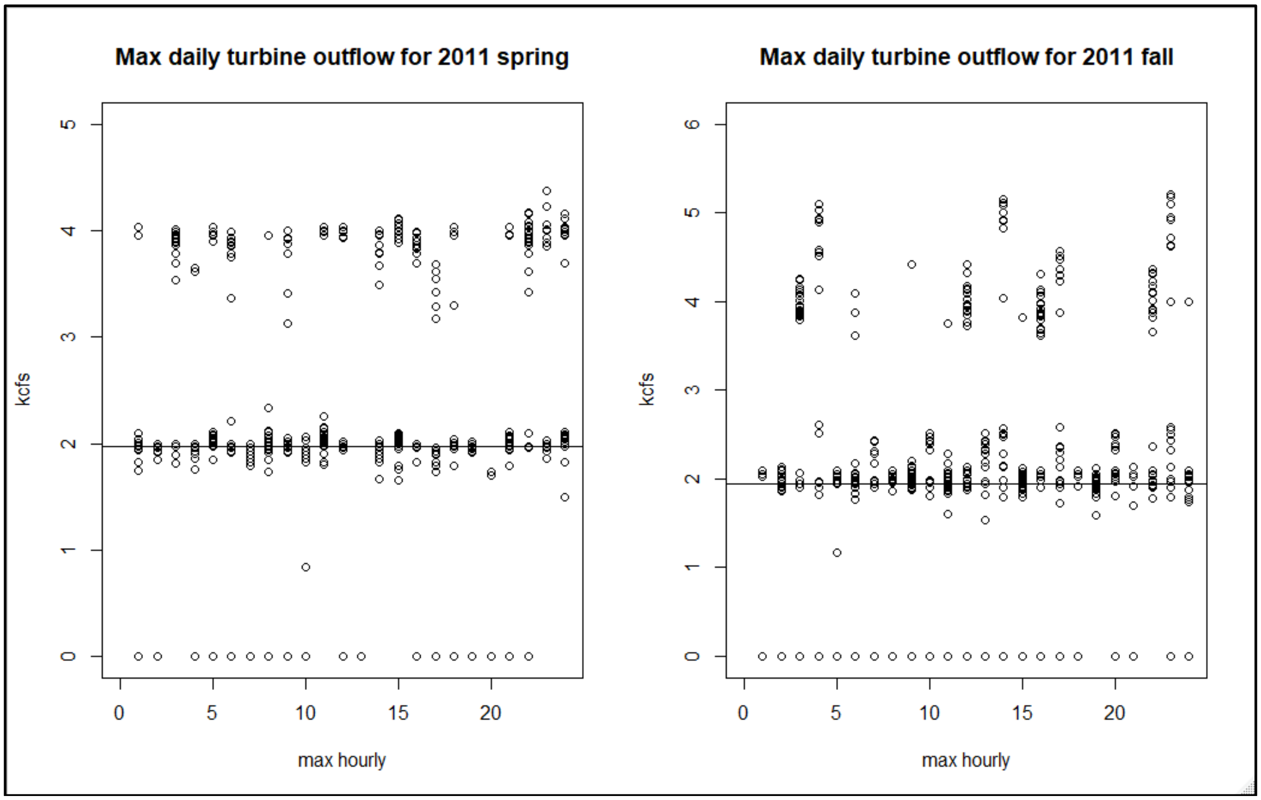

Figure 1-2. Detroit Spring and Fall Median Abundant Water Year Hourly Outflows. *Detroit Spring (Left) and Fall (Right) Median Abundant Water Year Hourly Outflows. The open dots represent the median hourly outflow. The solid line represents the median outflow for all data points.*

In general, less than 25% of the hourly outflow data was above the optimal inflow capacity for Detroit. We show the abundant year type here to demonstrate that even under ideal conditions, the FSS would still operate below optimal capacity for most of the time. Therefore, we deemed it inappropriate to assume optimal capacity. We consulted with the Kock et al. team to help determine reasonable inflows. The team agreed, it would be inappropriate to assume optimal capacity most of the time. They indicated that it was more reasonable to use the most frequently occurring daily outflow from Res-sim--with the caveat that the PDT should consider limiting power peaking at night when fish are most likely to pass and when variable flows would have the greatest impact of DPE. Furthermore, the team believed that the orientation of the collector (parallel to the dam face rather than perpendicular) would likely act as an efficient guidance structure and recommended utilizing the model coefficient for guide nets (see Kock et al. 2019).

We incorporated these suggestions into the current FCE calculator used to estimate DPE (see FBW, Appendix A sent to Cooperators on 03 June 2021). The results for DPE are presented with and without guide nets (see example in Table 1-17). In general, DPE improved 25%-30% when fish guidance considerations were included.

Table 1-17. Dam Passage Efficiency calculation for an FSS at Detroit for Alternative 4. *

Variables	Coefficient	To equation	Input values
c_1 (Chinook salmon) =	-0.923	1	1
c_2 (coho salmon) =	0.876	0	0
c_3 (sockeye salmon) =	0.631	0	0
c_4 (steelhead) =	1.474	0	0
c_5 Lead nets =	0.848	1	1
c_6 Inflow =	0.492	1.467	29.73269
c_7 Effective forebay area =	-1.086	0.567	24.2
c_8 Entrance area =	0.991	-0.408	82.49786
c_9 Effective forebay area x entrance area =	2.112	-2.273	n/a

Notes: Estimates are for Chinook. The cells in red represent that log probability and DPE assuming a guidance structure.

lp = 1.353 ; FCE = 0.795; W/O LN = 0.587; percent change = 0.261289

Dam Passage Efficiencies for Alternative 1

Chinook

Table 1-18. Dam Passage Efficiency calculation for an FSS at Detroit under Alternative 1

Variables	Coefficient	To equation	Input values
c_1 (Chinook salmon) =	-0.923	1	1
c_2 (coho salmon) =	0.876	0	0
c_3 (sockeye salmon) =	0.631	0	0
c_4 (steelhead) =	1.474	0	0
c_5 Lead nets =	0.848	1	1
c_6 Inflow =	0.492	1.392	28.316847
c_7 Effective forebay area =	-1.086	0.567	24.2
c_8 Entrance area =	0.991	-0.408	82.497864
c_9 Effective forebay area x entrance area =	2.112	-2.273	n/a

Notes: lp = 1.279; FCE = 0.782.

Table 1-19. Dam Passage Efficiency calculation for an FSS at Green Peter under Alternative 1

Variables	Coefficient	To equation	Input values
c_1 (Chinook salmon) =	-0.923	1	1
c_2 (coho salmon) =	0.876	0	0
c_3 (sockeye salmon) =	0.631	0	0
c_4 (steelhead) =	1.474	0	0
c_5 Lead nets =	0.848	1	1
c_6 Inflow =	0.492	1.392	28.316847
c_7 Effective forebay area =	-1.086	0.638	20.9
c_8 Entrance area =	0.991	-0.582	58.900502
c_9 Effective forebay area x entrance area =	2.112	-2.273	n/a

Notes: lp = 1.175; FCE = 0.764

Table 1-20 Dam Passage Efficiency calculation for an FSS at Cougar under Alternative 1.

Variables	Coefficient	To equation	Input values
c_1 (Chinook salmon) =	-0.923	1	1
c_2 (coho salmon) =	0.876	0	0
c_3 (sockeye salmon) =	0.631	0	0
c_4 (steelhead) =	1.474	0	0
c_5 Lead nets =	0.848	1	1
c_6 Inflow =	0.492	0.615	16.9901082
c_7 Effective forebay area =	-1.086	0.495	27.6
c_8 Entrance area =	0.991	0.310	180.046014
c_9 Effective forebay area x entrance area =	2.112	-2.273	n/a

Note: lp = 1.147; FCE = 0.759

Table 1-21. Dam Passage Efficiency calculation for Lookout Point FSS at under Alternative 1

Variables	Coefficient	To equation	Input values
c_1 (Chinook salmon) =	-0.923	1	1
c_2 (coho salmon) =	0.876	0	0
c_3 (sockeye salmon) =	0.631	0	0
c_4 (steelhead) =	1.474	0	0
c_5 Lead nets =	0.848	0	0
c_6 Inflow =	0.492	1.849	38.22774345
c_7 Effective forebay area =	-1.086	0.329	35.4
c_8 Entrance area =	0.991	-0.365	88.350753
c_9 Effective forebay area x entrance area =	2.112	-2.273	n/a

Note: lp = 0.541; FCE = 0.632

Table 1-22. Dam Passage Efficiency calculation for an FSS at Hills Creek under Alternative 1.

Variables	Coefficient	To equation	Input values
c_1 (Chinook salmon) =	-0.923	1	1
c_2 (coho salmon) =	0.876	0	0
c_3 (sockeye salmon) =	0.631	0	0
c_4 (steelhead) =	1.474	0	0
c_5 Lead nets =	0.848	1	1
c_6 Inflow =	0.492	0.177	12.74258115
c_7 Effective forebay area =	-1.086	-0.096	55.4
c_8 Entrance area =	0.991	0.310	180.046014
c_9 Effective forebay area x entrance area =	2.112	-2.273	n/a

Note: lp = 0.119; FCE = 0.530

Steelhead

Table 1-23. Dam Passage Efficiency calculation for an FSS at Detroit under Alternative 1.

Variables	Coefficient	To equation	Input values
c_1 (Chinook salmon) =	-0.923	1	1
c_2 (coho salmon) =	0.876	0	0
c_3 (sockeye salmon) =	0.631	0	0
c_4 (steelhead) =	1.474	1	1
c_5 Lead nets =	0.848	1	1
c_6 Inflow =	0.492	1.392	28.316847
c_7 Effective forebay area =	-1.086	0.567	24.2
c_8 Entrance area =	0.991	-0.408	82.497864
c_9 Effective forebay area x entrance area =	2.112	-2.273	n/a

Notes: lp = 2.279; FCE = 0.907

Table 1-24. Dam Passage Efficiency Calculation for a Green Peter FSS Under Alternative 1.

Variables	Coefficient	To equation	Input values
c_1 (Chinook salmon) =	-0.923	1	1
c_2 (coho salmon) =	0.876	0	0
c_3 (sockeye salmon) =	0.631	0	0
c_4 (steelhead) =	1.474	1	1
c_5 Lead nets =	0.848	1	1
c_6 Inflow =	0.492	1.392	28.316847
c_7 Effective forebay area =	-1.086	0.638	20.9
c_8 Entrance area =	0.991	-0.582	58.900502
c_9 Effective forebay area x entrance area =	2.112	-2.273	n/a

Notes: lp = 2.175; FCE = 0.898

Dam Passage Efficiencies for Alternative 2 –

To be inserted after alternative description completed and RES-SIM hydrology results available

Dam Passage Efficiencies for Alternative 3a and 3 b–

To be inserted after alternative description completed and RES-SIM hydrology results available

Dam Passage Efficiencies for Alternative 4 –e

To be inserted after alternative description completed and RES-SIM hydrology results available

Chinook

Table 1-25. Dam Passage Efficiency calculation for a Lookout Point FSS under Alternative 4.

Variables	Coefficient	To equation	Input values
c_1 (Chinook salmon) =	-0.923	1	1
c_2 (coho salmon) =	0.876	0	0
c_3 (sockeye salmon) =	0.631	0	0
c_4 (steelhead) =	1.474	0	0
c_5 Lead nets =	0.848	1	1
c_6 Inflow =	0.492	2.932	77.87132925
c_7 Effective forebay area =	-1.086	0.329	35.4
c_8 Entrance area =	0.991	0.286	176.701506
c_9 Effective forebay area x entrance area =	2.112	-2.273	n/a

Note: lp = 3.274; FCE = 0.964

Table 1-26. Dam Passage Efficiency calculation for a Detroit FSS under Alternative 4

Variables	Coefficient	To equation	Input values
c_1 (Chinook salmon) =	-0.923	1	1
c_2 (coho salmon) =	0.876	0	0
c_3 (sockeye salmon) =	0.631	0	0
c_4 (steelhead) =	1.474	0	0
c_5 Lead nets =	0.848	1	1
c_6 Inflow =	0.492	1.467	29.73269
c_7 Effective forebay area =	-1.086	0.567	24.2
c_8 Entrance area =	0.991	-0.408	82.49786
c_9 Effective forebay area x entrance area =	2.112	-2.273	n/a

Note; lp = 1.353; FCE = 0.795

Table 1-27. Dam Passage Efficiency calculation for an FSS at Hills Creek under Alternative 4.

Variables	Coefficient	To equation	Input values
c_1 (Chinook salmon) =	-0.923	1	1
c_2 (coho salmon) =	0.876	0	0
c_3 (sockeye salmon) =	0.631	0	0
c_4 (steelhead) =	1.474	0	0
c_5 Lead nets =	0.848	1	1
c_6 Inflow =	0.492	0.177	12.74258115
c_7 Effective forebay area =	-1.086	-0.096	55.4
c_8 Entrance area =	0.991	0.310	180.046014
c_9 Effective forebay area x entrance area =	2.112	-2.273	n/a

Note: lp = 0.119; FCE = 0.530

Table 1-28. Dam Passage Efficiency calculation for an FSS at Cougar under Alternative 4.

Variables	Coefficient	To equation	Input values
c_1 (Chinook salmon) =	-0.923	1	1
c_2 (coho salmon) =	0.876	0	0
c_3 (sockeye salmon) =	0.631	0	0
c_4 (steelhead) =	1.474	0	0
c_5 Lead nets =	0.848	1	1
c_6 Inflow =	0.492	1.314	26.90100465
c_7 Effective forebay area =	-1.086	0.495	27.6
c_8 Entrance area =	0.991	0.310	180.046014
c_9 Effective forebay area x entrance area =	2.112	-2.273	n/a

Note: lp = 1.847; FCE = 0.864

Table 1-29. Dam Passage Efficiency calculation for an FSS at Detroit under Alternative 4

Variables	Coefficient	To equation	Input values
c_1 (Chinook salmon) =	-0.923	1	1
c_2 (coho salmon) =	0.876	0	0
c_3 (sockeye salmon) =	0.631	0	0
c_4 (steelhead) =	1.474	1	1
c_5 Lead nets =	0.848	1	1
c_6 Inflow =	0.492	1.467	29.73269
c_7 Effective forebay area =	-1.086	0.567	24.2
c_8 Entrance area =	0.991	-0.408	82.49786
c_9 Effective forebay area x entrance area =	2.112	-2.273	n/a

Note: lp = 2.353; FCE = 0.913

Supporting Information for Biological Input Parameters Used for Modeling of the Willamette Valley System EIS Downstream Fish Passage Measures in the Fish Benefit Workbook (FBW)

1.2 - WINTER STEELHEAD -

1.2.1 DETROIT & BIG CLIFF

Assumptions:

- Steelhead lifestages
  - Fry/early parr (June, year-0 to December, year - 0)
  - Parr (December, year-0 to December, year - 1)
  - Smolt (December, year-1 to December, year - 2).
- Mortality for Big Cliff reservoir and dam is 15% as utilized in the Engineering Design Report (EDR) for Detroit fish passage (USACE 2017a).
- Baseline includes spilling for temperature management, which is equivalent to the spring spill measure 714. It is assumed that these measures are identical.

No Action Alternative (i.e. Baseline) / Measure 714 (Use spillway to pass fish in the spring).

Run Timing –

Downstream juvenile winter steelhead passage timing data for Detroit reservoir and dam is limited to studies which released artificially reared surrogates artificially reared from wild winter steelhead brood. Therefore timing inputs were developed by review of information from Green Peter and Foster dams where study of wild juvenile steelhead downstream passage has occurred. Romer et al. (2016) described that the "Typical life-history patterns observed for naturally-produced winter steelhead are dominated by age-2 smolts in the Columbia and Snake rivers as well as coastal Oregon streams (Busby et al. 1996). In the South Santiam River, juvenile O. mykiss migrate into Foster Reservoir at age-0, age-1, or age-2 and rear for a variable amount of time before exiting the reservoir. In the spring, only age-1 and age-2 fish are present in the basin. The first age-0 juveniles typically begin entering the reservoir in late June soon after emergence, and this age-class continues to enter the reservoir through the rest of the year (Romer et al. 2015). Juveniles can exit Foster Reservoir at any of the three age-classes, although age-2 smolts are the primary age class that continues to the Columbia River estuary (discussed later in this report)". Passage patterns observed at Green Peter Dam however we assume are more representative of how steelhead would be expected to use Detroit Reservoir, given both are larger than Foster Reservoir and operated for flood risk management. Wagner and Ingram (1973) observed that 69-88% of the juvenile winter steelhead passing downstream at Green Peter Dam in April and May. We calculated percentages observed monthly from Table 9 in Wagner and Ingram (Table 1-30, below) and used this as the primary basis for passage assumptions at Detroit and Green Peter dams. The average annual size of emigrating steelhead during the years 1969 to 1971 ranged from 176 mm to 197 mm. We assumed some age-0's would pass in their first summer but most in their first fall/winter; and that age-1's and age-2's would pass in spring. Information from studies of passage of winter steelhead at Foster Dam (Monzyk et al. 2017, Romer et al. 2017), and passage of tagged juvenile winter steelhead artificially reared and released into Detroit Reservoir (Beeman et al. 2013; Johnson et al. 2016) support the assumption that most juvenile winter steelhead would pass Detroit Dam in spring.

Table 1-30. Green Peter Dam Wild Reared Steelhead 1968-1971. *

Month	1968	1969	1970	1971	Avg
Jan	0%	3%	1%	0%	1%
Feb	nd	0%	3%	2%	2%
Mar	nd	3%	12%	1%	6%
Apr	24%	32%	30%	27%	28%
May	60%	43%	39%	61%	51%
Jun	10%	18%	13%	9%	12%
Jul	1%	0%	0%	0%	0%
Aug	nd	nd	nd	nd	nd
Sep	nd	nd	nd	nd	nd
Oct	0%	0%	0%	0%	0%
Nov	0%	0%	1%	0%	0%
Dec	4%	1%	0%	0%	1%

Notes: * Percentages of wild reared juvenile winter steelhead enumerated at the juvenile evaluation station at Green Peter Dam prepared from catch data in Table 9 from Wagner and Ingram (1973).

ND = no data.

The percentages of wild juvenile winter steelhead passing Green Peter Dam in 1969-1971 is very consistent with patterns of juvenile steelhead collected in the lower Santiam (Whitman et al. 2017; see Figure 5). Monitoring of wild juvenile winter steelhead migrating downstream into Foster Reservoir and passage Foster Dam although showed the majority of wild juvenile winter steelhead emigrate into Foster Reservoir as age-0 in early summer, most passed downstream at Foster Dam at Age 2 primarily in the spring (Monzyk et al. 2017). Romer et al. (2017) reports migration timing from screwtrapping into Foster Reservoir consistent with Monzyk et al. (2017), however screwtrapping below Foster Reservoir was found unreliable for assessing timing of wild juvenile winter steelhead since the trap did not collect fish passing over the spillway. Therefore, we adopted the monthly averages for Age 1 and Age 2 steelhead calculated from Wagner and Ingram.

For Age-0, we applied above reservoir catch patterns reported by Romer et al. (2017; see Figure 15), showing most Age-0 entering between July and December with most in August to October. However, Hughes et al. (2017) provided reservoir residency time for active tagged juveniles of up to 3 weeks in Foster Reservoir. Due to the larger size of Detroit Reservoir and smaller size of age-0 fry, we shifted the timing of reservoir entry one month forward, to account for reservoir residency and rearing of Age-0 steelhead prior to arrival in the dam forebay and their availability to pass downstream.

Comparison or run-timing information:

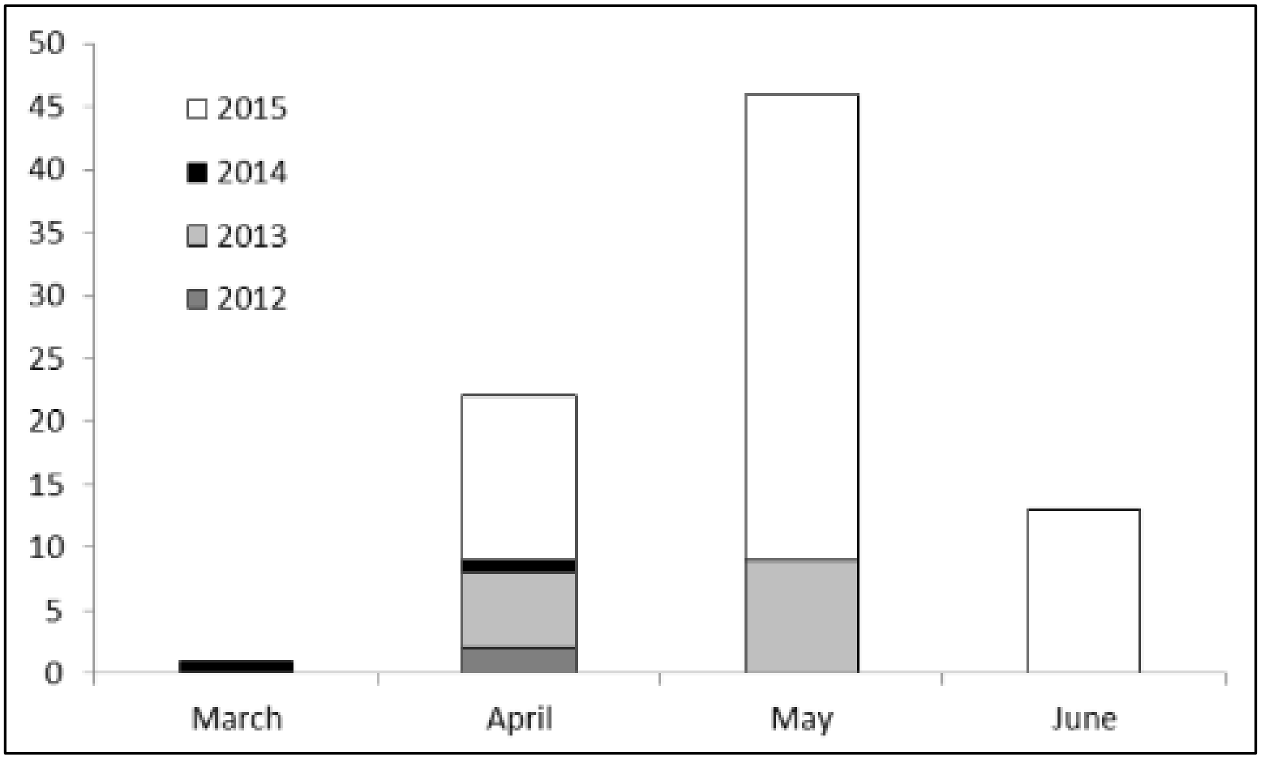

Figure 1-3. Monthly Steelhead smolt detections at Willamette Falls or the Columbia Estuary. *Steelhead smolt detections by month (N-82) at Willamette Falls or the Columbia Estuary during seaward migration. Year corresponds to the year of migration (or detection), not to year tagged (Romer et al. 2016; Figure 15).*

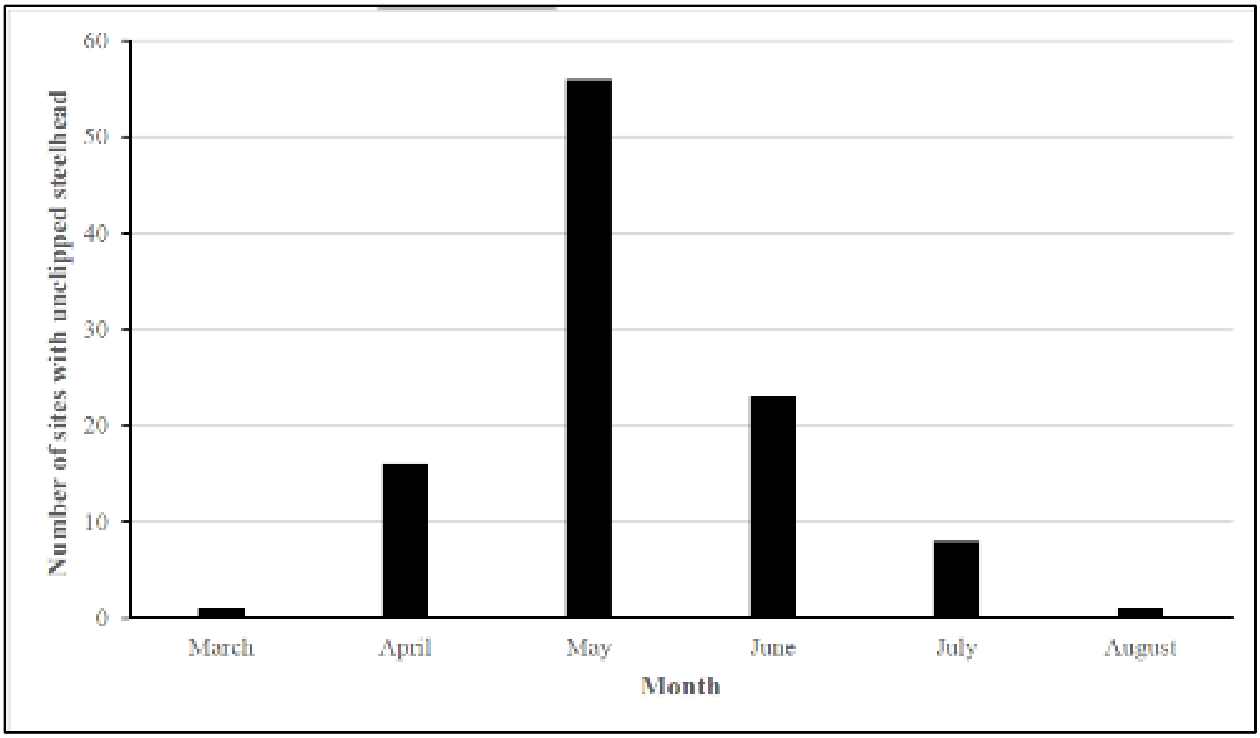

Figure 1-4. Scinc sites where unclipped juvenile steelhead were present, by Month. *Figure 5 from Monzyk et al. (2017)*

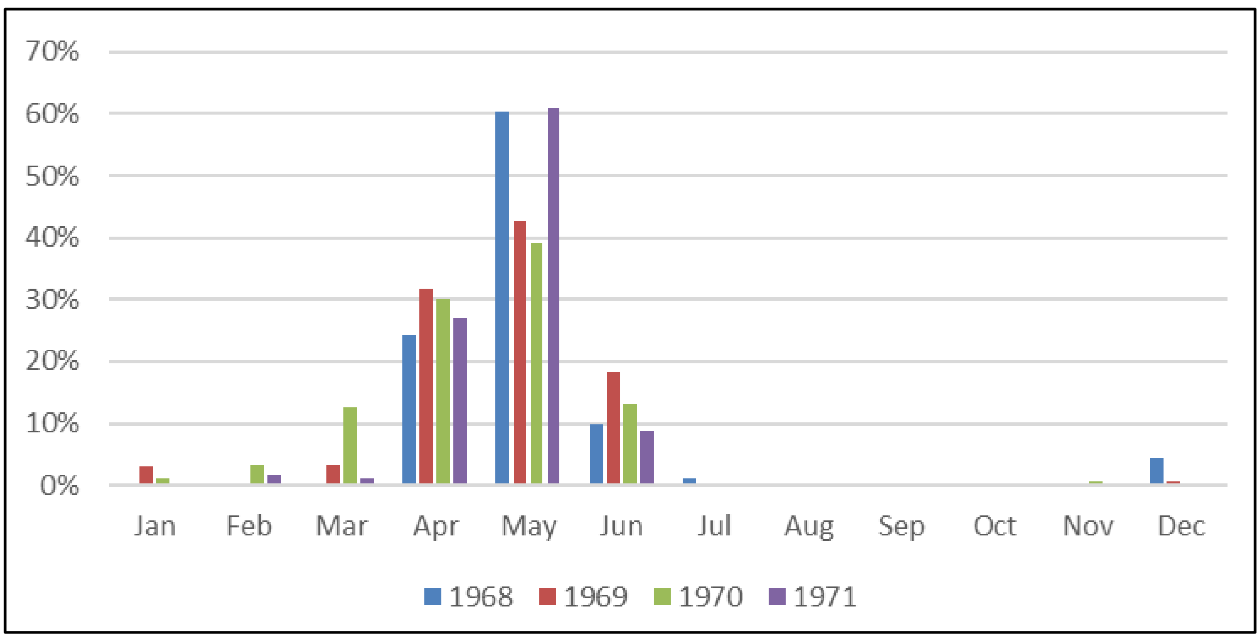

Figure 1-5. Juvenile Winter Steelhead Downstream Passage at Green Peter Dam. *Figure reproduced from data in Table 9, Wagner and Ingram (1973).*

Dam Passage Efficiency –

Beeman and Adams (2015) estimated DPE for steelhead in spring 2013 at Detroit Dam at 0.678, during which time all active tagged steelhead passed over the spillway which was operating through much of the study period. Their study also released active tagged steelhead in the fall, however no steelhead passed Detroit Dam during the fall study period when the reservoir was being drafted down to the minimum conservation pool elevation. As summarized by Beeman and Adams (2015), “The near lack of passage of tagged steelhead during the fall study period may be related to the use of a summer-run stock, but results from tagged winter-run steelhead at Foster Dam were similar to those we report, suggesting it is a seasonal phenomenon”.

Evaluations of juvenile steelhead passage at Foster Dam shows a strong preference for surface routes. Liss et al. (2020) estimated DPE from active tag hatchery steelhead (both summer and winter run) released into Foster Reservoir).

The fish weir provides a passage route downstream at the water surface and was modified in 2018. Other outlets at Foster Dam (spillbays and turbine penstocks) require fish to pass at different depths depending on the reservoir surface elevation. During low pool conditions of the Liss et al. study, with the new weir operating in 2018, DPE ranged from 0.43–0.53 for steelhead. The pool surface elevation was about 613’, with depths to the spillway crest of about 16’ and to the top of the turbine penstock of about 22’. For high pool operation in summer, also with the new weir operating, DPE for steelhead was 0.38.

Nearly all steelhead that passed downstream used the weir during the high pool study period. The pool elevation was about 635’, with depths to the spillway crest of about 38’ and to the top of the turbine penstock about 44’. Based on the combination of Beeman and Adams (2015) estimate for DPE at Detroit when above the spillway crest, the DPE estimates for Foster Dam from Liss et al, and Chinook DPE estimates for water depths to outlets beyond those covered by the previous references, we applied the Table 1-31 DPE estimates for Detroit Dam:

Table 1-31. Steelhead DPE estimates for Detroit Dam.

Pool Elevation	DPE	Note
1574	0.48	Max pool. 33' over spillway crest. Depth to top of outlet shallower than 33’ but depends on gate opening. Used the mid-value of .48 from the Foster DPE range of .43-.53 from Liss et al 2020, and no competing flows present
1557	0.68	15’ over spillway crest. Used Beeman and Adams DPE estimate since moderate depth to outlet and no competing flows present.
1541	0.68	Spillway crest. Used Beeman and Adams DPE estimate since shallow depth to outlet and no competing flows present.
1540	0.03	140’ over top of penstock. Value from Chinook DPE inputs.
1500	0.48	50’ over top of penstock. Used the mid-value of .48 from the Foster DPE range of .43-.53 from Liss et al 2020, and no competing flows present
1450	0.68	25' over top of penstock. Used Beeman and Adams 2015 DPE estimate since shallow depth to outlet.
1424	0.24	1 ft below min power pool. 74' over top of RO
1400	0.48	50’ over top of RO. Used the mid-value of .48 from the Foster DPE range of .43-.53 from Liss et al 2020, and no competing flows present
1375	0.68	25' over top of RO
1340	0.68	Upper RO. Used Beeman and Adams DPE estimate since shallow depth to outlet.

Route Effectiveness –

The Beeman and Adams 2015 report of the 2013 study included a spillway effectiveness value of 2.92 for steelhead released into tributaries above Detroit Reservoir, and 8.84 for fish released into the head of Detroit Reservoir (but there were few fish from which to make the estimate). Therefore’ an average of the two estimates, weighted by the sample size, was used of 3.74 for the spillway RE value. In the 2013 study, no steelhead passed downstream when the pool was below the spillway crest during the fall study and therefore RE values were applied from Alden 2014 for the RO and turbines. The turbine RE value recommended by Alden of 1.16 for Detroit Dam is similar to their recommended RE value for Foster turbines of 1.0. Having the RO as a lower RE value of 0.542 at flow ratios of less than one makes sense, since this would occur when turbines are also operating at a much shallower depth.

Route Survival –

For turbines and ROs, applied the same values used in Alden (2014) for this dam. For spillway survival, Beeman et al. (2015) estimated survival at Detroit Dam of 0.78 (range 0.70 to 0.95) for active-tagged juveniles with a size representative of parr and smolt. Since tagged fish passed over the spillway in this study we are applying the estimate of 0.78 for Detroit spillway for all lifestages of juvenile winter steelhead, also assuming age-0 survival would be this rate or higher due to their smaller size.

Measure 392+105: FSS with SWS

Flow range determined in the Detroit Design Documentation Report (DDR) for the Floating Screen Structure (FSS) is 1,000 – 5,600 CFS, with all flow to the Selective Withdrawal Structure (SWS) going through FSS to avoid competing flow. Above 5,600 through the FSS we are not in NMFS fry criteria anymore and would want lower survival for fry -- here we assume that above 5,600, water would be drawn in from a low-level inlet and assume no fish in that part of the water column.

Run Timing –

We adjusted timing to align with average monthly surface spill operations in spring to account for the increased attraction from surface spill. For measure 392, we adjusted baseline run timing back one month, assuming more normative run timing for all life stages with an FSS operating throughout the year when above the minimum conservation pool elevation.

Dam Passage Efficiency –

Above minimum conservation pool– DPE within the pool elevation operating range of the FSS was estimated separately for each alternative. The method and results are described in Appendix A of this document.

Table 1-32. Dam Passage Efficiency values by Alternative.

Alternative	DPE within the FSS pool elevation operating range
1	.907
2a and 2b	.94
3a and 3b	Not applicable
4	.91

Note: Dam Passage Efficiency, below minimum conservation pool - applied DPE values from DET baseline.

Route Effectiveness –

Applied same values as used for baseline RE for existing routes. For the FSS per measure 392, applied the Applied Alden (2014) value of 13.11. Alden provided the rationale for the 13.11 value stating "steelhead collection effectiveness for surface type collectors and bypasses in the Columbia and Snake Rivers ranged from 5.3-24.6, with an average of 13.11 (See table in spreadsheet). This value was based on a flow ratio of 0.04. The 13.11 value was used for all flow ratios. At a flow ratio of 0.2 through the FSS the 13.11 value results in 78% of the steelhead entering the collector".

Route Survival –

98% for all life stages for the fish passage route (FSS). Other routes same as baseline. The FSS is assumed to have a passage survival of 98% for all target species collected, based on structures operating in the Northwest similar to the FSS concepts being considered for the WVS EIS (see USACE 2015 section 2.5.5).

Measure 40 – Deep fall drawdown to 10ft over the top of the upper RO's – Target start date 15 Nov and maintained for three weeks.

Run Timing –

Same as baseline.

Dam Passage Efficiency –

Same as baseline.

Route Effectiveness –

Same as baseline.

Route Survival –

Same as baseline.

Measure 720: Spring delay refill with target elevation at 10' over the top of the upper RO's. May 1 to May 21 at target elevation.

Run Timing –

Same as Measure 392.

Dam Passage Efficiency –

Same as baseline.

Route Effectiveness –

Same as baseline.

Route Survival –

Same as baseline.

1.2.2 FOSTER

- Baseline includes spilling for temperature management, which is equivalent to the spring spill measure 714. It is assumed that these measures are identical.
- Lifestage definitions same as DET

Baseline

Run Timing –

Information from Romer et al. (2017) and previous reports from their screw trap monitoring efforts consistently show the majority of juvenile wild winter steelhead that enter Foster reservoir are age-0 fish while age-2 fish appear to comprise the majority of fish exiting the reservoir. Romer et al. points out that this suggests that the reservoir serves as rearing habitat for a large portion of the juvenile population. Therefore, the above reservoir screwtrap data is not necessarily representative of timing of passage from Foster Reservoir to downstream of Foster Dam. The below Foster Dam screwtrap operated for a few years below the turbines also may be of limited value since most steelhead prefer to pass over the fishweir or the spillways. However, Monzyk et al. (2017) reported that travel time from Foster Dam to Willamette Falls was about 6 days (based on PIT detections), and therefore Willamette Falls Passage timing would be reasonable for estimating monthly Foster Dam passage timing. They reported detections of PIT tagged juvenile steelhead, that were released above Foster Dam, occurred March to June at Willamette Falls with a monthly pattern very similar to that observed by Wagner and Ingram (1973) for Green Peter Dam passage (see comparison of run timing in figures presented above for Detroit Run Timing). Therefore, we used the same run timing applied for Green Peter Dam for Foster Dam.

Dam Passage Efficiency –

Applied data from Liss et al. (2020). The fish weir provides a passage route downstream at the water surface. Other outlets require fish to pass at variable depths. During low pool, with the new weir operating in 2018, DPE ranged from 0.43–0.53 for steelhead. The pool elevation was about 613’, with depths to the spillway crest of about 16’ and to the top of the turbine penstock about 22’. For high pool operation in summer, with the new weir operating in 2018, DPE for steelhead was 0.38. Nearly all steelhead that passed downstream used the weir during the high pool study period. The pool elevation was about 635’, with depths to the spillway crest of about 38’ and to the top of the turbine penstock about 44’. We assumed the lower end of the DPE range of estimates for a high pool DPE, the higher end of the DPE estimates for the low pool DPE and applied a value from the middle of the DPE estimate range for an elevation between low and high pool. We did not distinguish DPE among parr and smolt lifestages assuming the active tag data are applicable to both parr and smolts. We assumed fry would show a similar preferences for passing at lower pool elevations when depths to outlets are lower.

Table 1-33. Foster Baseline Measure Dam Passage Efficiency

Pool Elevation	Fry	parr	smolt
635	0.38	0.38	0.38
623	0.43	0.43	0.43
613	0.53	0.53	0.53

Route Effectiveness –

Applied Alden (2014), which included the rationale that "Draft hydroacoustic data collected in 2013 indicate that 54% of the fish passed the dam through the weir, with 23% through the spillway. Effectiveness values were set to achieve 54% passage through the weir (fish passage structure at a flow of ratio of 20%. It was assumed that the weir passed 20% of the flow during the testing period, but this will need to be confirmed when data are available. Data is based primarily on Chinook and not steelhead. Liss et al. (2020) assessed passage efficiency of hatchery-reared winter steelhead outfitted with active tags. Average values across the three study years for fish weir effectiveness was 4.44 and was 1.97 for the spillway (see Table S.3; Liss et al. 2020, copied below). These newer data are consistent with the previous values applied by Alden for the weir and spillway of 4.8 and 2.0, respectively. However, the estimates provided by Liss et al. also show that passage effectiveness varies between low and high pool and among years.

Table 1-34. Table S.3 from Liss et al. 2020.

(Table S.3 continued)								
	STH2 – Spring						S-STH – Spring	
	2015		2016		2018		2018	
Metric	Low Pool	High Pool	Low Pool	High Pool	Low Pool	High Pool	Low Pool	High Pool
DPE	**0.432 (0.026)**	**0.762 (0.021)**	**0.529 (0.035)**	**0.667 (0.024)**	**0.464 (0.023)**	**0.378 (0.028)**	**0.439 (0.043)**	**0.519 (0.026)**
FPE	**0.355 (0.026)**	**0.749 (0.022)**	**0.375 (0.035)**	**0.649 (0.025)**	**0.319 (0.022)**	**0.371 (0.028)**	**0.341 (0.041)**	**0.517 (0.026)**
SPE || Dam	0.852 (0.034)	0.994 (0.006)	0.739 (0.053)	1.000 (0.000)	0.683 (0.032)	0.982 (0.013)	0.776 (0.055)	0.995 (0.005)
FWE || Dam	0.426 (0.048)	0.971 (0.013)	0.434 (0.060)	0.973 (0.014)	0.318 (0.032)	0.973 (0.016)	0.328 (0.062)	0.979 (0.011)
SBE || Dam	0.426 (0.048)	0.023 (0.012)	0.304 (0.055)	0.027 (0.014)	0.365 (0.033)	0.009 (0.009)	0.448 (0.065)	0.016 (0.009)
Fish Weir Effect.	2.908 (0.325)	5.992 (0.079)	4.782 (0.656)	7.353 (0.102)	2.160 (0.218)	3.430 (0.055)	2.228 (0.419)	3.451 (0.037)
Spill Bay Effect.	0.947 (0.106)	0.102 (0.050)	0.753 (0.137)	0.146 (0.072)	0.903 (0.082)	0.046 (0.046)	1.109 (0.162)	0.081 (0.046)
Spillway Effect.	1.429 (0.057)	2.534 (0.015)	1.493 (0.107)	3.120 (0.000)	1.238 (0.058)	2.037 (0.026)	1.407 (0.099)	2.064 (0.011)

Route Survival –

Applied averages of estimated survival for subs and parr for each route from Liss et al. (2020). Low and high pool survival estimates were available for yearlings, and so the average across both pool elevations was applied.

Measure 392

Run Timing –

Same as baseline.

Dam Passage Efficiency –

Measure 392 for Foster Dam is a concept of either further improving the fish weir operated in Spillbay 4 or constructing a dedicated fish collection and bypass pipe in the same vicinity as the fish weir, with either concept operating up to about 600 cfs. Until further refinement of this concept, we assumed a DPE consistent with the highest DPE measured at the dam for steelhead to date of 0.76 as reported in Table 5.6 of Liss et al. (2020).

Route Effectiveness –

Applied Alden (2014)

Route Survival –

For spillway and turbines, used same values as for baseline. For fish passage route, assumed 98%, where fish passage concept is either a modified overflow weir or a dedicated fish pipe (see USACE 2015 section 2.5.5).

1.2.3 GREEN PETER

Lifestage definitions same as DET.

Baseline

Not applicable – no fish outplanted above dam.

Measure 392: GPR FSS –

Run Timing –

Same as DET timing for Measure 392.

Dam Passage Efficiency –

DPE within the pool elevation operating range of the FSS was estimated separately for each alternative. The method and results are described in Chinook Attachment A of this Chapter. Dam Passage Efficiency values by Alternative when above minimum conservation pool.

Table 1-35. Green Peter Dam Passage Efficiency

Alternative	DPE within the FSS pool elevation operating range
1	0.898
2a and 2b	Not applicable
3a and 3b	Not applicable
4	Not applicable

Below minimum conservation pool elevations, we applied DPE values from baseline for similar depths to outlets at GPR.

Route Effectiveness –

Applied DET RE values due to similarity in dam configuration. Local data on RE for existing routes at GPR not available.

Route Survival –

Route survival was 98% for fish passage route (see USACE 2015, section 2.5.5). Spillway, turbines and RO assumed the same as DET due to similar dam configuration.

Measure 714 and 721: Spring/summer spill

Run Timing –

Applied DET baseline timing.

Dam Passage Efficiency –

Applied DPE input values developed for DET baseline adjusted for depths to outlets at GPR. Assumed highest DPE when pool surface elevation < depth over top of outlet.

Route Effectiveness –

Applied DET RE values due to similarity in dam configuration. Local data on RE for existing routes at GPR not available.

Route Survival –

Applied route survival from DET due to similarity in dam configuration. No site specific data on juvenile downstream passage survival for spillway, turbines and ROs.

Measure 40 (deep fall drawdown)

Run Timing –

Applied DET baseline timing.

Dam Passage Efficiency –

Applied DPE input values developed for DET baseline adjusted for depths to outlets at GPR. Assumed highest DPE when pool surface elevation < depth over top of outlet.

Route Effectiveness –

Applied DET RE values due to similarity in dam configuration. Local data on RE for existing routes at GPR not available.

Route Survival –

Applied route survival from DET due to similarity in dam configuration. No site specific data on juvenile downstream passage survival for spillway, turbines and ROs.

Measure 720 (spring delay refill)

Run Timing –

Applied DET baseline timing.

Dam Passage Efficiency –

Applied DPE input values developed for DET baseline adjusted for depths to outlets at GPR. Assumed highest DPE when pool surface elevation < depth over top of outlet.

Route Effectiveness –

Applied DET RE values due to similarity in dam configuration. Local data on RE for existing routes at GPR not available.

Route Survival –

Applied route survival from DET due to similarity in dam configuration. No site specific data on juvenile downstream passage survival for spillway, turbines and ROs.

REFERENCES

Alden. 2014. Willamette River Fish Benefit Workbook Parameterization: Steelhead. Memorandum to Robert Wertheimer and Richard Piaskowski, U.S. Army Corps of Engineers. Prepared by Kevin Malone, Isaac Willig, Shari Dunlop, 01 April 2014.

Beeman, J.W. and N.S. Adams, eds. 2015. In-reservoir behavior, dam passage, and downstream migration of juvenile Chinook salmon and juvenile steelhead from Detroit Reservoir and Dam to Portland, Oregon, February 2013–February 2014. U.S. Geological Survey Open-File Report 2015-1090. http://dx.doi.org/10.3133/ofr20151090.

Beeman, J. W., H. C. Hansel, A. C. Hansen, S. D. Evans, P. V. Haner, T. W. Hatton, E. E. Kofoot, J. M. Sprando and C. D. Smith. 2013. Behavior and dam passage of juvenile Chinook salmon at Cougar Reservoir and Dam, Oregon, March 2012 - February 2013. U.S. Department of the Interior, U.S. Geological Survey, Cook, Washington. Prepared in cooperation with the U.S. Army Corps of Engineers.

Hughes, J, S Liss, R Flaherty, E Fischer, B Bellgraph, C Vernon, and G Johnson. 2017. Evaluation of Juvenile Salmonid Passage and Behavior at Foster Dam Using Radio Telemetry, 2016. PNNL-26416. Final report submitted by the Pacific Northwest National Laboratory to the U.S. Army Corps of Engineers, Portland, Oregon.

Johnson, M. A., T. A. Friesen, P. M. Olmsted, and J. R. Brandt. 2016. Migration and Survival of Juvenile Steelhead Released above and below Dams in the North Santiam River. Included as an addendum to Migration, survival, growth, and fate of hatchery juvenile Chinook salmon released above and below dams in the Willamette River Basin. Annual report to the U.S. Army Corps of Engineers, Portland District. Task Order W9127N-10-2-0008-0034. Oregon Department of Fish and Wildlife, Corvallis.

Liss SA, KR Znotinas, JS Hughes, BJ Bellgraph, CR Vernon, RA Harnish, ES Fischer, and SE Blackburn. 2020. Evaluation of Foster Dam Juvenile Fish Passage, 2018. PNNL-29587. Final report submitted by the Pacific Northwest National Laboratory to the U.S. Army Corps of Engineers, Portland, Oregon.

Monzyk, F, J Romer, R, and T Friesen. 2017. Downstream Movement and Foster Dam Passage of Juvenile Winter Steelhead in the South Santiam River. Prepared for the U. S. ARMY CORPS OF ENGINEERS PORTAND DISTRICT – WILLAMETTE VALLEY PROJECT. Prepared by the Oregon Department of Fish and Wildlife Willamette Research, Monitoring, and Evaluation Program, Corvallis Research Lab, Corvallis, Oregon. Task Order Number: W9127N-10-2-008-0033. December 2017

Romer, J.D., F.R. Monzyk, R. Emig, and T.A. Friesen. 2016. Juvenile salmonid outmigration monitoring at Willamette Valley Project reservoirs. Oregon Department of Fish and Wildlife, Corvallis. Report to U.S. Army Corps of Engineers, Portland District.

Romer, J, F Monzyk, R Emig, T Friesen. 2017. Juvenile salmonid outmigration monitoring at Willamette Valley Project reservoirs. Oregon Department of Fish and Wildlife, Corvallis. Report to U.S. Army Corps of Engineers, Portland District. Task Order Number: W9127N-10-2-0008-0035. September 2017

Wagner, E, and Ingram, P. 1973. Evaluation of fish facilities and passage at Foster and Green Peter Dams on the South Santiam River drainage in Oregon. Fish Commission of Oregon, Portland.

Whitman, LD, RK Schroeder, and TA Friesen. 2017. Evaluating Migration Timing and Habitat For Juvenile Chinook Salmon And Winter Steelhead In The Mainstem Willamette River And Major Spawning Tributaries. Prepared by Oregon Department of Fish and Wildlife, Willamette Research, Monitoring, and Evaluation, Corvallis Research Laboratory, Corvallis, Oregon 97333. US Army Corps of Engineers Task Order Number W9127N-16-P-0157. Final Report, May 19, 2017.

1.2.4 STEELHEAD ATTACHMENT A

Fish Benefits Workbook (FBW) Dam Passage Efficiency (DPE) Calculations for Floating Screen Structures, Willamette Valley System EIS and ESA consultation fish effects analysis

Floating screen structures (FSS) are dynamic in that they can accommodate varying elevations while taking advantage of available outflows. The FSS design includes two screened flumes or barrels that can accommodate a wider range of inflows better than a single flume design. Data on the fish collection efficiency of these and similar structures is limited but growing. For spring Chinook salmon, a target species for passage at Willamette dams, a wide range of collection rates have been observed among floating surface collectors operating in the Pacific Northwest (Kock et al. 2019). Some of these differences would be attributable to differences in designs and local conditions, making comparisons difficult among existing surface collectors. Kock et al. (2019) used a hierarchical log-linear regression to identify which design aspects most successfully predicted dam passage efficiency. They are: effective forebay size at a distance 500 meters from the dam face (ha), entrance size (m^2), collector inflow (m^3/s), and the presence of nets that improve fish guidance or efficiency (See Table 1 adapted from Kock et al. 2019). While this model is heavily focused on physical attributes of dam configuration and proposed engineering design dimensions for a collector, it is important to recognize that the collectors discussed in the EIS and the BA have yet to be successfully implemented and there is considerable risk and uncertainty about the realized effectiveness of these structures. Under modeled and simulated conditions, these collectors are expected to perform reasonably, but real time management or unobserved conditions could impact the effectiveness of proposed collectors, particularly in cases where the predictor variables represent the highest extremes of the functional relationships described in Kock et al. (2019). For this reason, dam passage efficiency should be interpreted in the lens of perfect information and actual results may vary.

Table 1-36. Coefficients for each significant predictor of fish collection efficiency.

TABLE 7. Coefficient estimates, SEs, and tests of significance for the effect of each predictor variable on fish collection efficiency (FCE).

Variable	Coefficient estimate	SE	*t*-value	*P*-value
Intercept (Chinook Salmon)	−0.923	0.356	NA	NA
Coho Salmon	0.876	0.371	2.361	0.023
Sockeye Salmon	0.631	0.383	1.647	0.107
Steelhead	1.474	0.539	2.737	0.009
Lead nets	0.848	0.313	2.705	0.009
Inflow	0.492	0.068	7.188	<0.001
Effective forebay area	−1.086	0.183	−5.945	<0.001
Entrance area	0.991	0.233	4.254	<0.001
Effective forebay area × entrance area	2.112	0.362	5.835	<0.001

Note: Table 7 adapted from Kock et al. 2019 showing the coefficients for each significant predictor of fish collection efficiency.

Forebay size for application of the Kock et al. regression model was estimated following the methods described by Kock et al. (2019). An FSS has been designed for Detroit and for Cougar;

however, FSS's are also measures proposed for several other projects for the Willamette Systems EIS. The most relevant information about what inflows and entrance sizes may be reasonably expected comes from the design plans for Detroit and Cougar.

Forebay size

Similar to Kock et al. (2019), effective forebay size was calculated as the water surface area from the face of the dam to the area 500m from the dam face. This was calculated for each project of interest:

Table 1-37. Effective forebay size for several Willamette Systems projects

Project	Size	Unit
Hills Creek	55.4	Ha
Green Peter	20.9	Ha
Cougar	27.6	Ha
Foster	47.9	Ha
Detroit	24.2	Ha
Lookout Point	35.4	Ha

Inflow and Entrance Specifications

We used Detroit and Cougar and scaled the designs and operations to the projects for which they were most similar.

Minimum and maximum flows through the FSS for DET and CGR were based on design flow ranges as documented in the DDRs. The FSS inflow operating range for a Hills Creek Dam FSS were assumed from the Cougar Dam FSS design, given the similarity in dam configuration and turbine capacity. Total FSS inflow capacity for GRP and LOP were determined by scaling based on the DET design flow. This was accomplished by dividing the DET total design flow by the DET turbine capacity, and then multiplying the result with the total turbine capacity flow at GRP and LOP. Due to the frequency at which flows can be less than 1000 cfs from GRP Dam, it was assumed that pumped flow would be used to supplement the FSS inflows up to 1000 cfs for the minimum FSS operating range at GRP.

Table 1-38. Detroit specifications used for Green Peter and Lookout Point Scaling. *

Project	Max total turbine capacity at min con	FSS V-screen design flow	Scaler (design flow / turbine capacity)
DET	4960	4600 (double barrel)	0.927

Note: Green Peter and Lookout Point do not currently have an FSS design. Therefore, proposed FSS's at these locations were scaled to the Detroit FSS based on turbine capacity.

Table 1-39. Proposed FSS specifications for Green Peter and Lookout. *

Project	Max total turbine capacity at min con	DET FSS Scaler	Estimated Double V-screen design flow	Total V-screen design flow assumed for EIS
LOP	8100	.927	7509	6000
GPR	4420	.927	4097	4000

Note: * Proposed FSS specifications for Green Peter and Lookout, scaled to the Detroit FSS design.
LOP Adjusted down design flow, based on Kock et al. 2019 model of FSC fish guidance efficiency indicating efficiency would be high assuming a double V-screen designed of 6000 cfs.

For Detroit and Green Peter, when dam outflows are below the minimum operational flow, it is assumed that minimum flows are supplemented and recirculated with pumped flow from forebay.

Table 1-40. Minimum and maximum flows through each FSS structure by project *

Project	Minimum FSS flow **	Maximum FSS flow **	Notes
Detroit FSS[1]	1000	5600	Per Detroit DDR
Cougar FSS[2]	300	1000	Per Cougar DDR
Green Peter FSS	1000	4000	Based on DET FSS scaler * GPR turbine capacity (See table above)
Lookout Pt FSS	1350 (equivalent to cavitation limit for DEX)	6000	Based on DET FSS scaler * LOP turbine capacity, adjusted based on Kock et al. FSC model (see table above)
Hills Creek FSS	300	1000	Assumed from CGR DDR

Notes: * Minimum and maximum flows (cfs) through each FSS structure by project. For Detroit and Green Peter, whendam outflows are below the minimum operational flow, it is assumed that minimum flows are supplemented and recirculated with pumped flow from forebay

** All flows shown in cubic feet per second (cfs).

1. Detroit FSS: There are two entrances in the FSS, capable of handling flow ranges from 1,000 cfs to 5,600 cfs. The design flow rate for fish collection operations is 4,500 cfs, with each channel operating at a flow of 2,250 cfs. Future provisions for pumped attraction flow will accommodate 1,000 cfs to drive flow through the FSS and continue attracting and collecting fish from the forebay. – per Final DDR.

2. Cougar FSS: There are two entrances on the Dual Entrance Angled FSS, with the starboard collection channel sized to pass 400 cubic feet per second (cfs) and the port collection channel sized to pass 600 cfs. Including two entrances instead of only one allows for better control of hydraulic conditions over the full range of design flows (300 to 1,000 cfs). – per 90% DDR.

We applied these scalers at other projects of interest. Entrance size for a conceptual FSS at Hills Creek Dam was assumed from the Cougar Dam FSS design given the similarity in dam configuration and turbine capacity. These scaled relationships provided the most likely dimensions for an FSS at each project of interest based on available information (Table 4). Due to the frequency at which flows can be less than 1000 cfs from Green Peter Dam, it was assumed that pumped flow would be used to supplement the FSS inflows up to 1000 cfs for the minimum FSS operating range at GRP.

Table 1-41. Estimated FSS entrance dimensions, minimum and maximum outflow capacities *

Project	Maximum FSS flow (cfs)	Entrance area (sq ft)	Minimum FSS Flow (cfs)
DET FSS	5600	1776	1000
GPR FSS	4000	1268	1000
LOP FSS	6000	1902	1350
CGR FSS	1000	1938	300
HCR FSS	1000	1938	300

Notes: 1. Estimated dimensions for FSS entrances, minimum, and maximum outflow capacities based on turbine capacities and the relationship between entrance size and inflows.

2. Dimensions are indicated in Imperial units but were converted to Metric for use in the log regression.

Entrance area is given for two flumes operating. When the FSS is operated at minimum inflow, only one barrel may operate. At these times, the entrance area is reduced by half. We examined Res-Sim output for the period of record during peak fish passage times: April 1 – July 1 and September 1 to December 1 to estimate each project's most likely flows. We developed a frequency distribution by binning dam discharge by 100 cfs increments. If the most frequently occurring flow was less than two times the minimum flow at a given project, we assumed single barrel operation and reduced the entrance size by half.

FCE Calculator

Once we had calculated the dimensions of each potential collector, we used these in the log-linear regression model from Kock et al. We adapted a spreadsheet "FCE Calculator" which captures the regression coefficients and log transformations to predict DPE.

Logistic regression equation for factors affecting FCE (from Kock et al. 2019)

$$lp = c_1 + c_2 \cdot I_{coho} + c_3 \cdot I_{sockeye} + c_4 \cdot I_{steelhead} + c_5 \cdot L + c_6 \cdot F + c_7 \cdot A + c_8 \cdot E + c_9 \cdot A \cdot E$$

$$FCE = \frac{\exp(lp)}{1 + \exp(lp)}$$

Figure 1-6. Logistic regression equation used to predict DPE (indicated as FCE, here).

The spreadsheet calculator allows the user to input their own values into the regression. These values are standardized per Kock et al. using the mean and standard error from their hierarchical analysis. Since data do not currently exist for collectors in the Willamette, we used the mean and standard deviation of multiple collectors evaluated in Kock et al. (see Supplement

3 in Kock et al. 2019) to approximate a standardized estimate (i.e., $\frac{x-\bar{x}}{sd}$). These standardized inputs are then log transformed and imputed to the log regression equation for each proposed collector. The regression result (*lp*) must be untransformed from log space to provide DPE (Dam Passage Efficiency will be indicated as FCE within Chapter 1). All inputs were converted to Metric prior to analysis.

Table 1-42. Example of FCE calculator run.

Variables	Coefficient	To equation	Input values
c_1 (Chinook salmon) =	-0.923	1	1
c_2 (coho salmon) =	0.876	0	0
c_3 (sockeye salmon) =	0.631	0	0
c_4 (steelhead) =	1.474	0	0
c_5 Lead nets =	0.848	0	0
c_6 Inflow =	0.492	1.392	28.316847
c_7 Effective forebay area =	-1.086	0.567	24.2
c_8 Entrance area =	0.991	-0.408	82.497864
c_9 Effective forebay area x entrance area =	2.112	-2.273	n/a

Notes: lp = 0.279; FCE = 0.569

Calculation and justification for inflows through each collector

The FCE calculator was used to predict DPE for each structure where an FSS is proposed in Alternatives 1 and 4. Although the model is informative in that it can integrate information from very different collector types based on specific design features common to all collectors, the model assumes constant inflow through the collector. There are two main reasons that we expect variable inflows through proposed collectors: 1) The USACE conducts power peaking at several projects (Green Peter, Lookout Point, and Detroit dams) where hourly outflows change dramatically over the course of 24 hours, and 2) available water in a given year does not necessarily support the hypothesis that the collector would run at optimal capacity at all times.

To evaluate what flows might be expected, we examined the frequency of the daily average outflows predicted by Res-Sim and binned by 100 cfs intervals, under alternatives 1 and 4. As expected, the most frequently occurring outflows were substantially less than the optimal capacity assumed for each collector. In some cases, the flows were below the capacity needed to run even one barrel of an FSS. In these cases, we assumed supplemental pumps would be required to increase the inflow to minimum operating capacity (one barrel); however, at power peaking projects, the daily average may not accurately reflect hours of the day when inflows could also be quite high.

We used hourly outflow information from DBQuery to determine hourly outflow pattens in a deficit, sufficient, and adequate year type. Each year was then divided into different fish passage seasons: spring (April 1-July 1) and fall (September 1-December 1). We calculated the quantiles for hourly outflows (Table 1-43) and plotted the median hourly outflow by season (Figure 1-7).

Table 1-43. Spring and Fall Quantiles for Detroit hourly outflows in an abundant year. *

Season	0%	25%	50%	75%	100%
Spring 2011	0	0	1.97	2.075	4.38
Fall 2011	0	0	1.95	2.14	5.21

Note: * Quantiles for hourly outflows at Detroit in an abundant year type (2011) in the spring and fall.

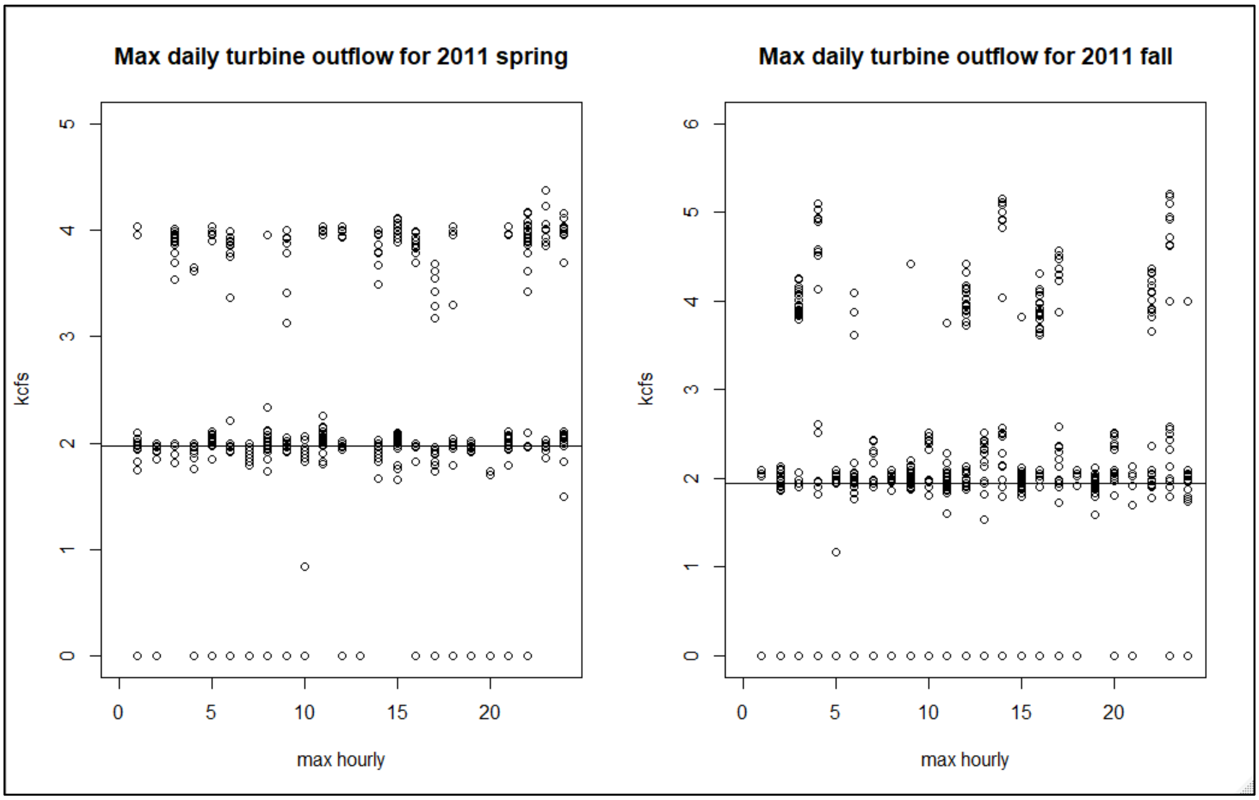

Figure 1-7. Detroit Median Hourly Spring and Fall Outflows in Abundant Water Years. *Median hourly outflows from Detroit for an abundant water year type (2011) in spring (left) and fall (right). The open dots represent the median hourly outflow. The solid line represents the median outflow for all data points.*

In general, less than 25% of the hourly outflow data was above the optimal inflow capacity for Detroit. We show the abundant year type here to demonstrate that even under ideal conditions, the FSS would still operate below optimal capacity for a majority of the time. Therefore, we deemed it inappropriate to assume optimal capacity. We consulted with the Kock et al. team to help determine reasonable inflows. The team agreed, it would be inappropriate to assume optimal capacity most of the time. They indicated that it was more reasonable to use the most frequently occurring daily outflow from Res-sim--with the caveat that the PDT should consider limiting power peaking at night when fish are most likely to pass and when variable flows would have the greatest impact of DPE. Furthermore, the team believed that the orientation of the collector (parallel to the dam face rather than perpendicular) would likely act as an efficient guidance structure and recommended utilizing the model coefficient for guide nets (see Kock et al. 2019).

We incorporated these suggestions into the current FCE calculator used to estimate DPE (see FBW, Appendix A sent to Cooperators on 03 June 2021). The results for DPE are presented with and without guide nets (see example in Table 2). In general, DPE improved 25%-30% when fish guidance considerations were included.

Table 1-44. DPE Calculation for an FSS at Detroit for Alternative 4.

Variables	Coefficient	To equation	Input values
c_1 (Chinook salmon) =	-0.923	1	1
c_2 (coho salmon) =	0.876	0	0
c_3 (sockeye salmon) =	0.631	0	0
c_4 (steelhead) =	1.474	0	0
c_5 Lead nets =	0.848	1	1
c_6 Inflow =	0.492	1.467	29.73269
c_7 Effective forebay area =	-1.086	0.567	24.2
c_8 Entrance area =	0.991	-0.408	82.49786
c_9 Effective forebay area x entrance area =	2.112	-2.273	n/a

Notes: Estimates are for Chinook. The cells in red represent that log probability and DPE assuming a guidance structure.

lp = 1.353; FCE = 0.795; W/o LN = 0.587; percent change = 0.261289

Dam Passage Efficiencies for Alternative 1

Table 1-45. DPE calculation for an FSS at Detroit under Alternative 1.

Variables	Coefficient	To equation	Input values
c_1 (Chinook salmon) =	-0.923	1	1
c_2 (coho salmon) =	0.876	0	0
c_3 (sockeye salmon) =	0.631	0	0
c_4 (steelhead) =	1.474	1	1
c_5 Lead nets =	0.848	1	1
c_6 Inflow =	0.492	1.392	28.316847
c_7 Effective forebay area =	-1.086	0.567	24.2
c_8 Entrance area =	0.991	-0.408	82.497864
c_9 Effective forebay area x entrance area =	2.112	-2.273	n/a

Note: lp = 2.279: FCE = 0.907

Table 1-46. Dam Passage Efficiency calculation for an FSS at Green Peter under Alternative 1.

Variables	Coefficient	To equation	Input values
c_1 (Chinook salmon) =	-0.923	1	1
c_2 (coho salmon) =	0.876	0	0
c_3 (sockeye salmon) =	0.631	0	0
c_4 (steelhead) =	1.474	1	1
c_5 Lead nets =	0.848	1	1
c_6 Inflow =	0.492	1.392	28.316847
c_7 Effective forebay area =	-1.086	0.638	20.9
c_8 Entrance area =	0.991	-0.582	58.900502
c_9 Effective forebay area x entrance area =	2.112	-2.273	n/a

Notes lp = 2.175; FCE = 0.898

Dam Passage Efficiencies for Alternative 2a and 2b

Table 1-47. Dam Passage Efficiency calculation for a Detroit FSS Alternatives 2a and 2b.

Variables	Coefficient	To equation	Input values
c_1 (Chinook salmon) =	-0.923	1	1
c_2 (coho salmon) =	0.876	0	0
c_3 (sockeye salmon) =	0.631	0	0
c_4 (steelhead) =	1.474	1	1
c_5 Lead nets =	0.848	1	1
c_6 Inflow =	0.492	1.849	38.22774345
c_7 Effective forebay area =	-1.086	0.567	24.2
c_8 Entrance area =	0.991	-0.408	82.497864
c_9 Effective forebay area x entrance area =	2.112	-2.273	n/a

Notes: lp = 2.736; FCE = 0.939

Dam Passage Efficiencies for Alternative 3a and 3b– *Not applicable*

Dam Passage Efficiencies for Alternative 4

Table 1-48. Dam Passage Efficiency calculation for a Detroit FSS under Alternative 4.

Variables	Coefficient	To equation	Input values
c_1 (Chinook salmon) =	-0.923	1	1
c_2 (coho salmon) =	0.876	0	0
c_3 (sockeye salmon) =	0.631	0	0
c_4 (steelhead) =	1.474	1	1
c_5 Lead nets =	0.848	1	1
c_6 Inflow =	0.492	1.467	29.73268935
c_7 Effective forebay area =	-1.086	0.567	24.2
c_8 Entrance area =	0.991	-0.408	82.497864
c_9 Effective forebay area x entrance area =	2.112	-2.273	n/a

Notes: lp = 2.353; FCE = 0.913

CHAPTER 2 - FISH BENEFIT WORKBOOK RESULTS

2.1 CHINOOK SALMON NO ACTION ALTERNATIVE (NAA OR BASELINE)

2.1.1 North Santiam - Detroit

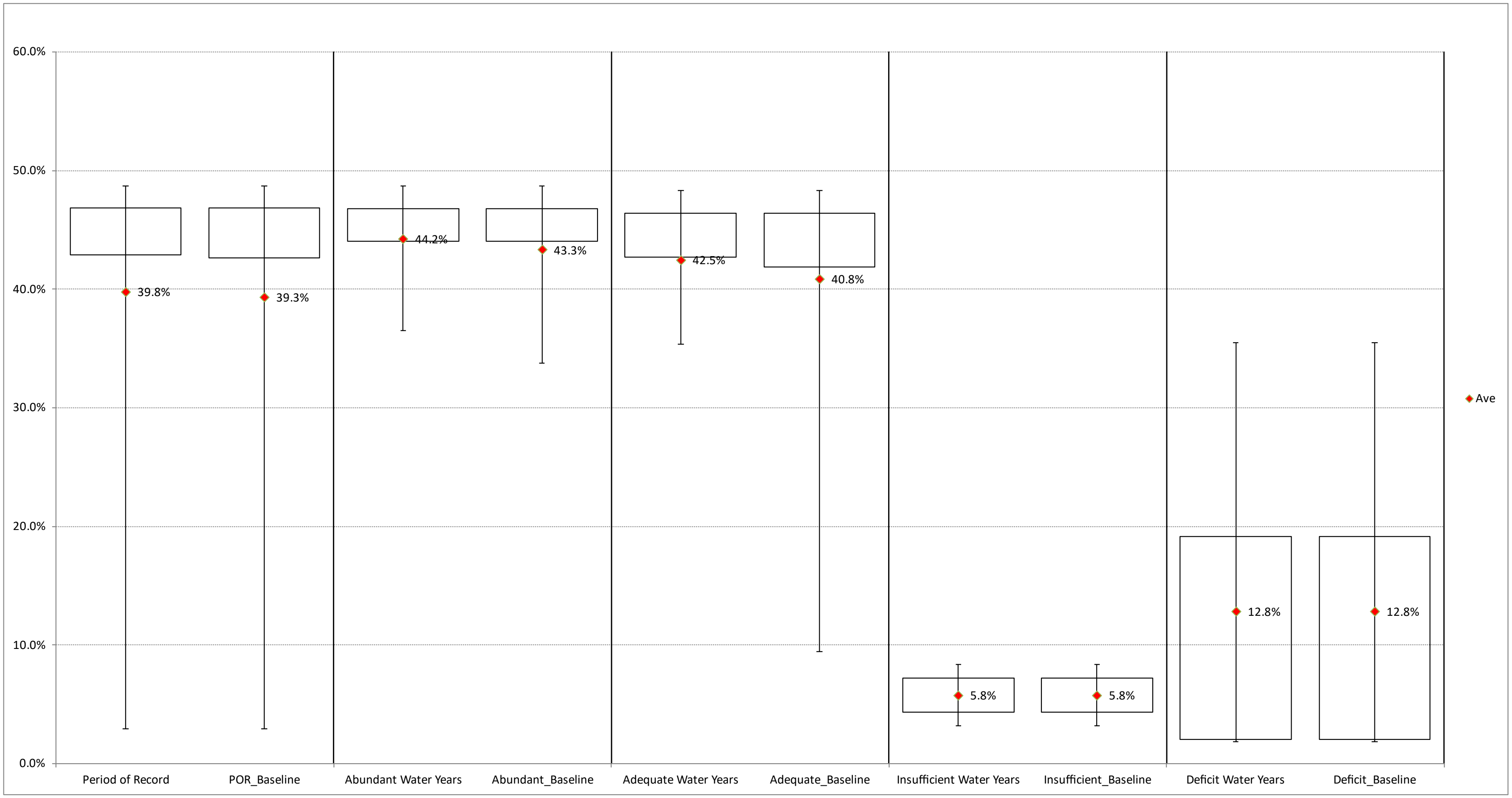

Figure 2-1. Detroit Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Detroit for juvenile spring Chinook fry under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

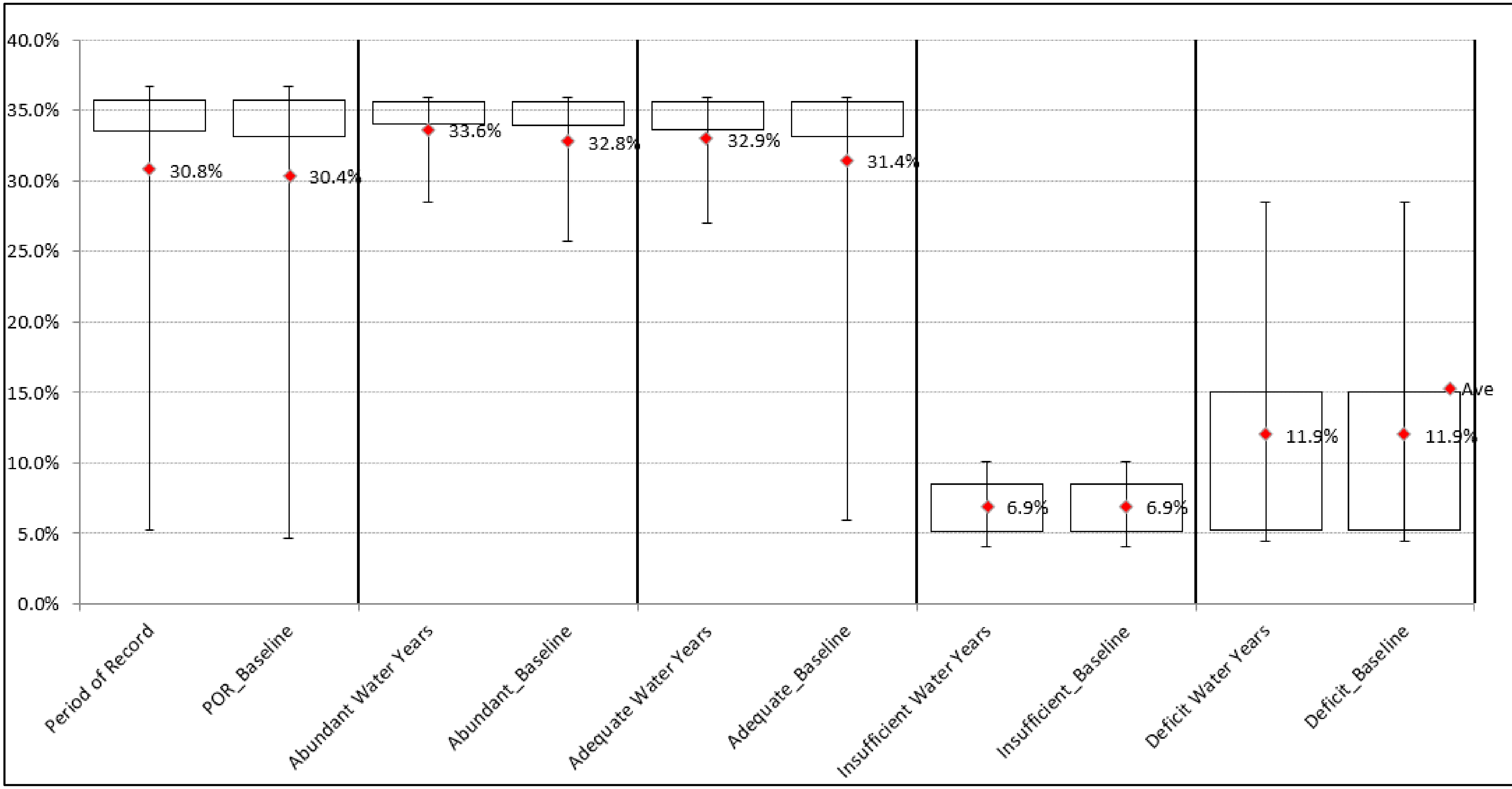

Figure 2-2. Detroit Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Detroit for juvenile spring Chinook sub-yearlings under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

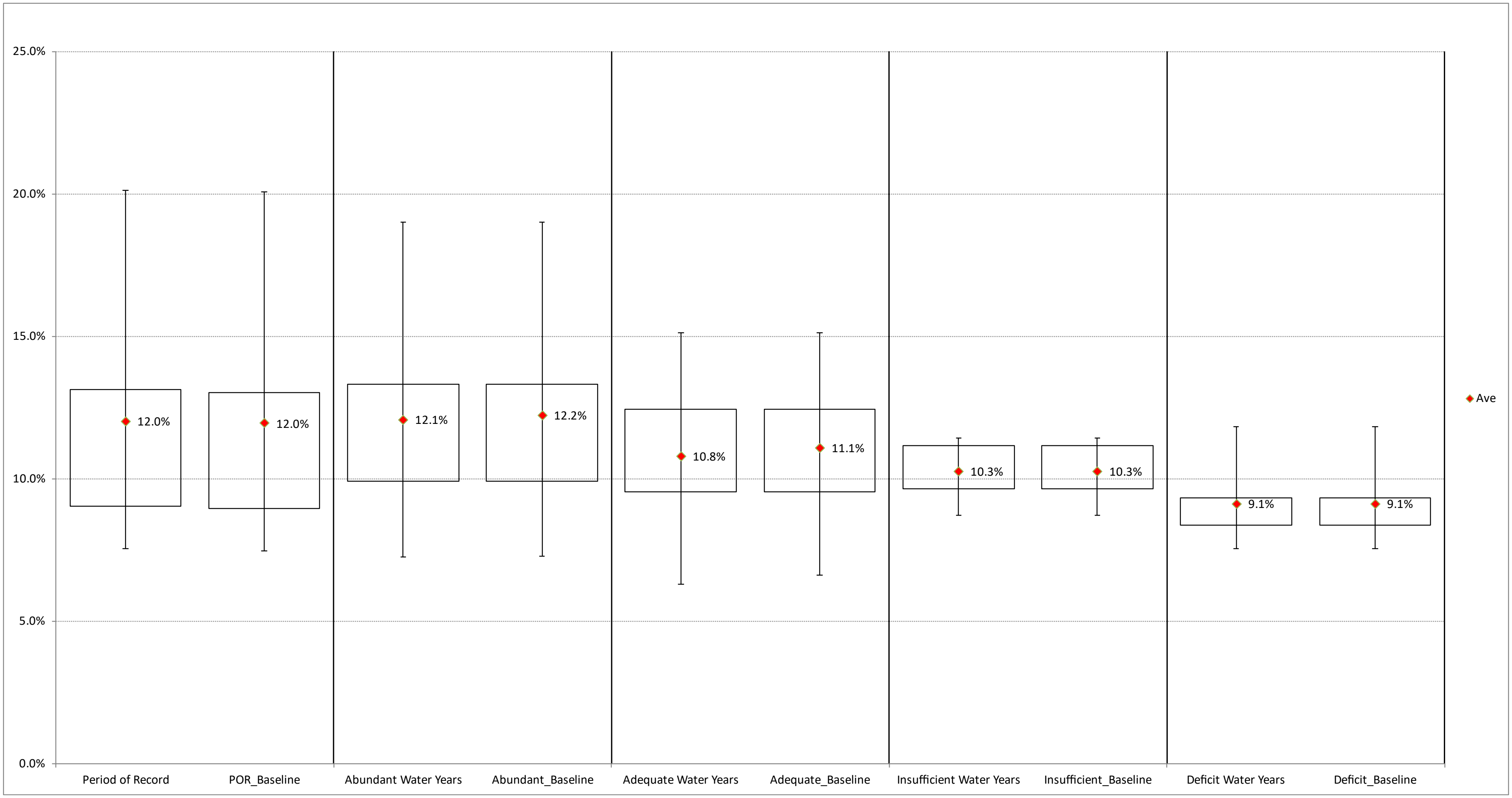

Figure 2-3. Detroit Juvenile Spring Chinook Yearlings Downstream Dam Passage Survival Under the No Action Alternative*.*
Downstream dam passage survival at Detroit for juvenile spring Chinook yearlings under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.

2.1.2 South Santiam - Foster

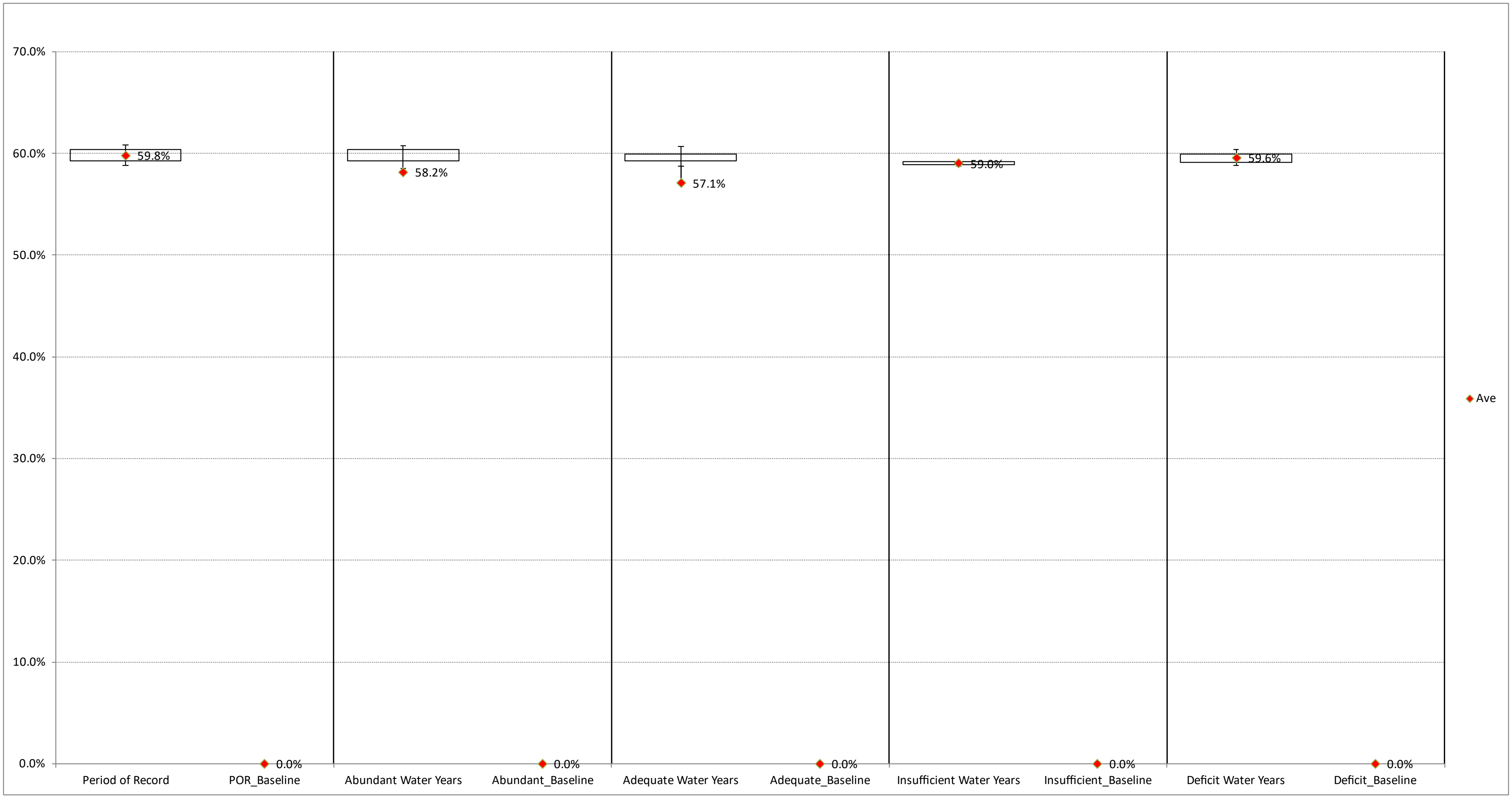

Figure 2-4. Foster Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Foster for juvenile spring Chinook fry under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

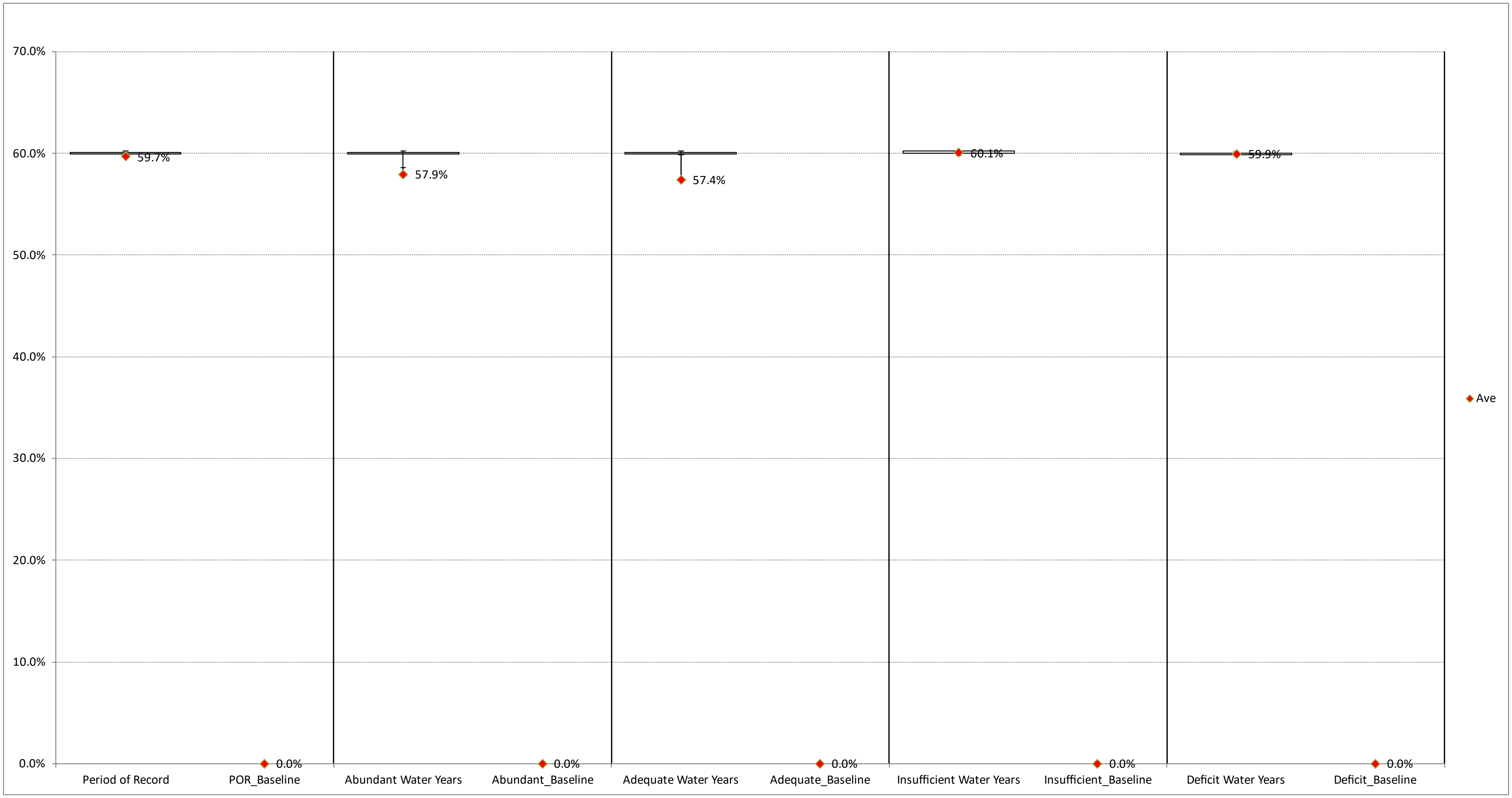

Figure 2-5. Foster Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Foster for juvenile spring Chinook sub-yearlings under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

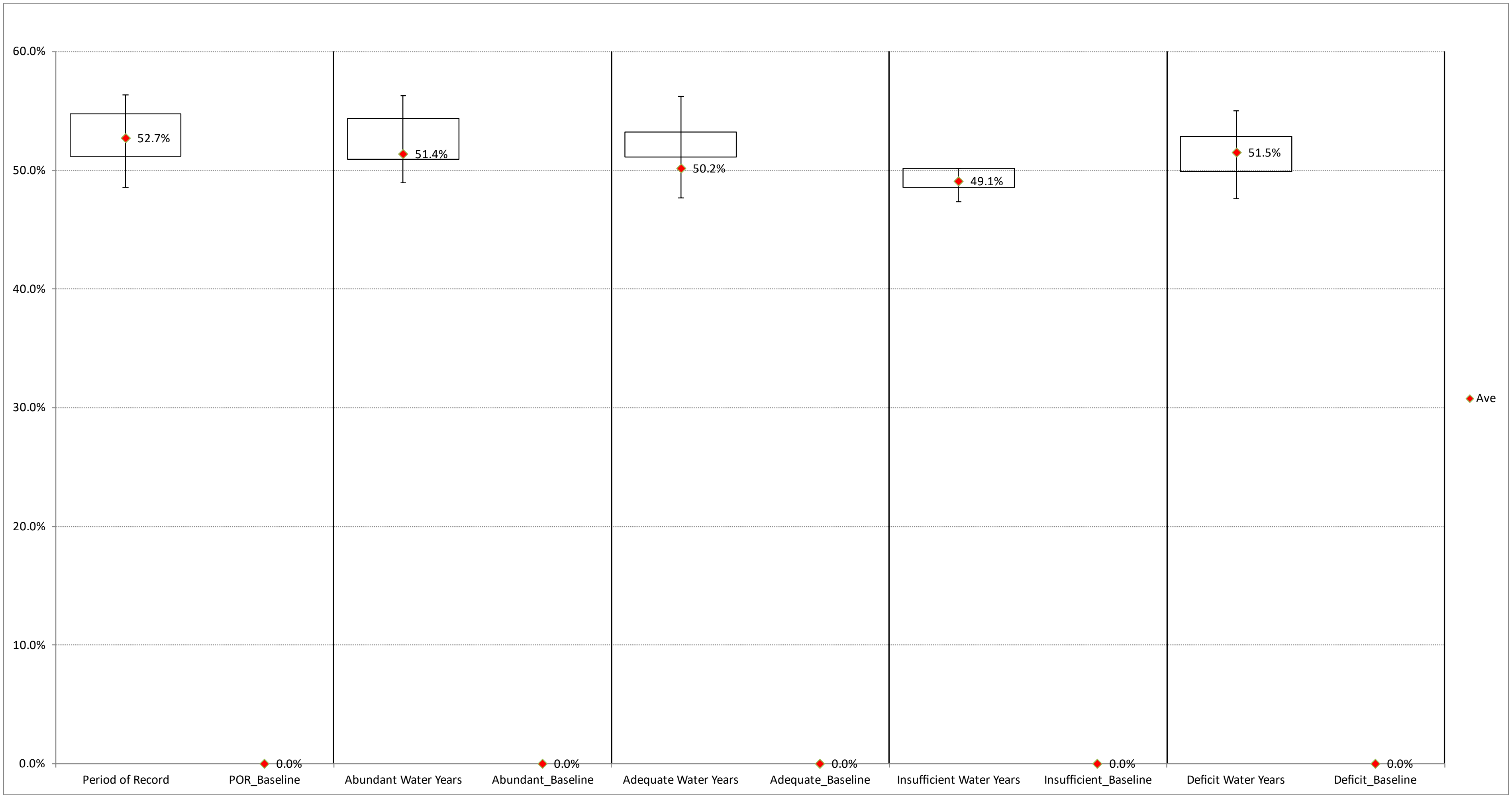

Figure 2-6. Foster Juvenile Spring Chinook Yearlings Downstream Dam Passage Survival Under the No Action Alternative.
Downstream dam passage survival at Foster for juvenile spring Chinook yearlings under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.

2.1.3 South Santiam – Green Peter

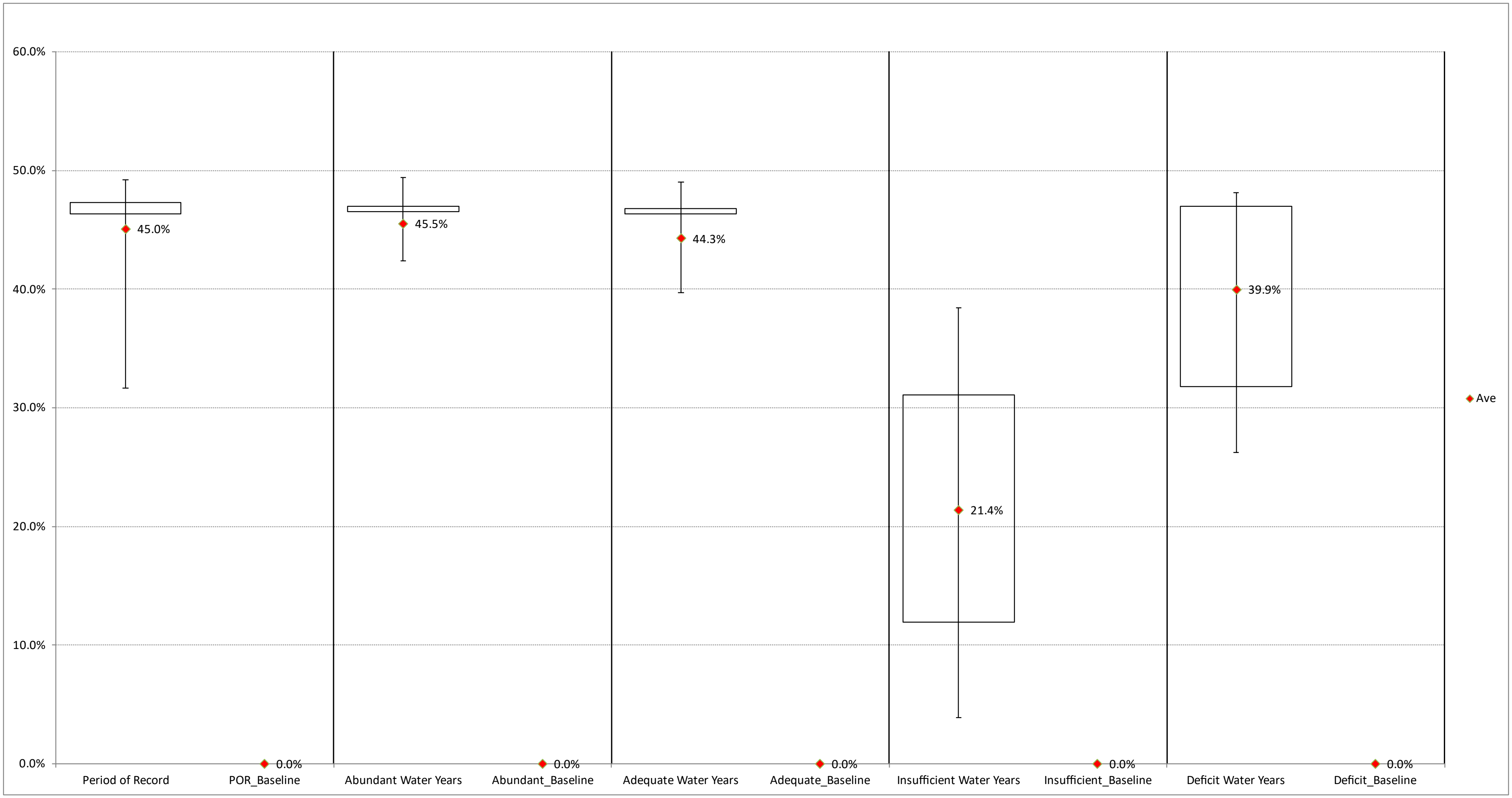

Figure 2-7. Green Peter Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Green Peter for juvenile spring Chinook fry under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

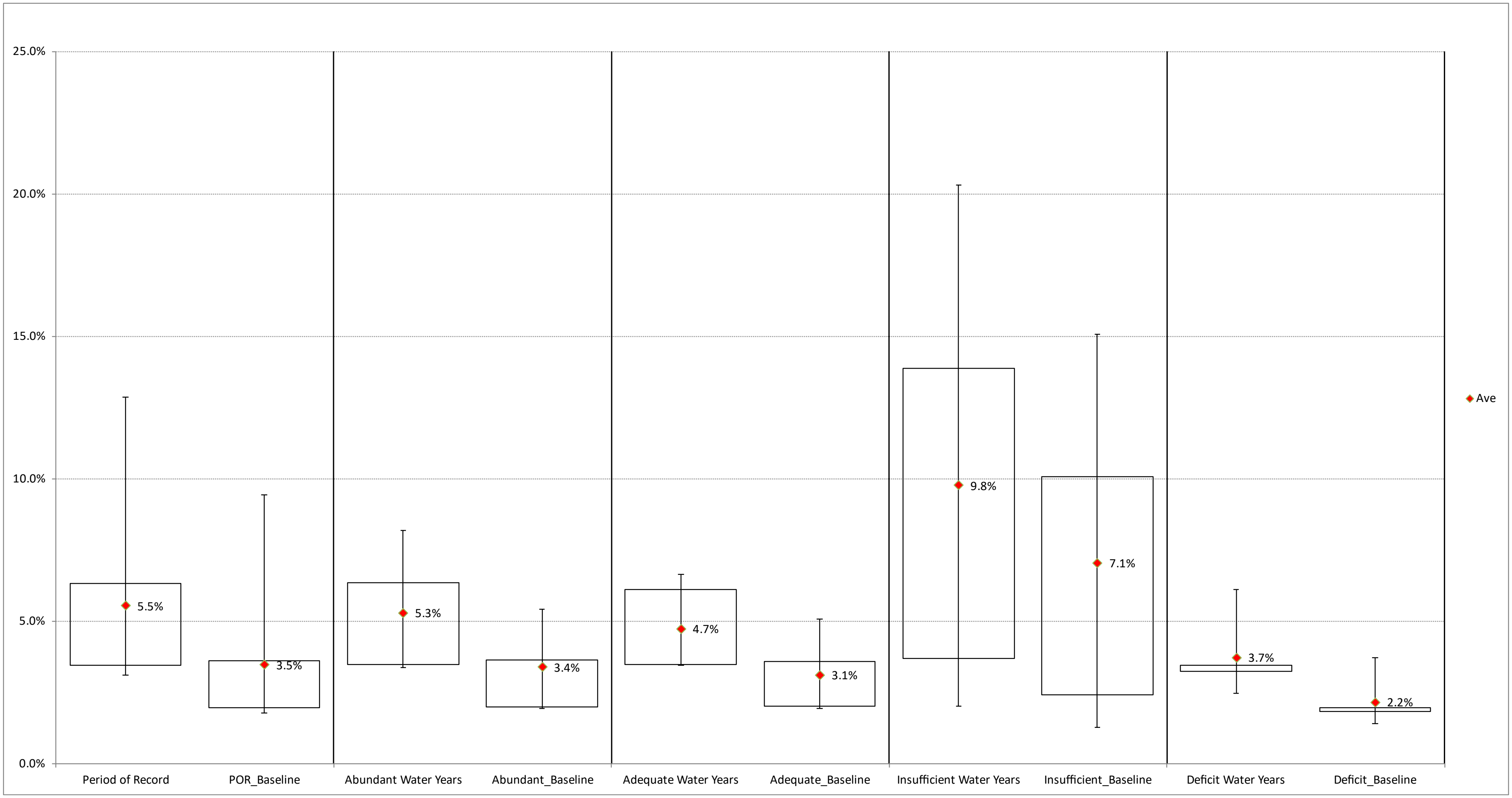

Figure 2-8. Green Peter Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Green Peter for juvenile spring Chinook sub-yearlings under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

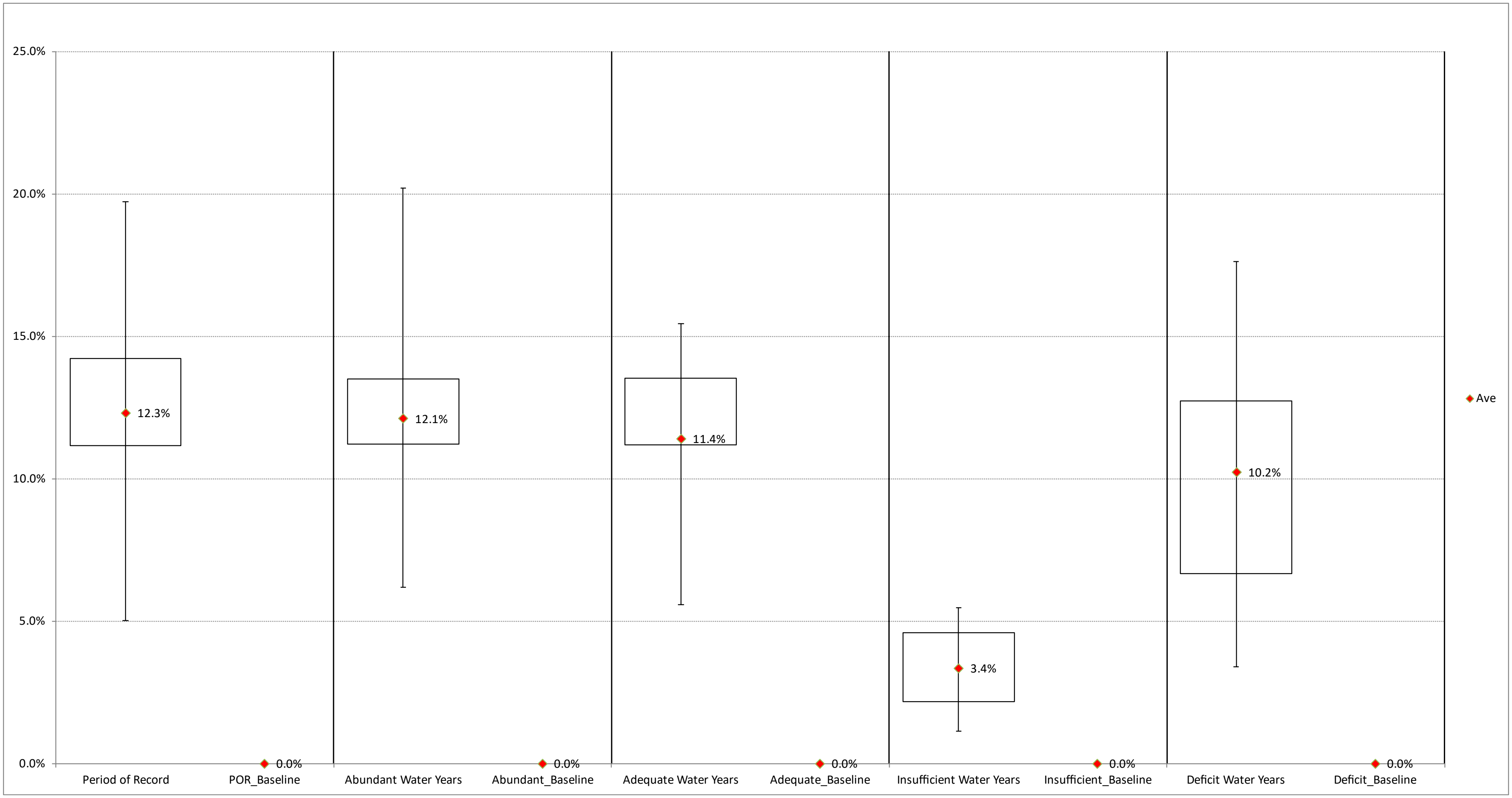

Figure 2-9. Green Peter Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Green Peter for juvenile spring Chinook yearlings under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.1.4 McKenzie – Cougar

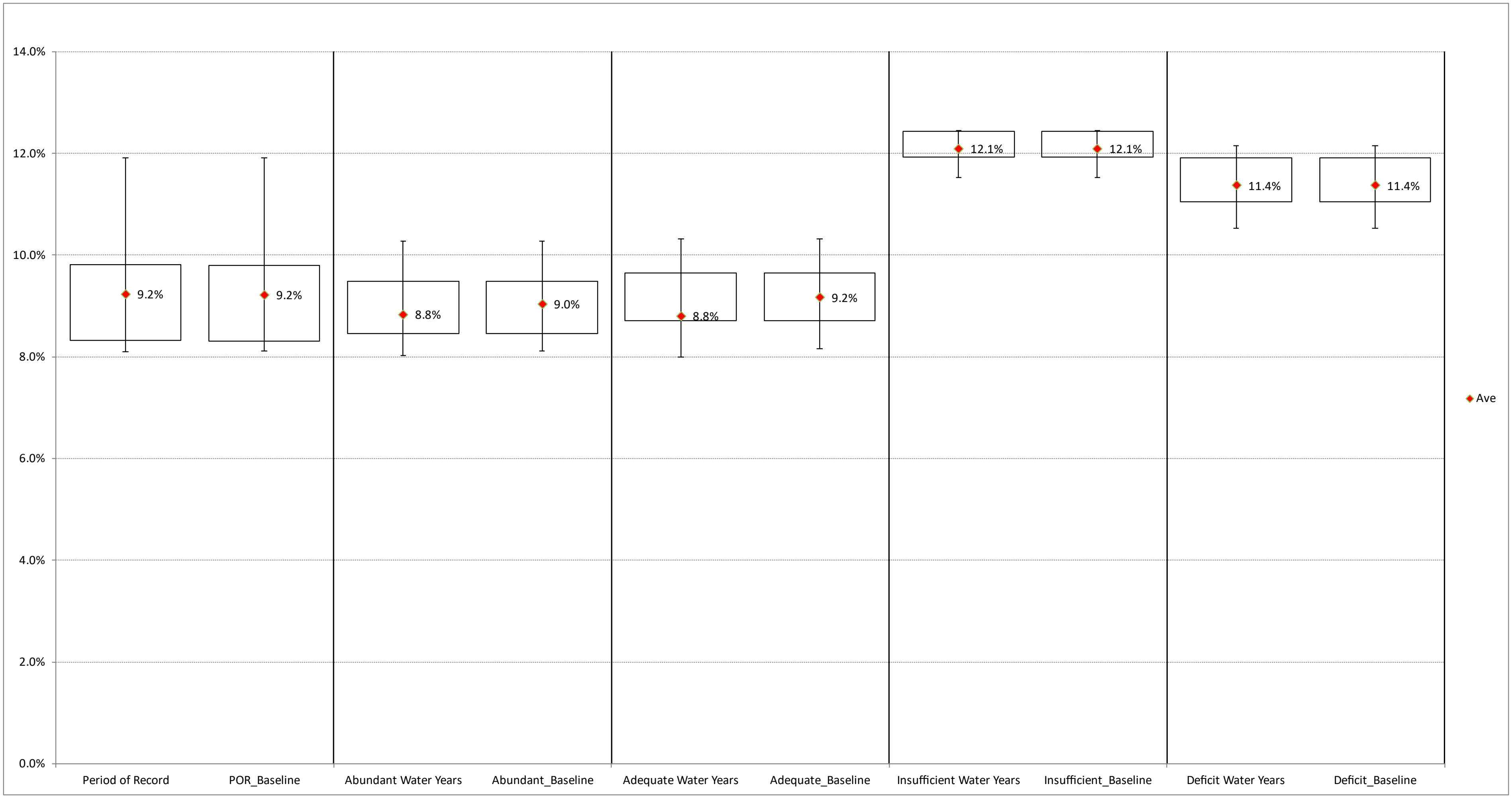

Figure 2-10. Cougar Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Cougar for juvenile spring Chinook fry under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

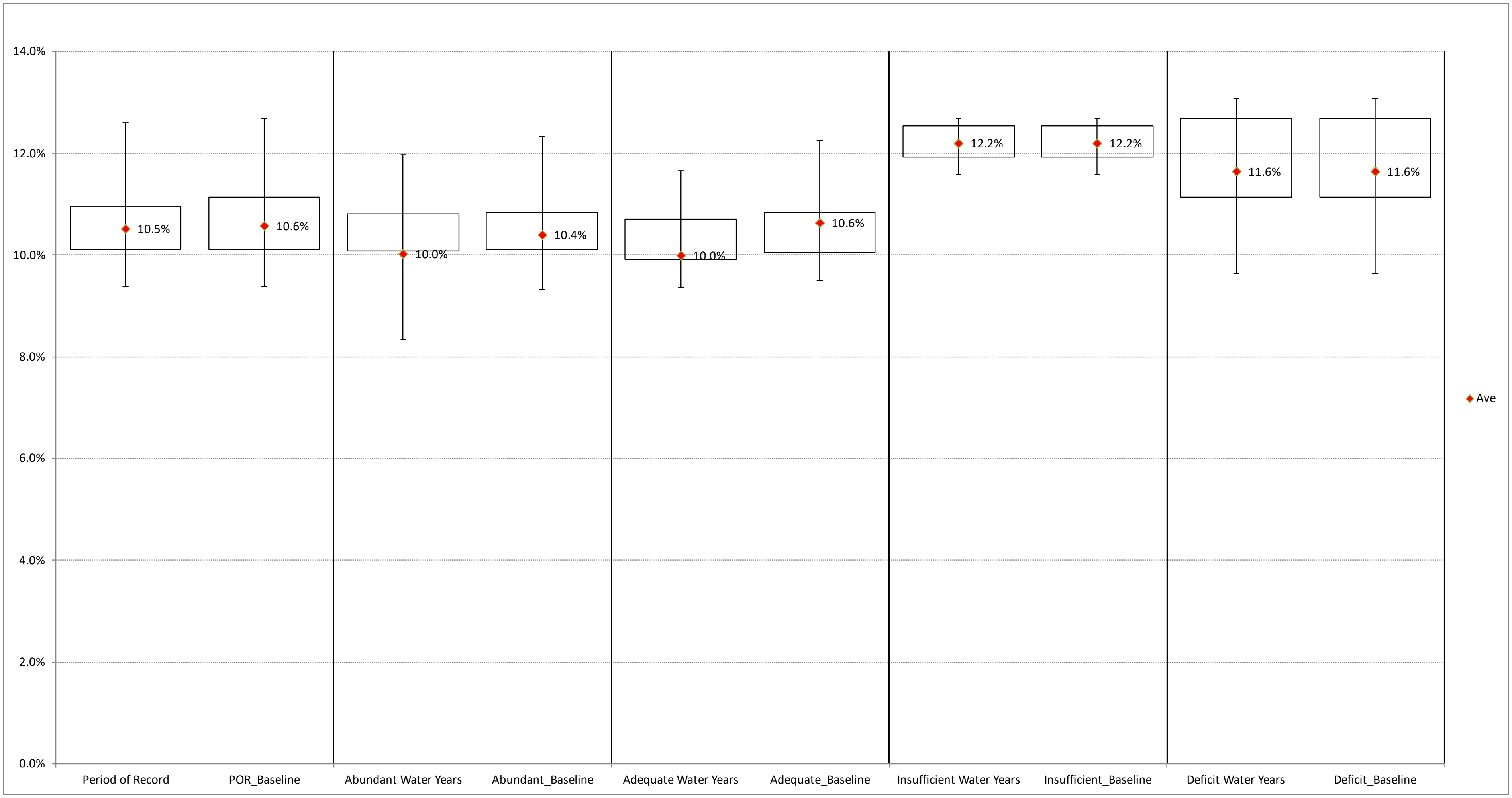

Figure 2-11. Cougar Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Cougar for juvenile spring Chinook sub-yearlings under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

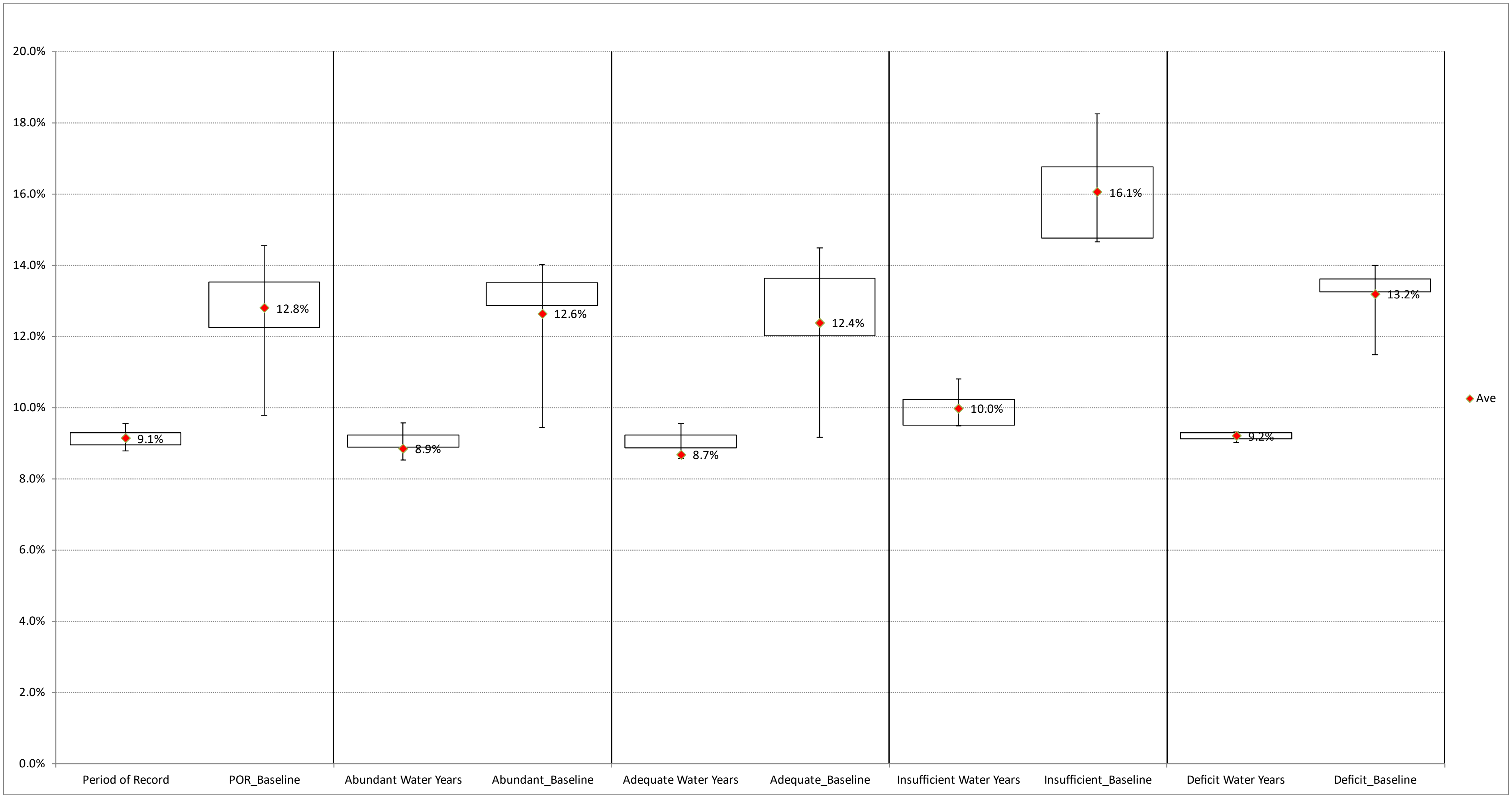

Figure 2-12. Cougar Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Cougar for juvenile spring Chinook yearlings under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.1.5 Middle Fork - Lookout Point

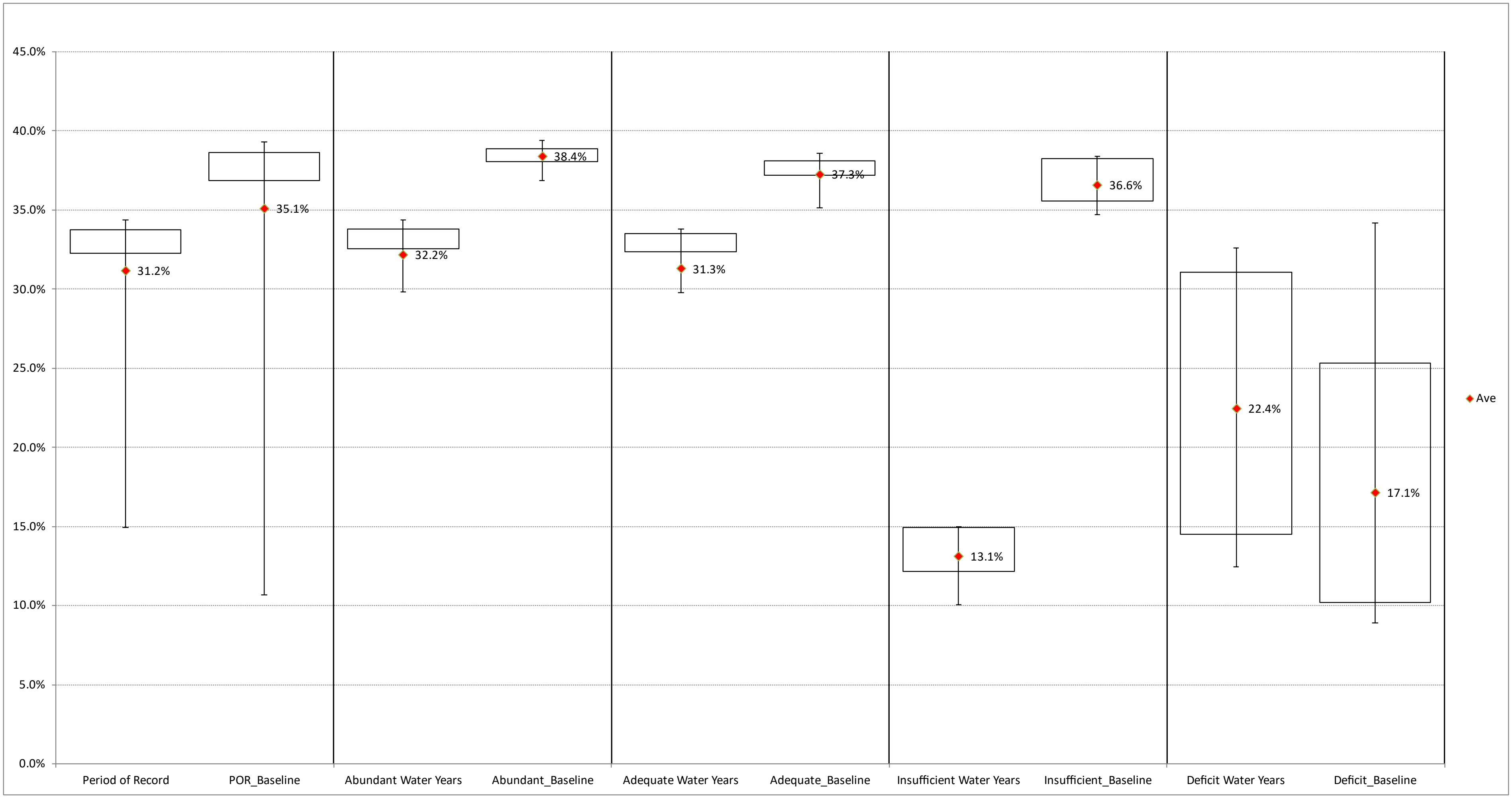

Figure 2-13. Lookout Point Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook fry under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

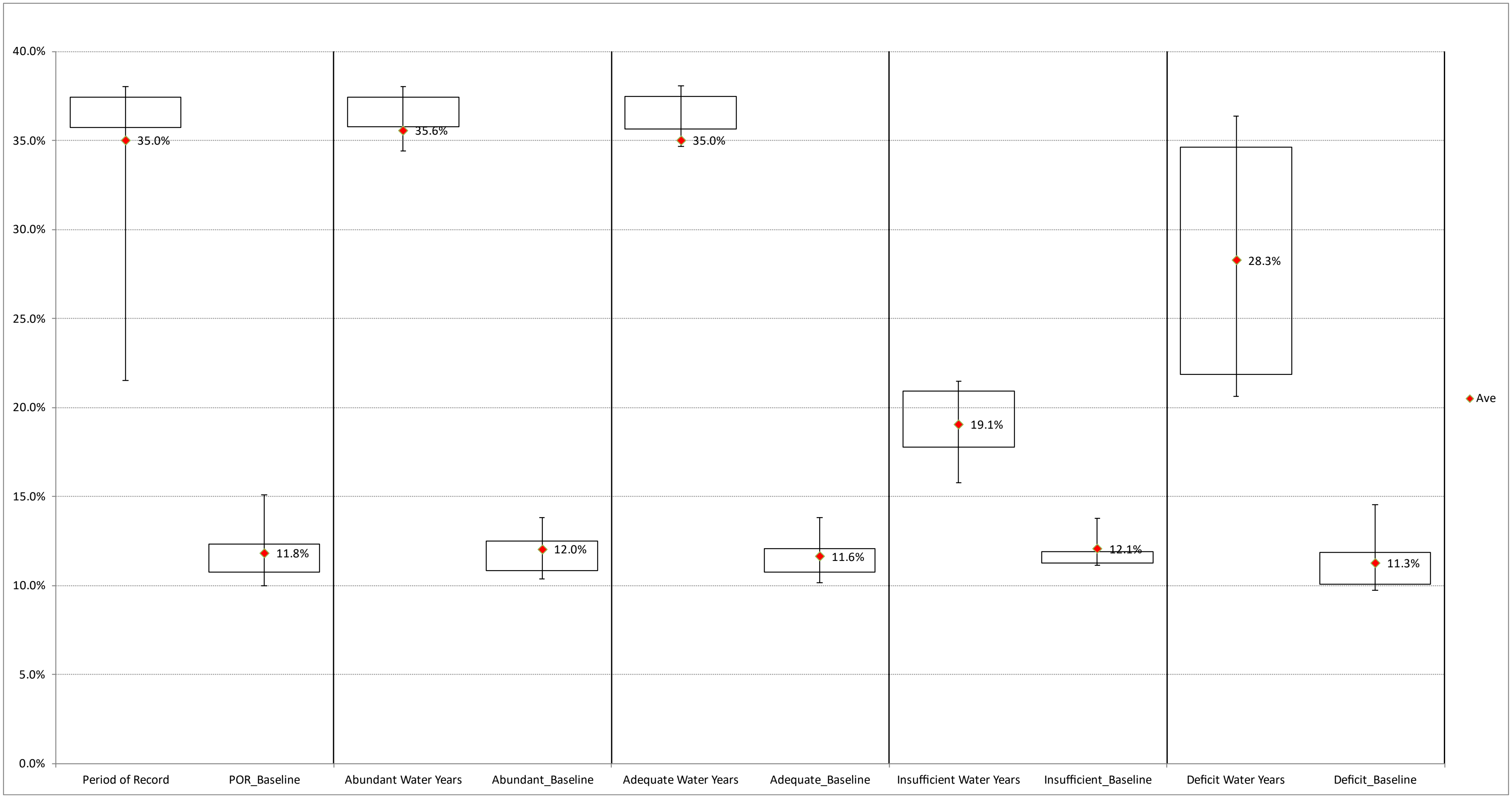

Figure 2-14. Lookout Point Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook sub-yearlings under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

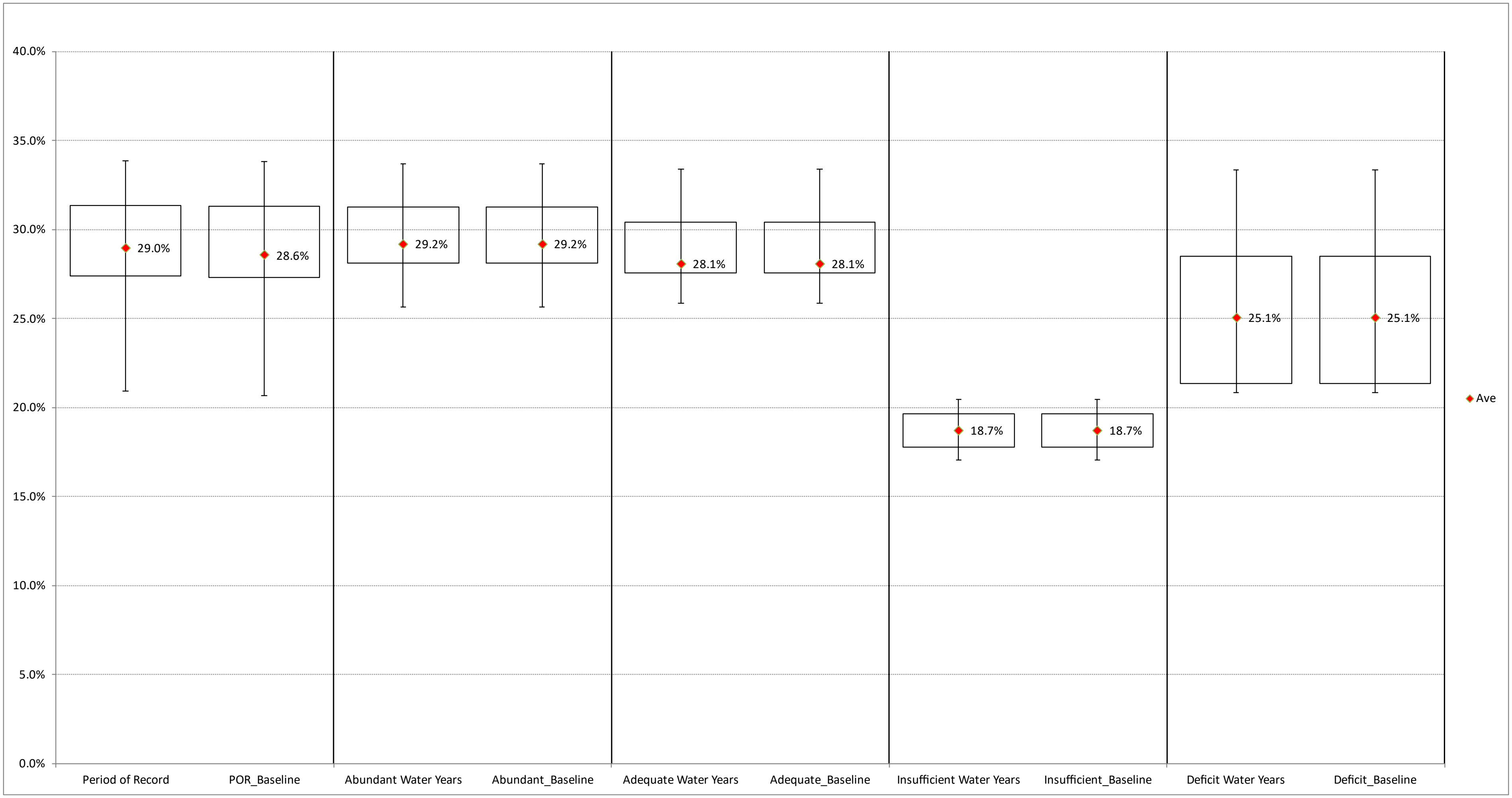

Figure 2-15. Lookout Point Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook yearlings under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.1.6 Middle Fork- Hills Creek

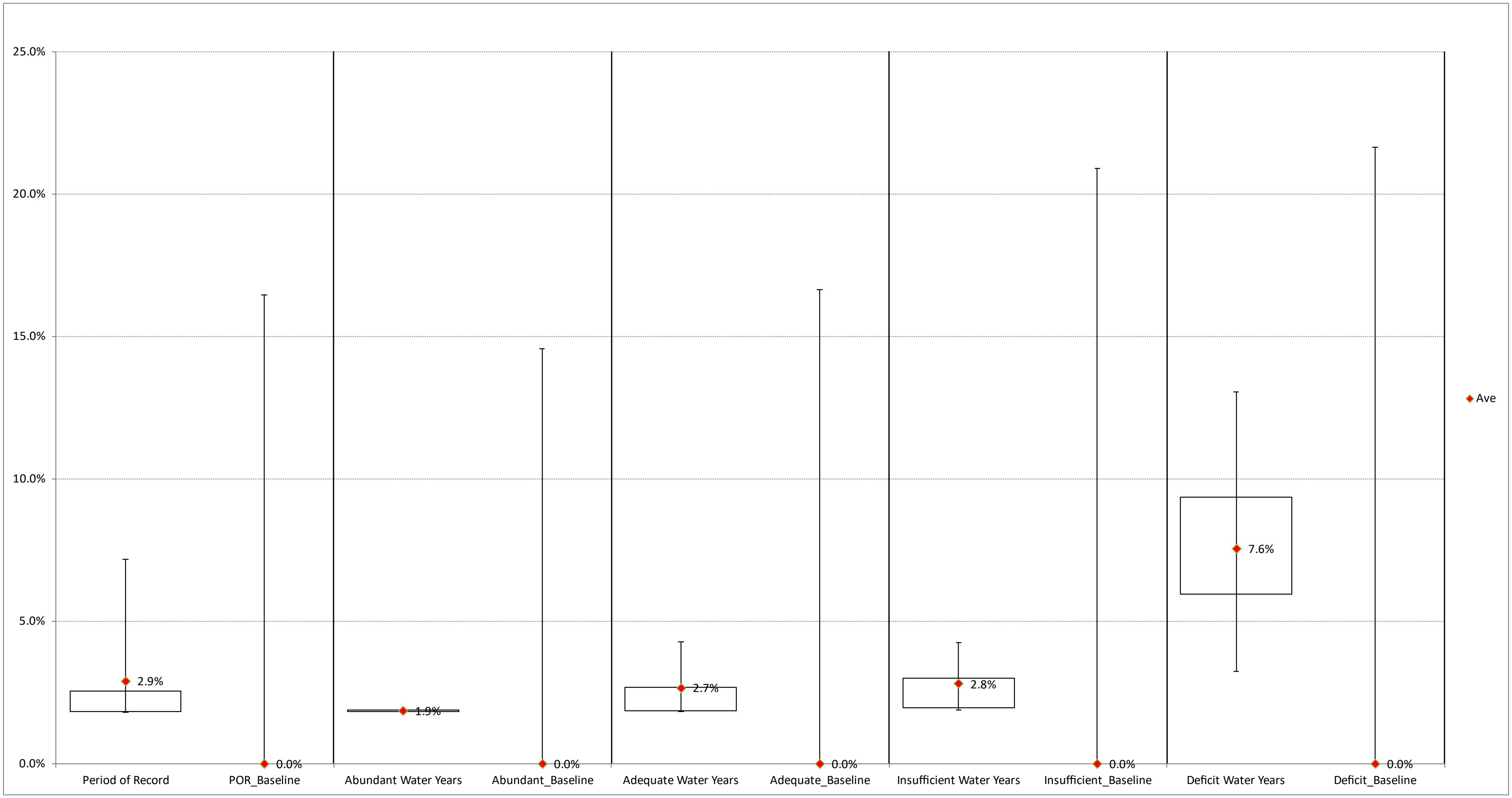

Figure 2-16. Downstream dam passage survival at Hills Creek for juvenile spring Chinook fry under the No Action Alternative. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook fry under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

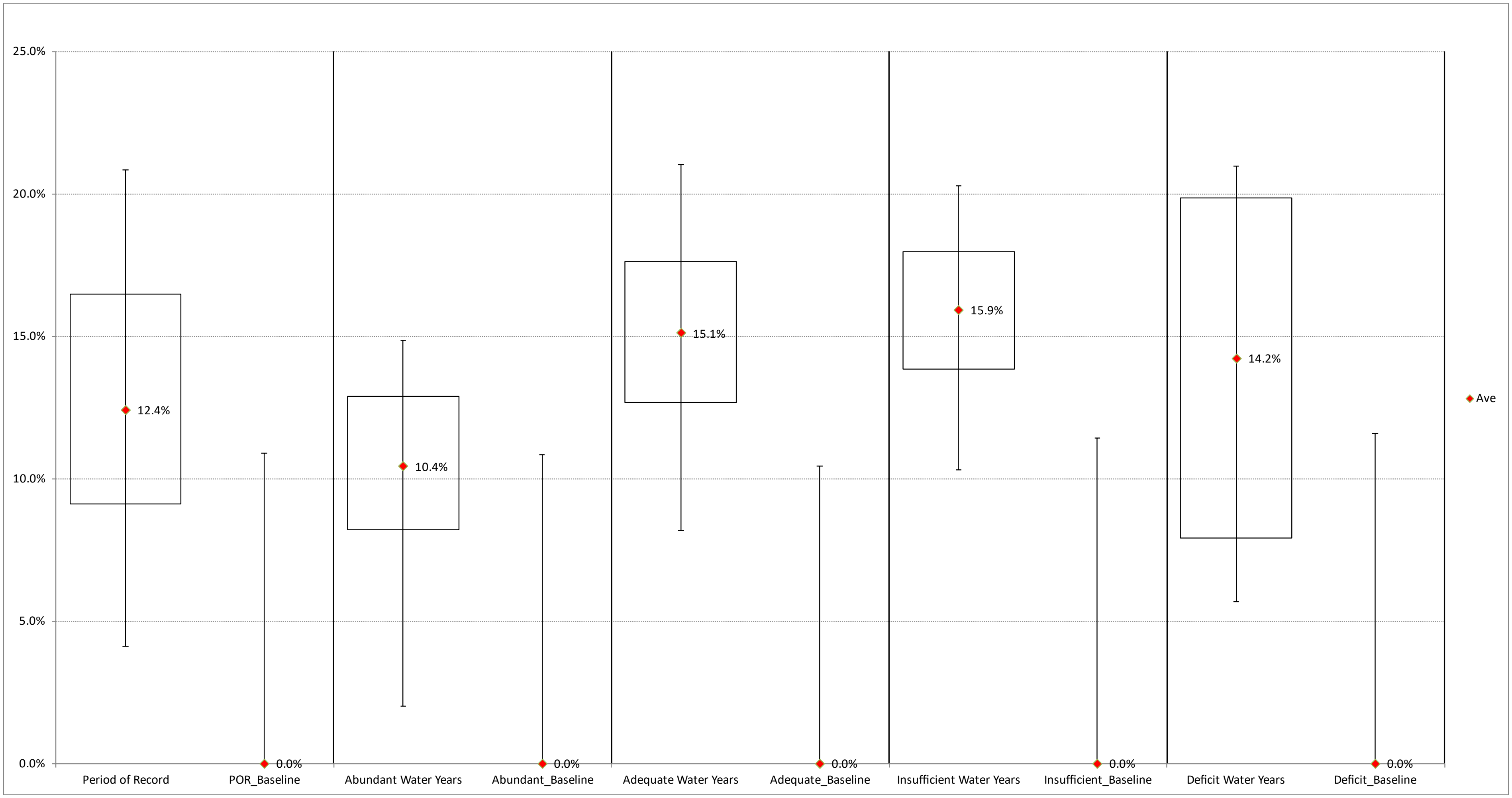

Figure 2-17. Hills Creek Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook sub-yearlings under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

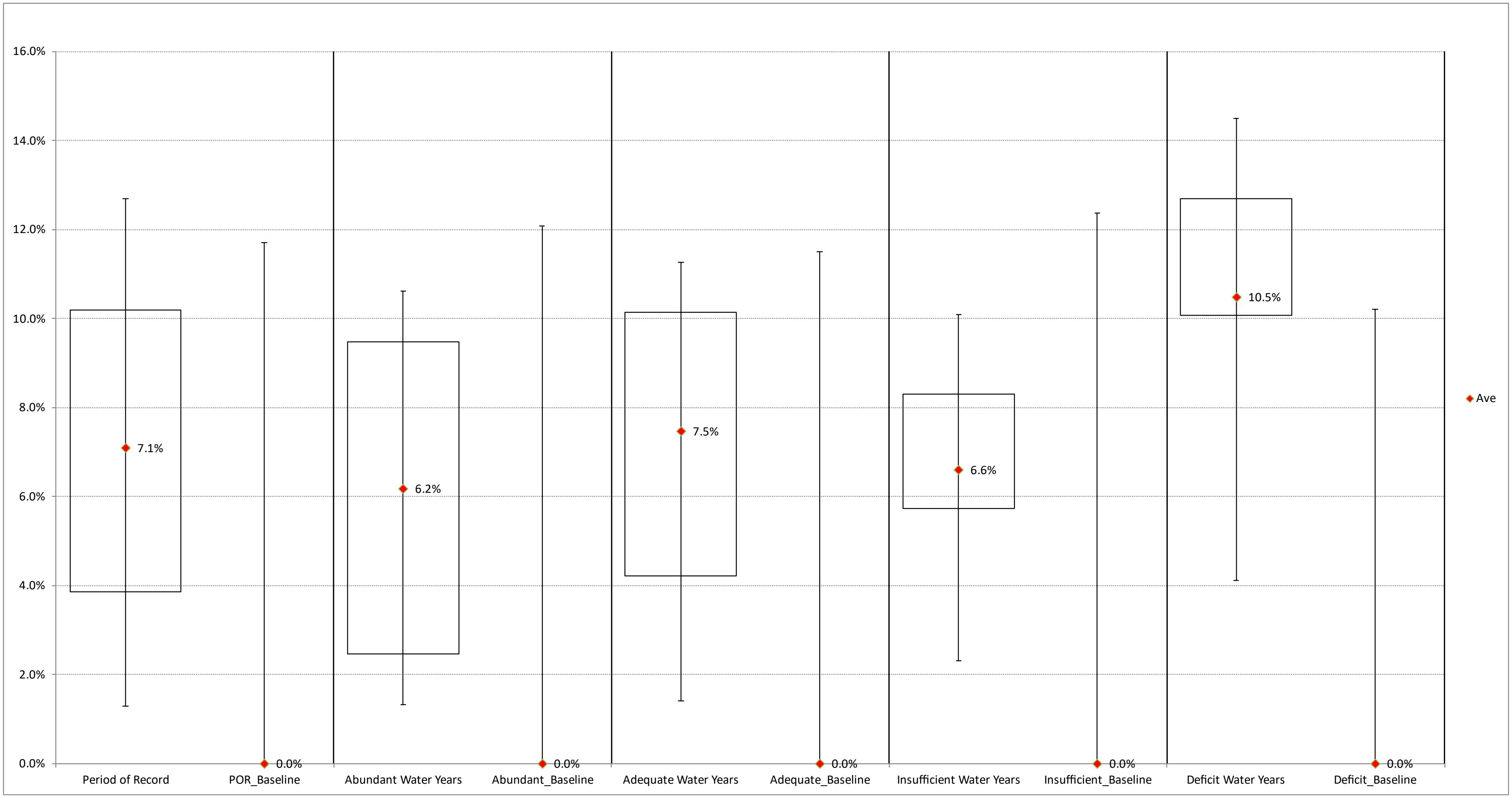

Figure 2-18. Hills Creek Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook yearlings under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.2 CHINOOK SALMON ALTERNATIVE 1

2.2.1 North Santiam - Detroit

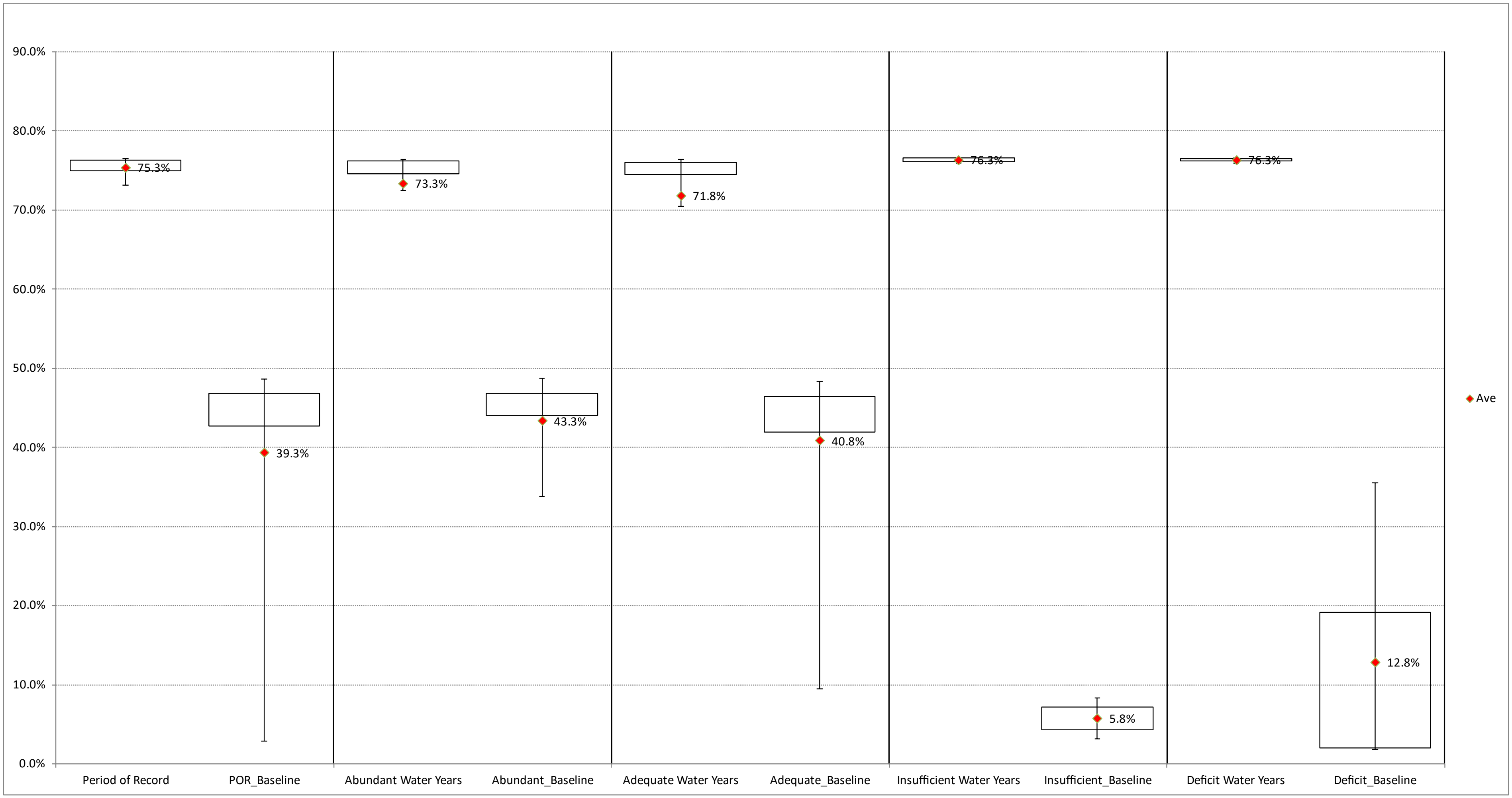

Figure 2-19. Detroit Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 1. *The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

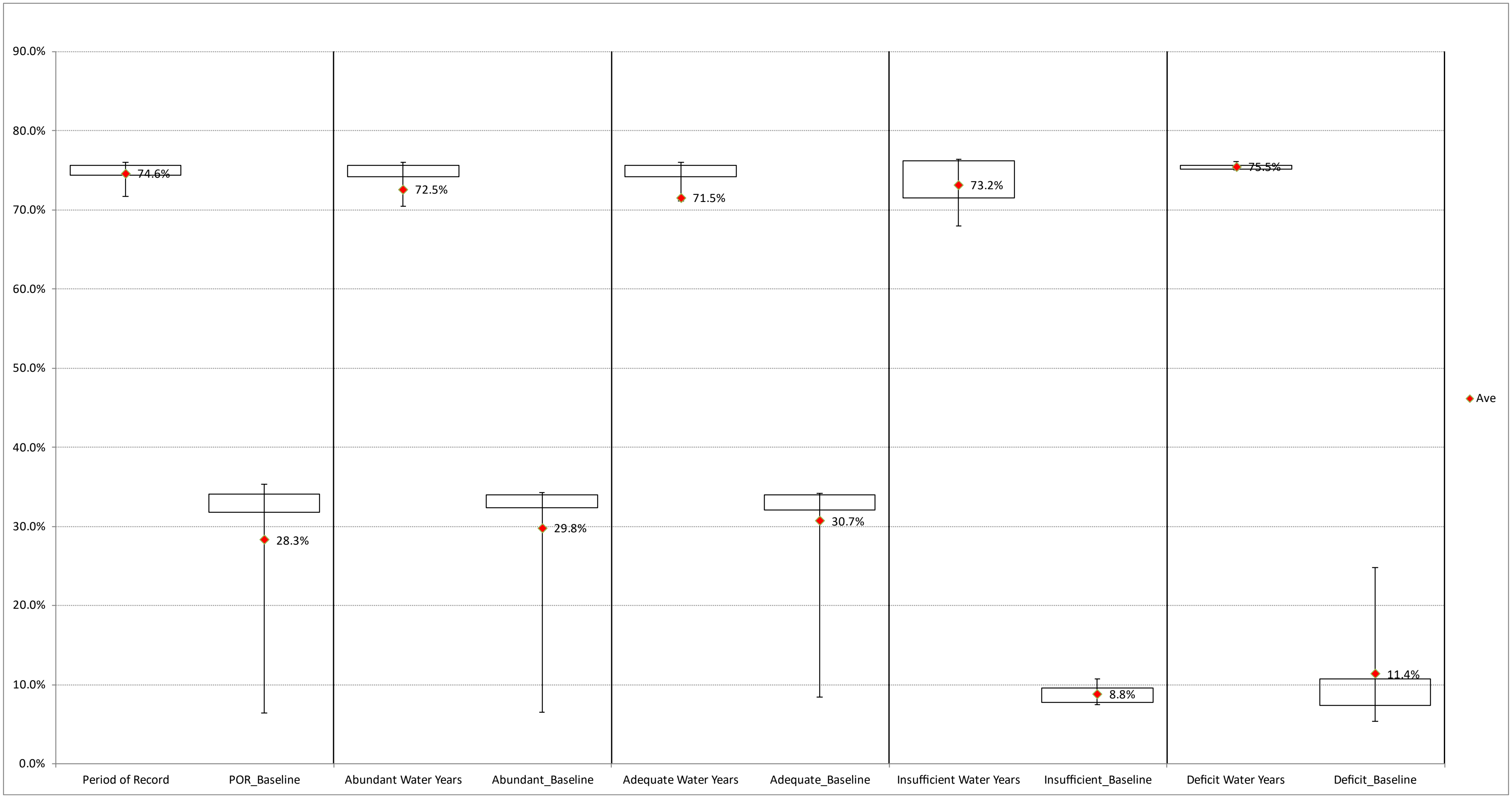

Figure 2-20. Detroit Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Detroit for juvenile spring Chinook sub-yearling under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

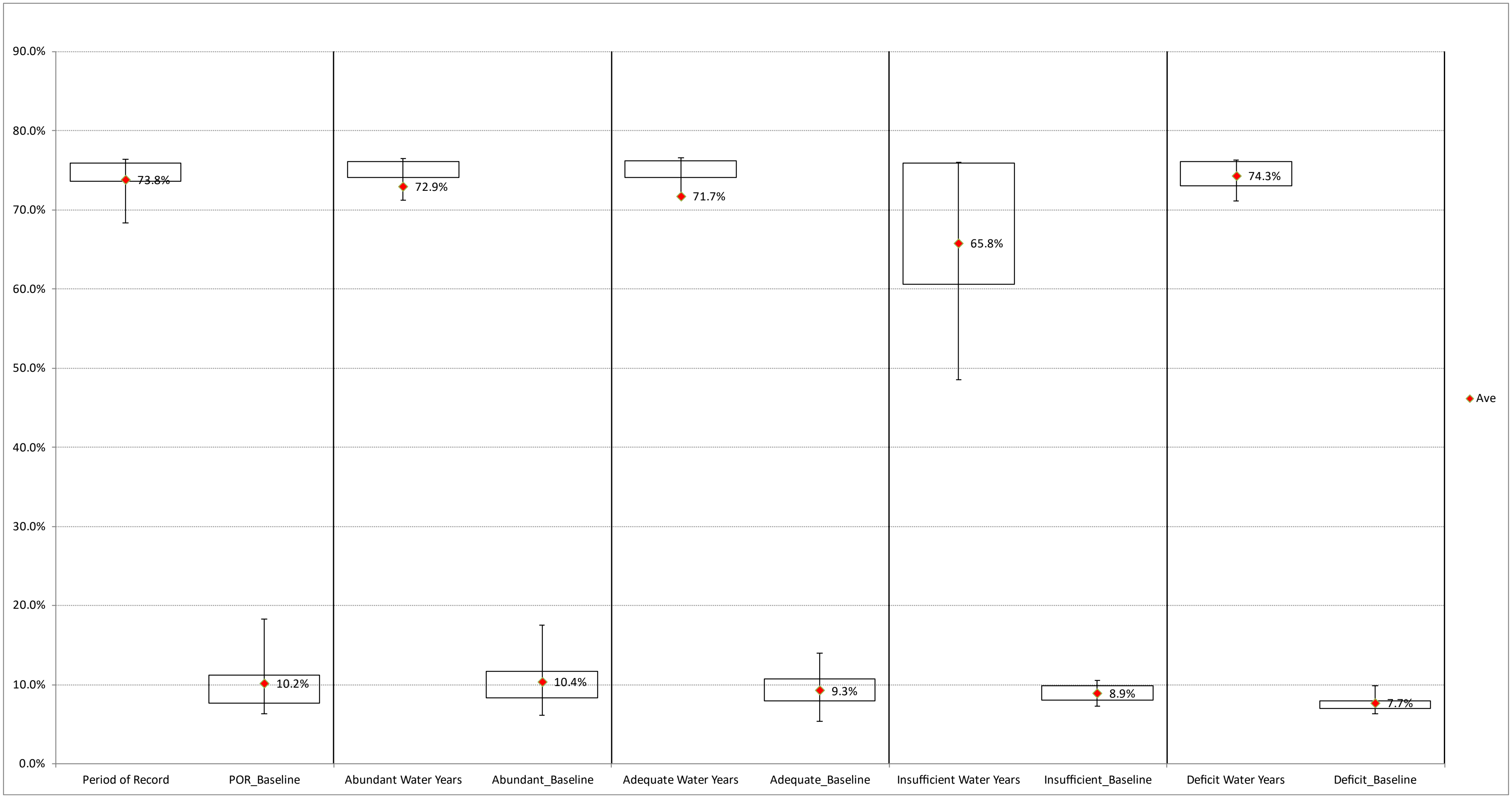

Figure 2-21. Detroit Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Detroit for juvenile spring Chinook yearling under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.2.2 South Santiam - Foster

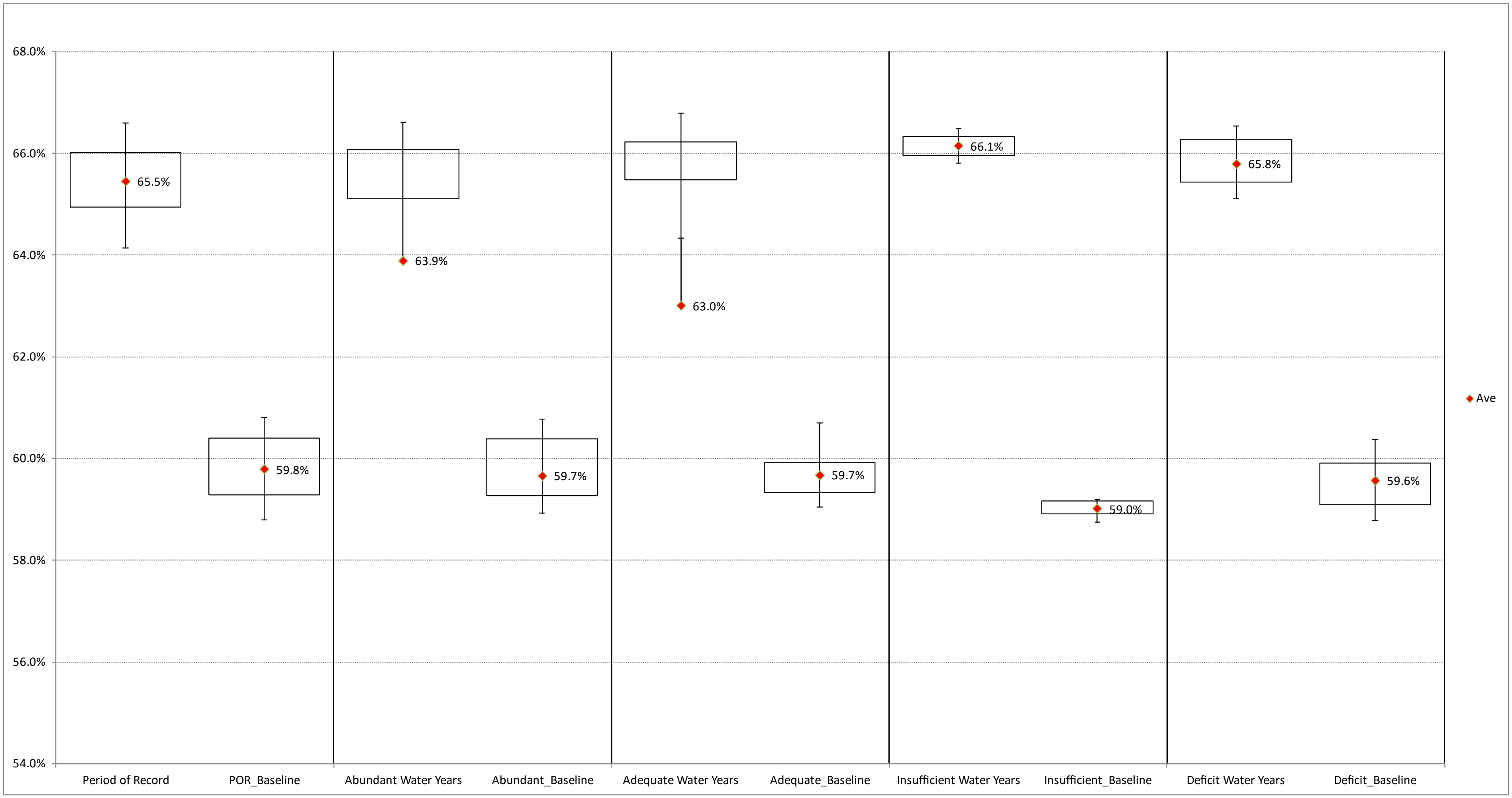

Figure 2-22. Foster juvenile spring Chinook fry Downstream dam passage survival under Alternative 1. *Downstream dam passage survival at Foster for juvenile spring Chinook fry under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

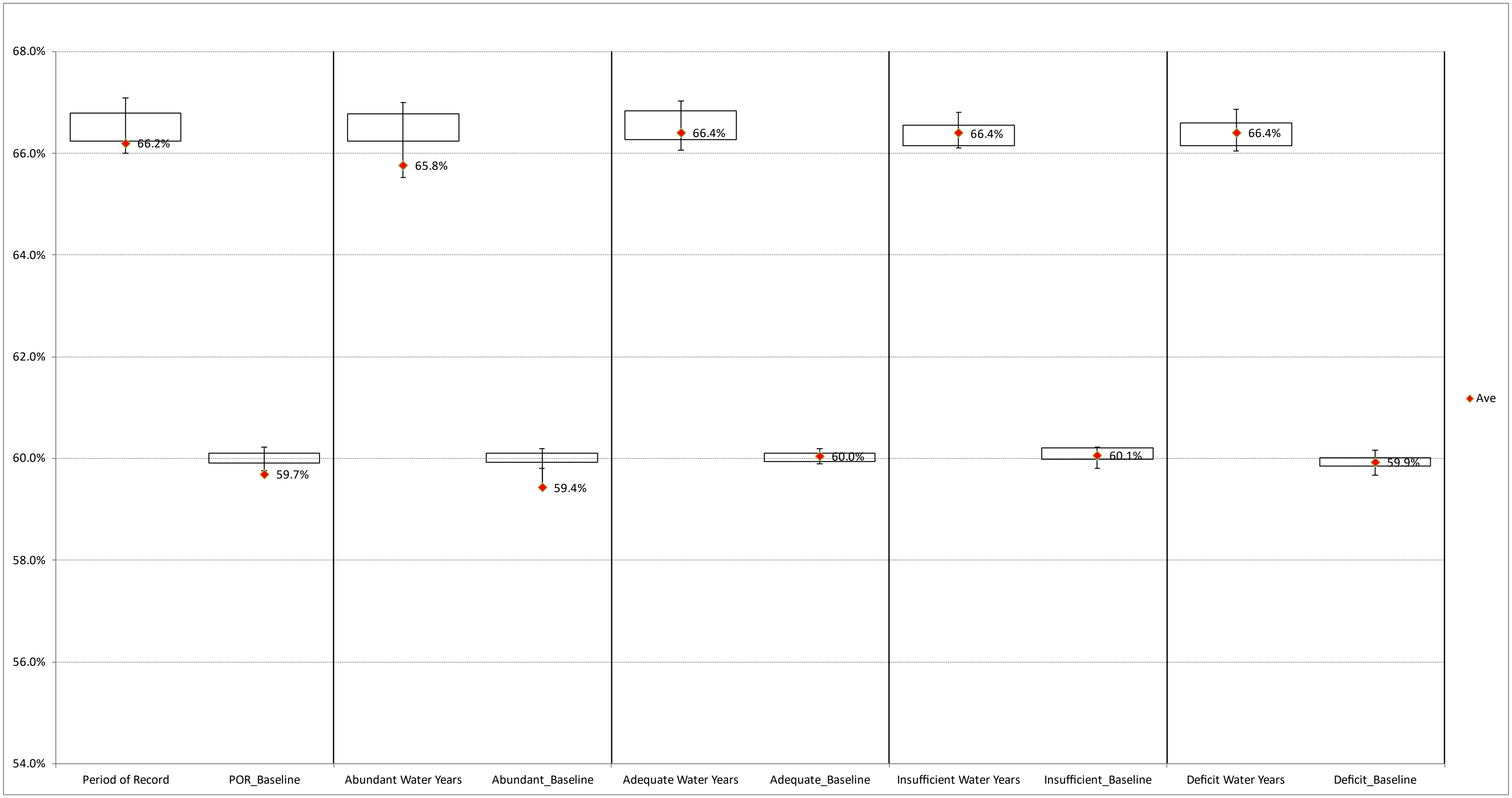

Figure 2-23. Foster Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Foster for juvenile spring Chinook sub-yearlings under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

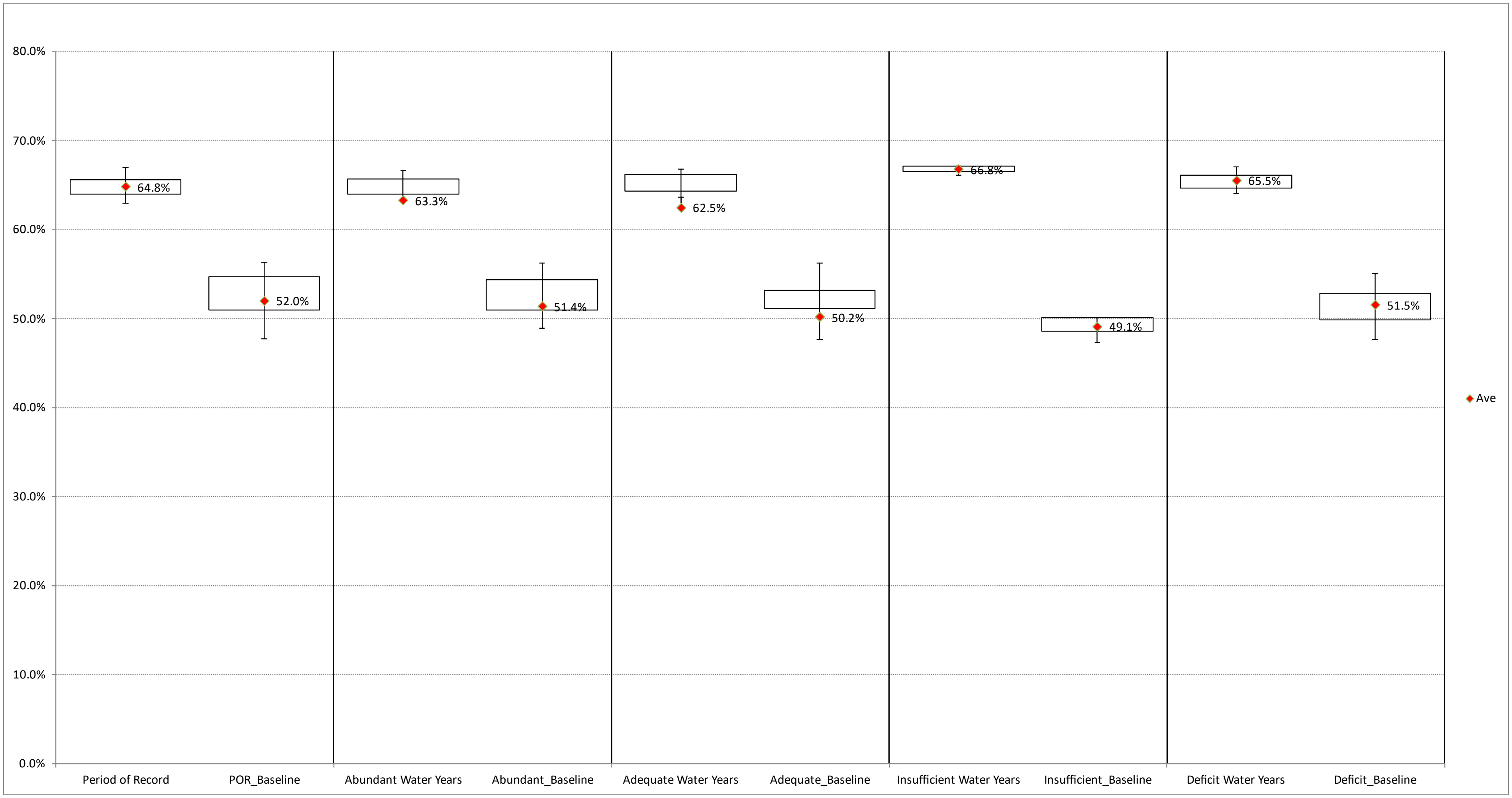

Figure 2-24. Foster Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Foster for juvenile spring Chinook yearlings under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.2.3 South Santiam – Green Peter

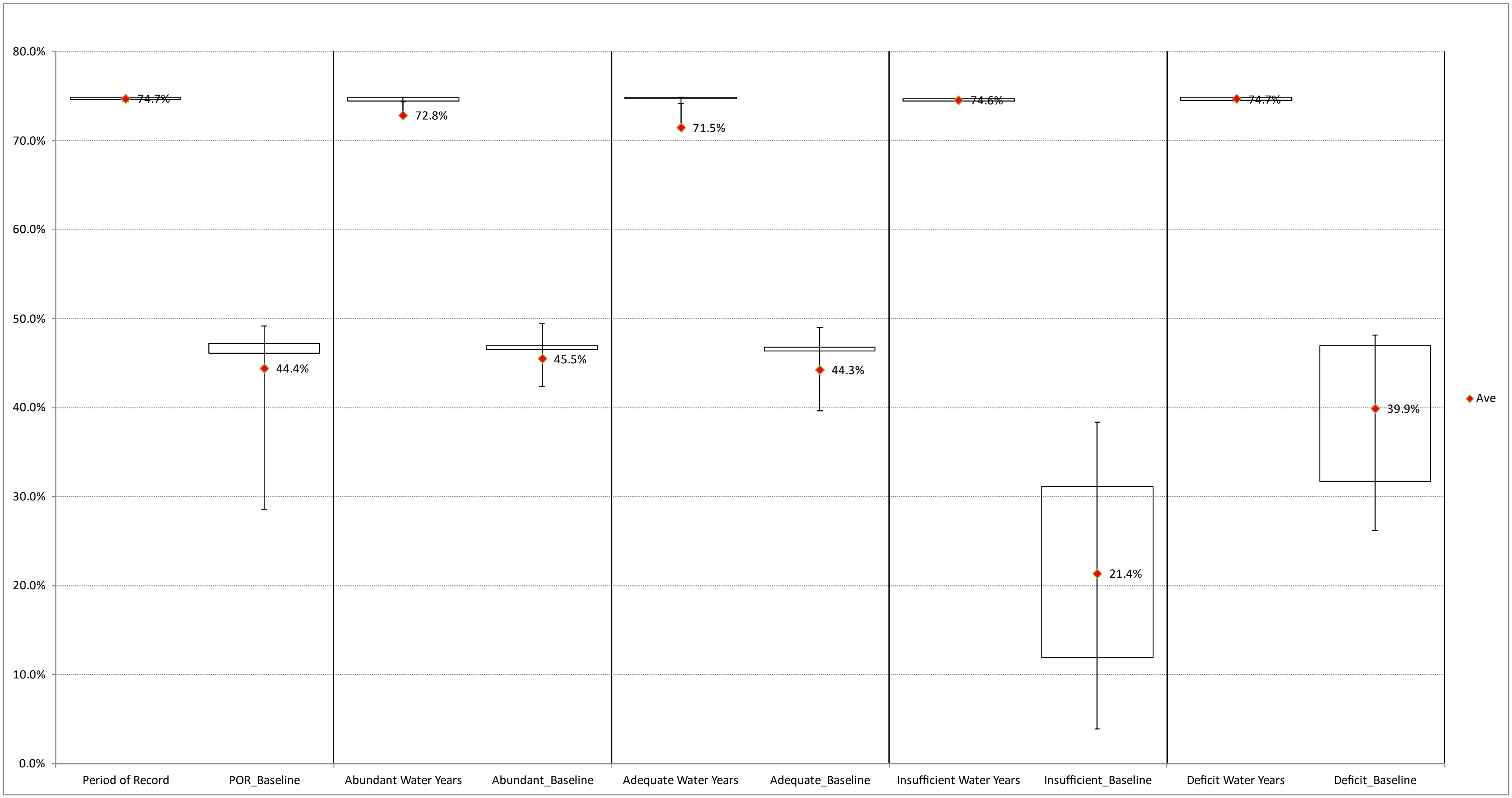

Figure 2-25. Green Peter Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Green Peter for juvenile spring Chinook fry under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

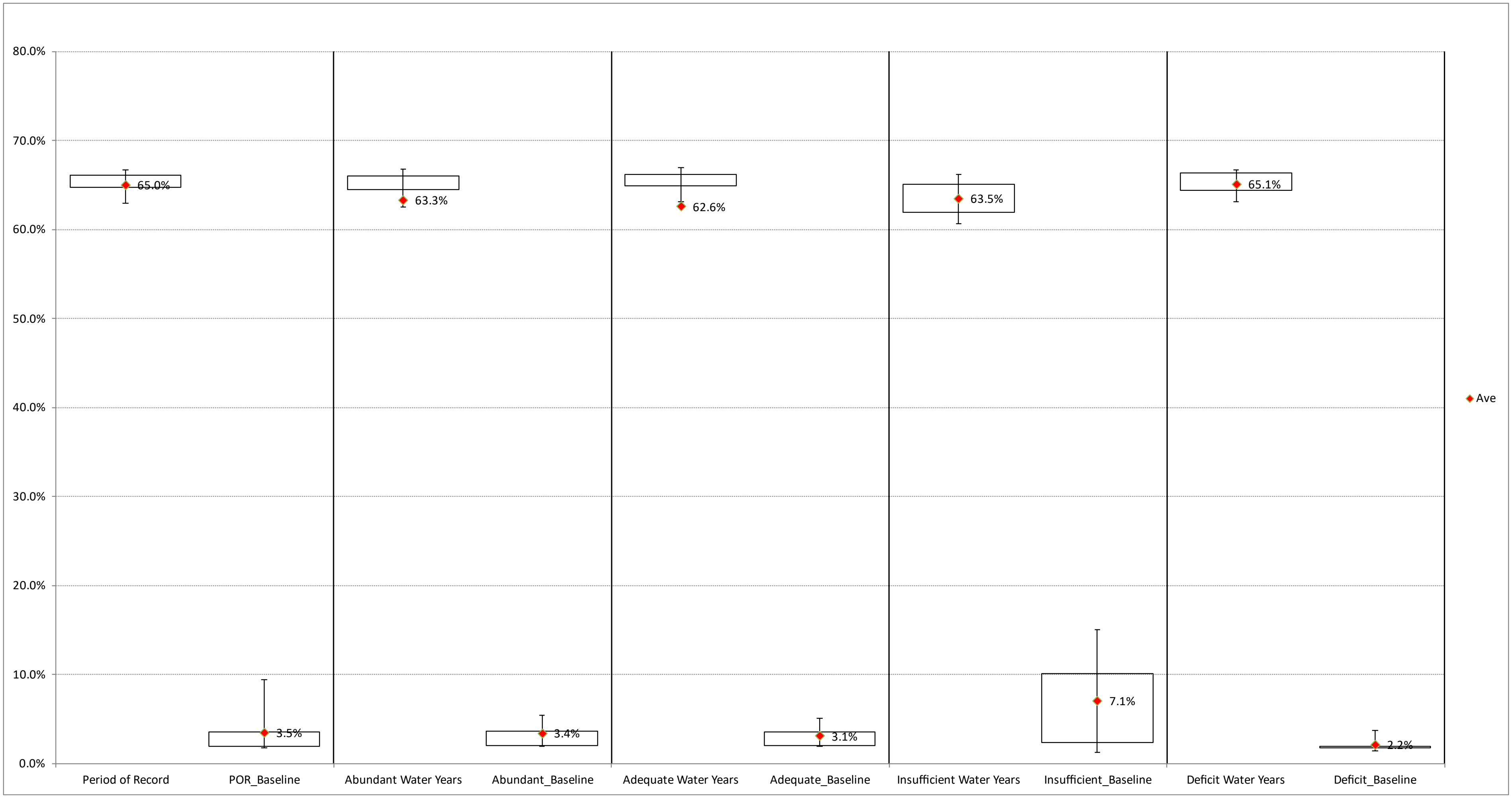

Figure 2-26. Green Peter Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Green Peter for juvenile spring Chinook sub-yearling under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

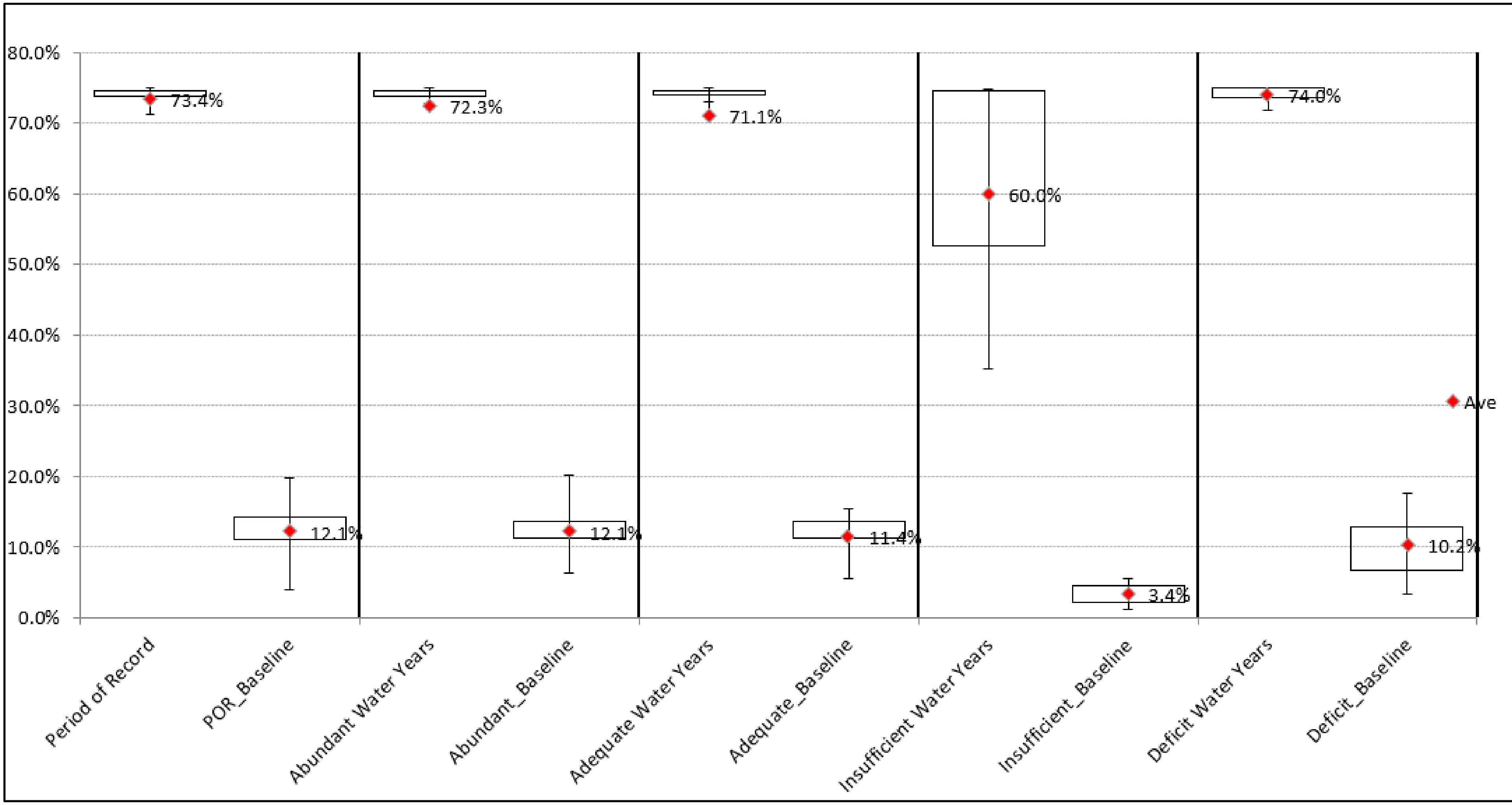

Figure 2-27. Green Peter Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Green Peter for juvenile spring Chinook yearling under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.2.4 McKenzie – Cougar

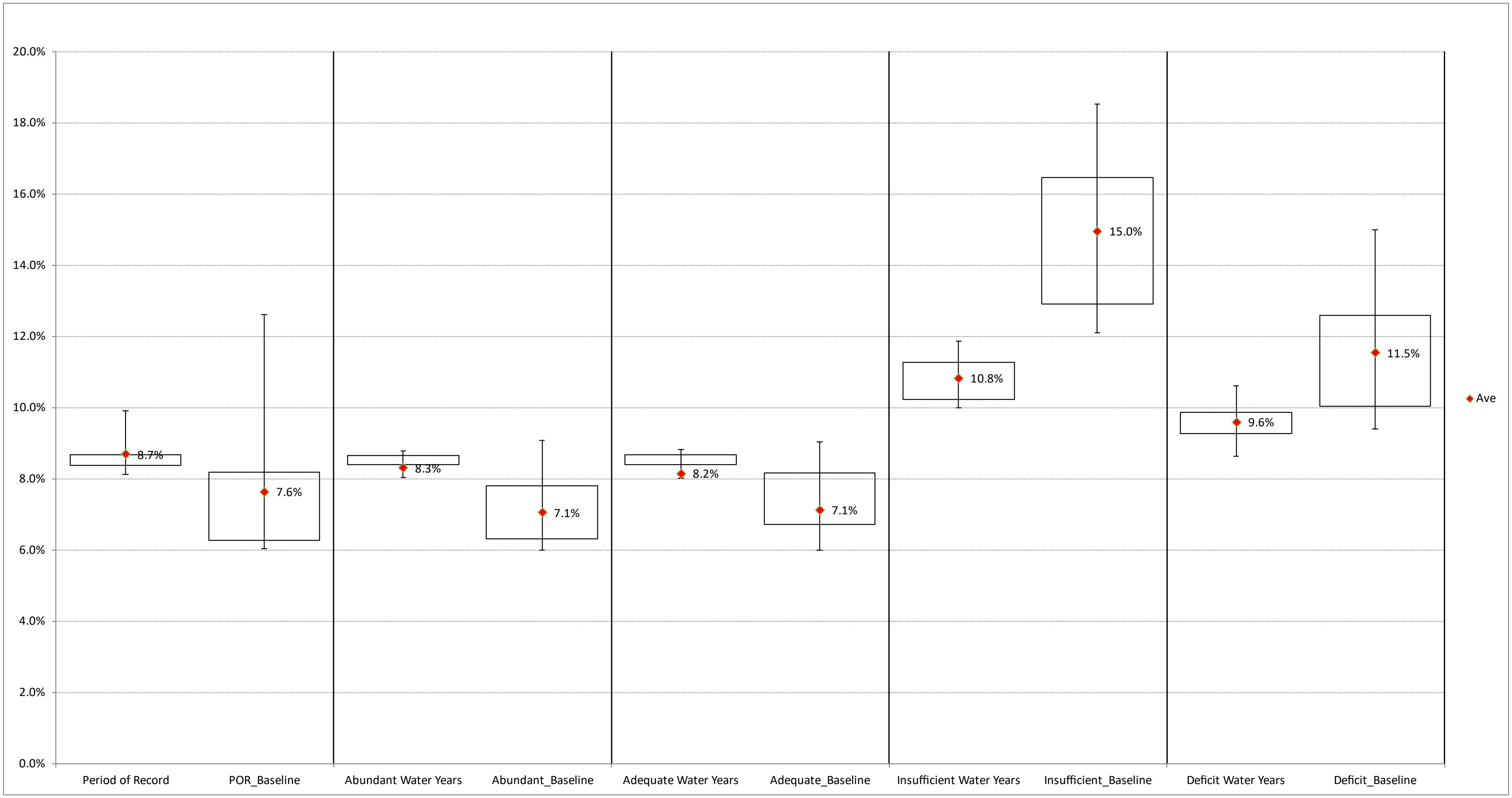

Figure 2-28. Cougar Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Cougar for juvenile spring Chinook fry under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

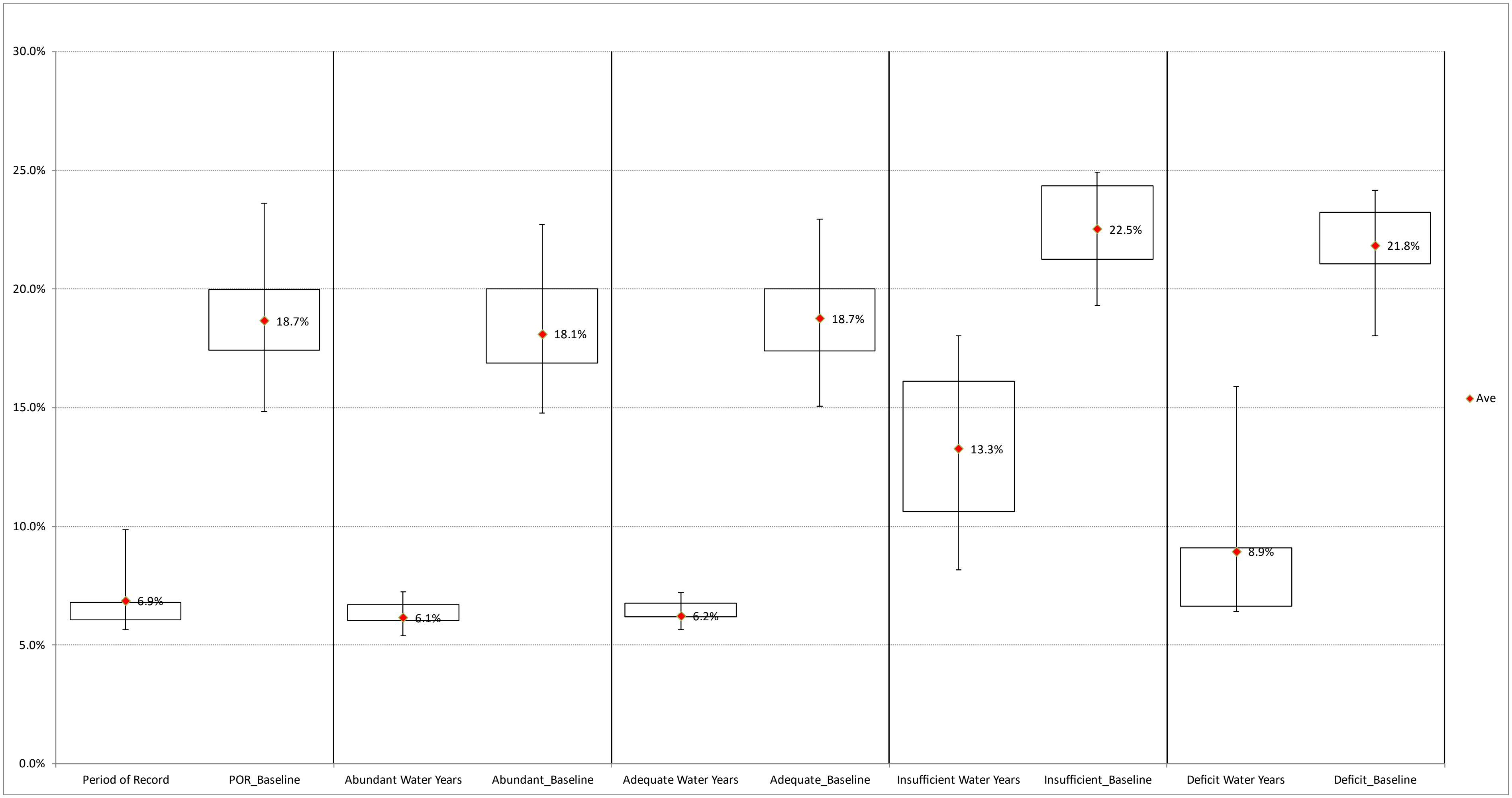

Figure 2-29. Cougar Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Cougar for juvenile spring Chinook sub-yearlings under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

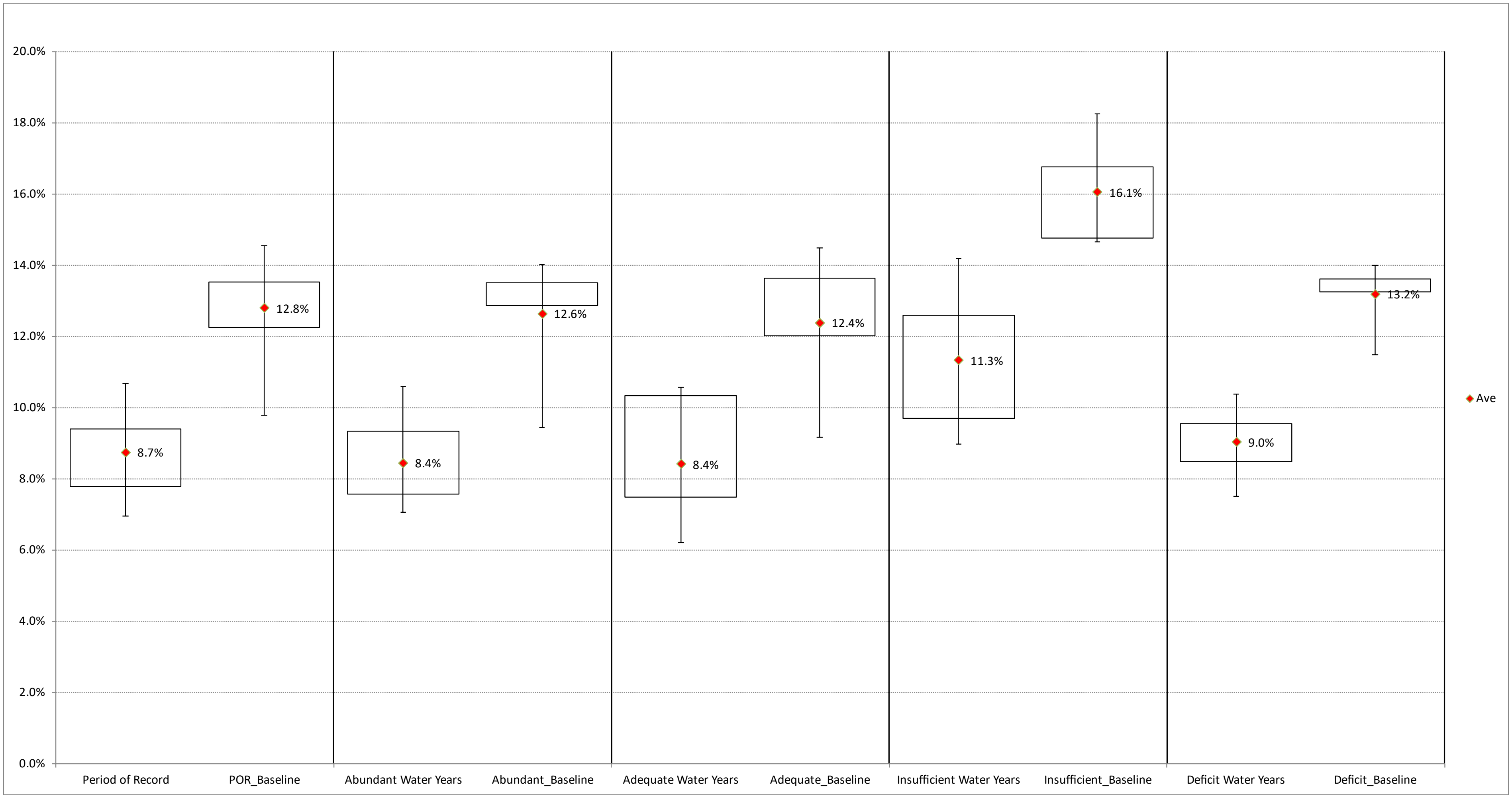

Figure 2-30. Cougar Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Cougar for juvenile spring Chinook yearlings under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.2.5 Middle Fork – Lookout Point

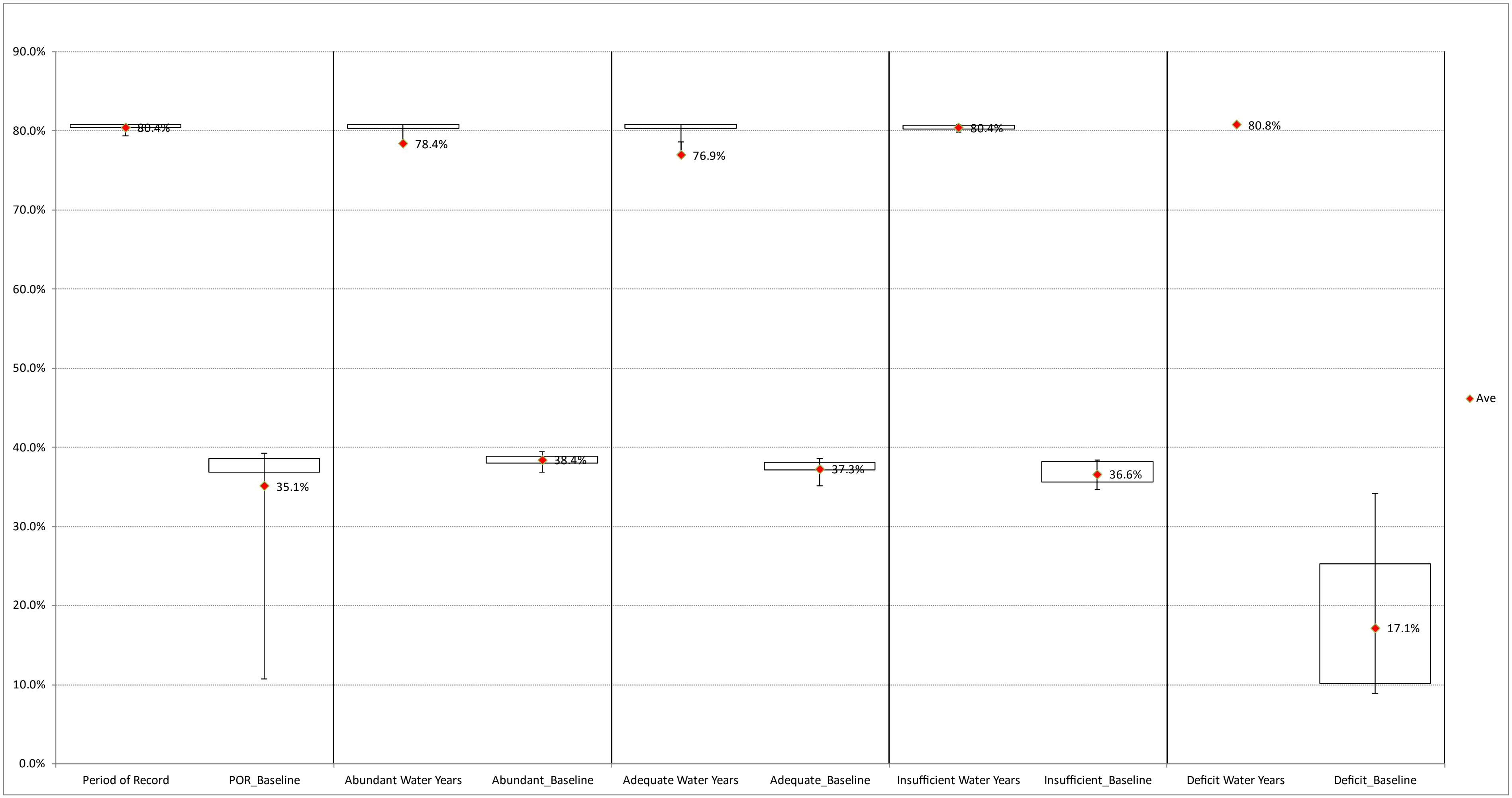

Figure 2-31. Lookout Point Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook fry under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

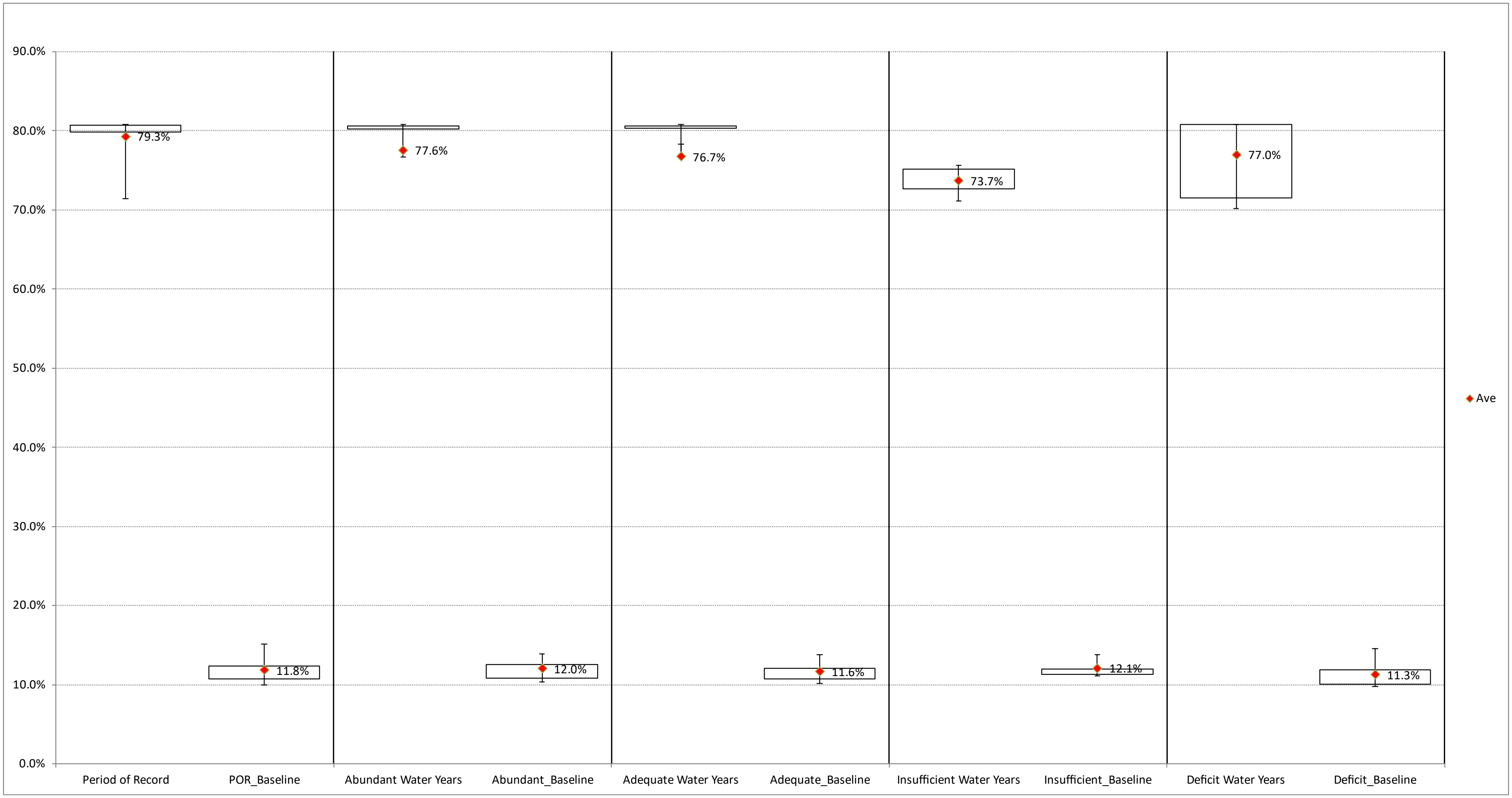

Figure 2-32. Lookout Point Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook sub-yearlings under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

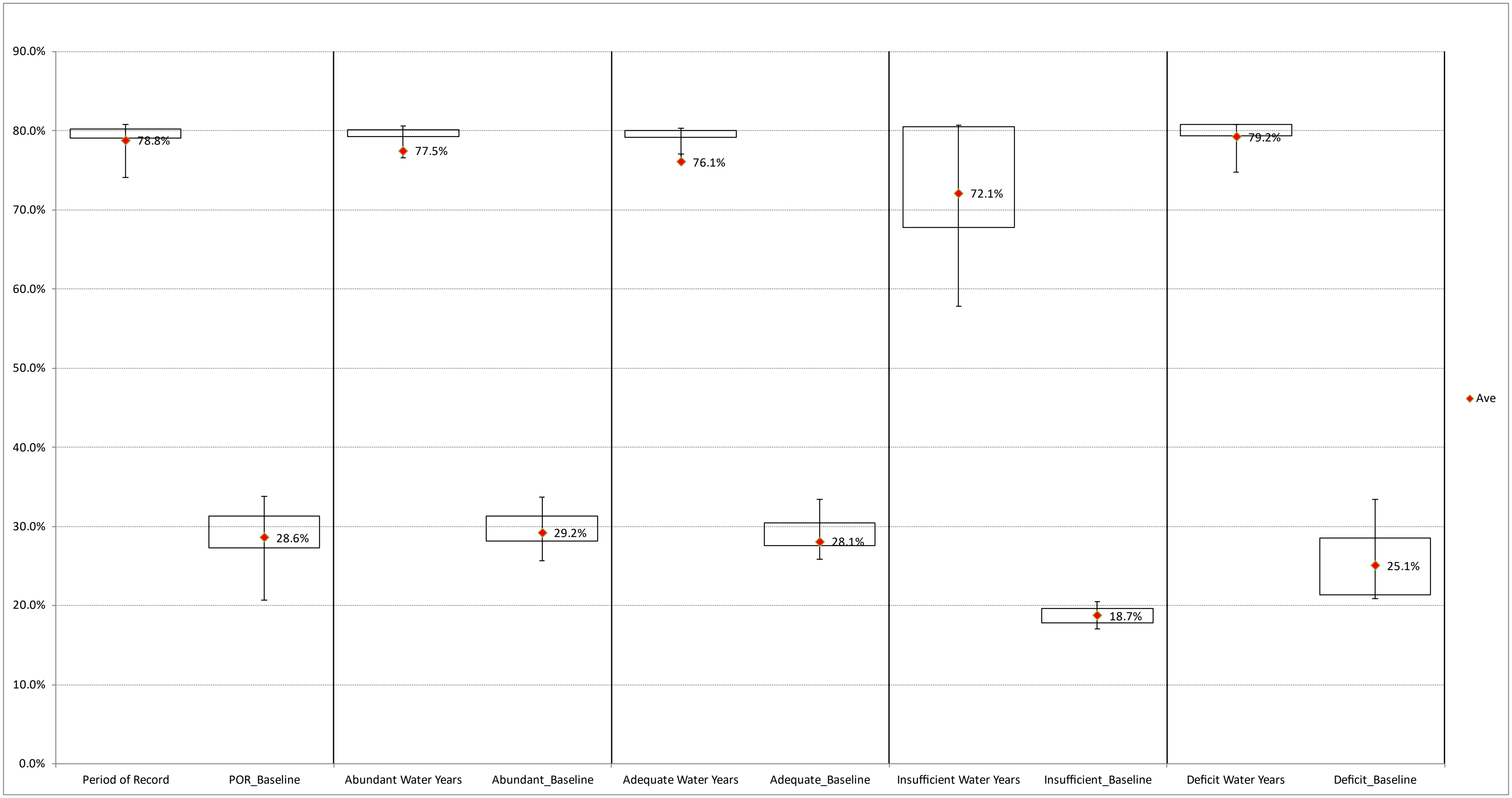

Figure 2-33. Lookout Point Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook yearlings under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

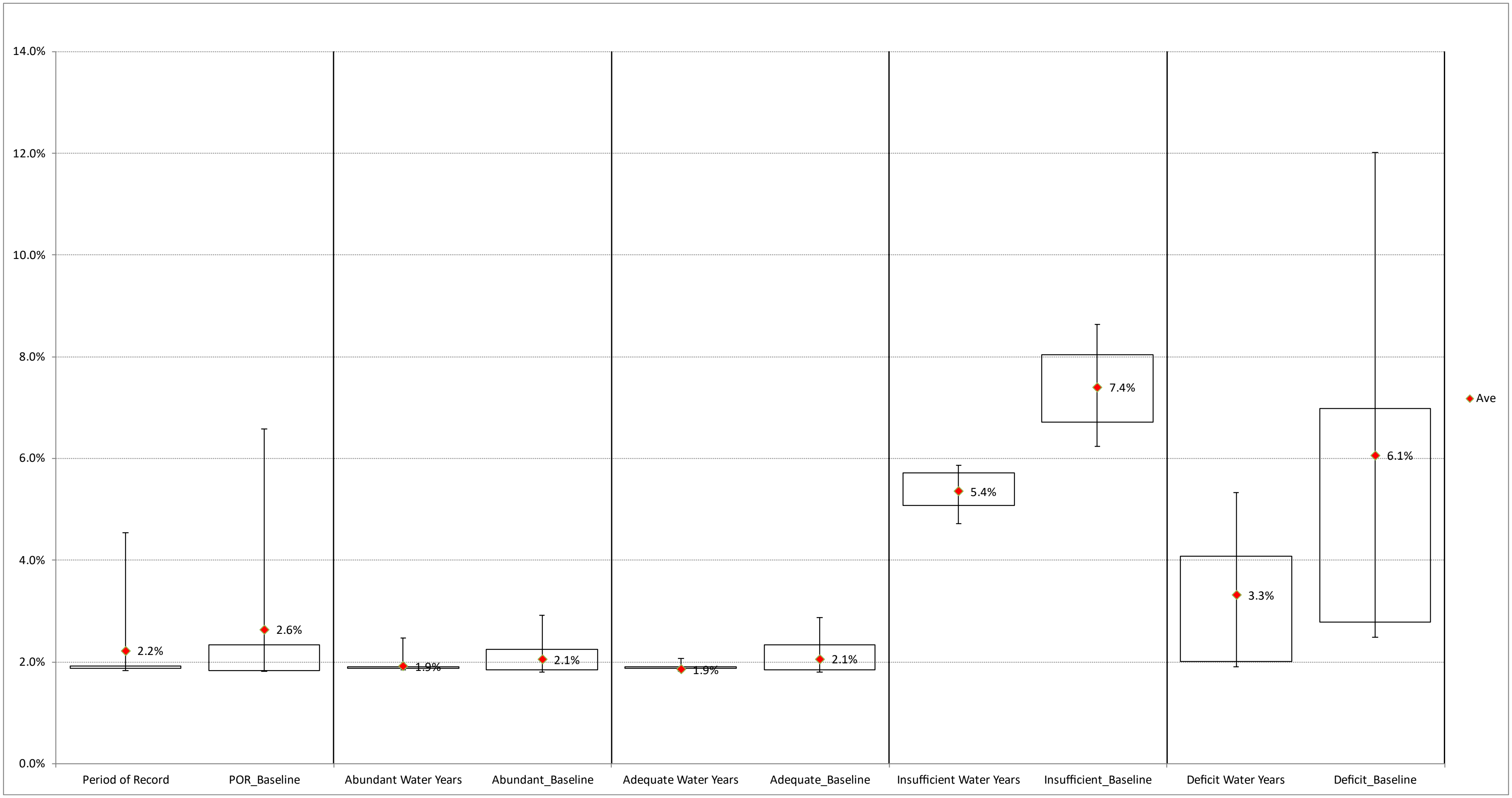

Figure 2-34. Hills Creek Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook fry under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

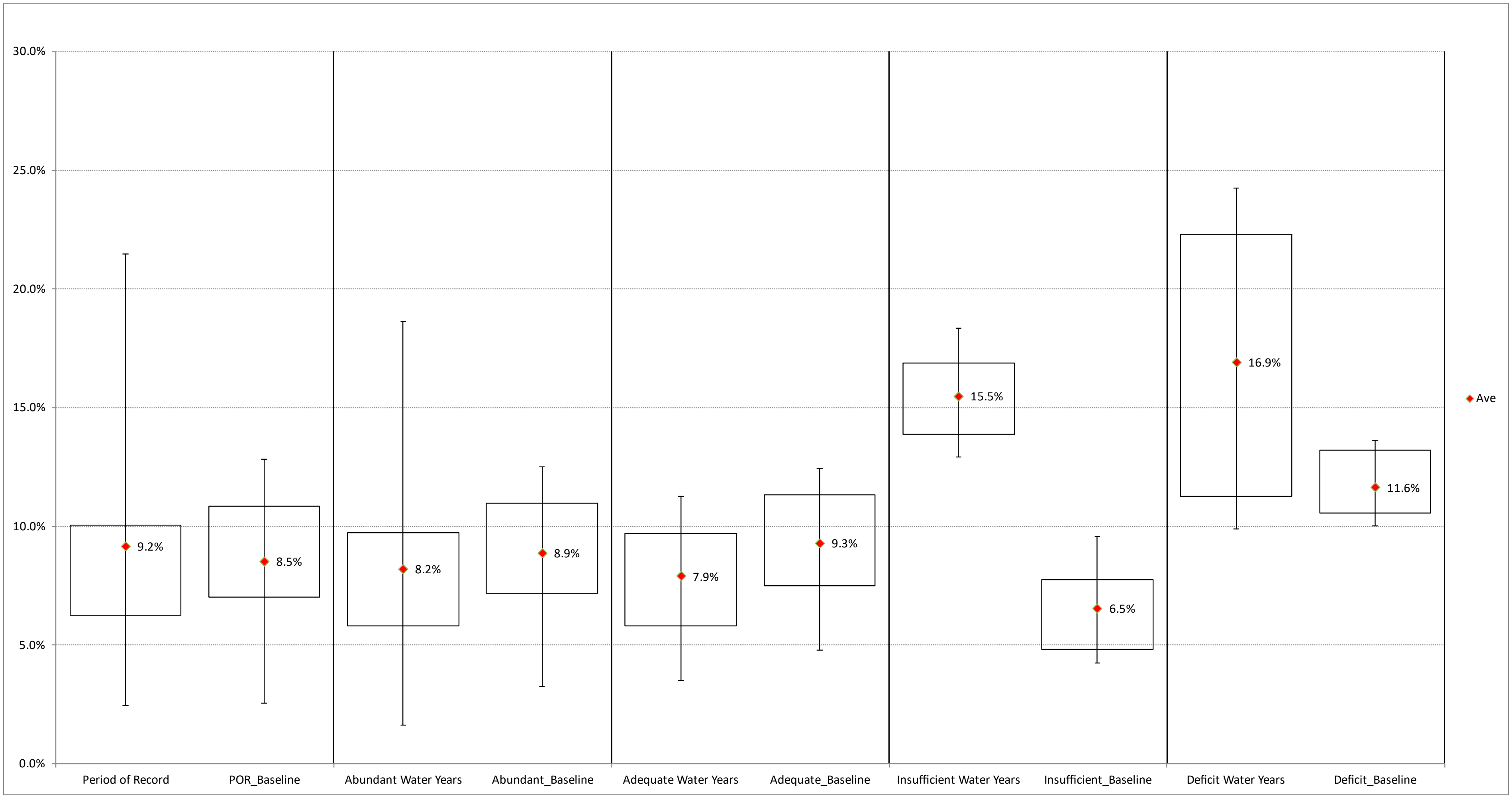

Figure 2-35. Hills Creek Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook sub-yearlings under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

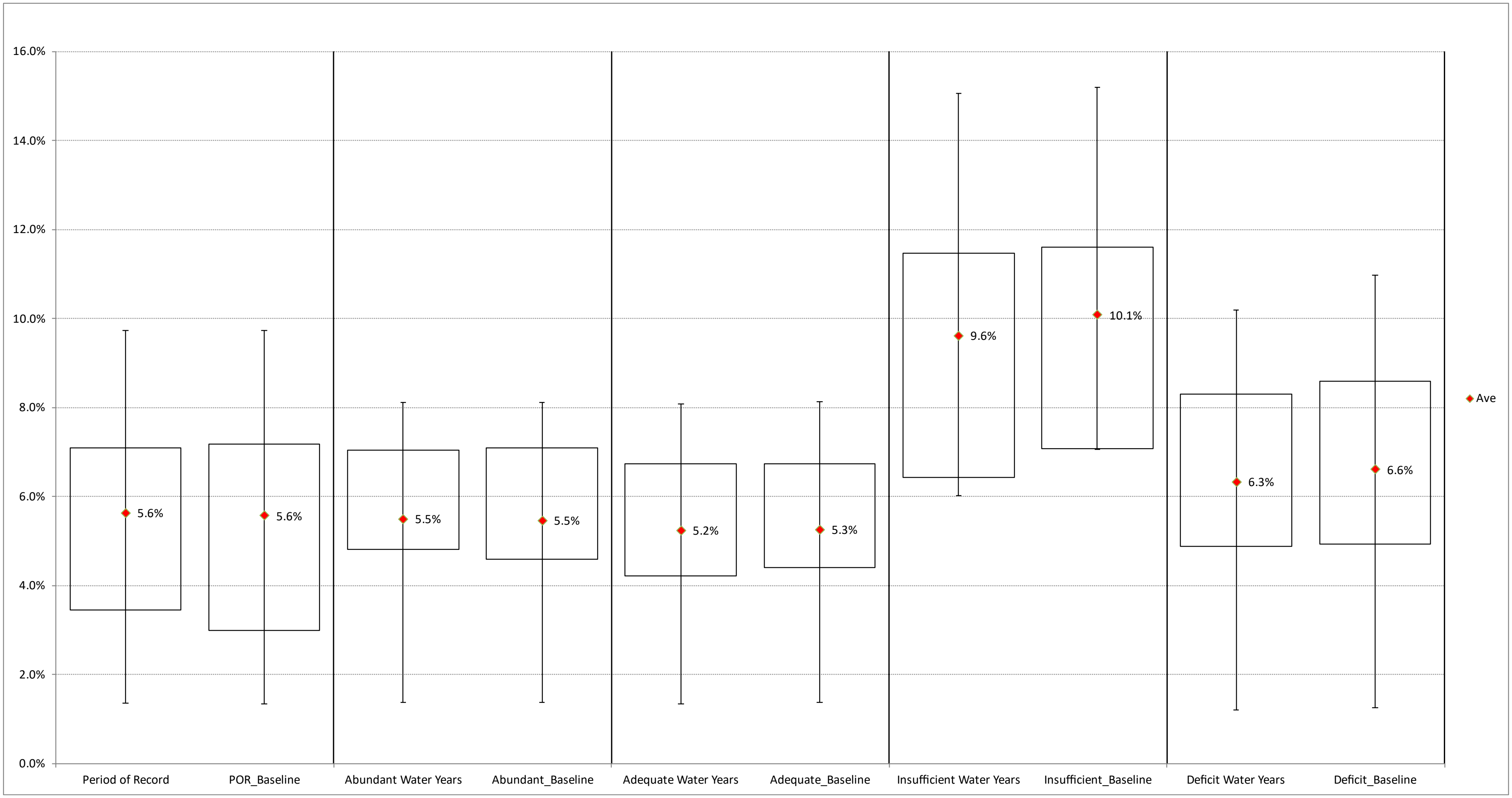

Figure 2-36. Hills Creek Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook yearlings under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.3 CHINOOK SALMON ALTERNATIVE 2A

2.3.1 North Santiam - Detroit

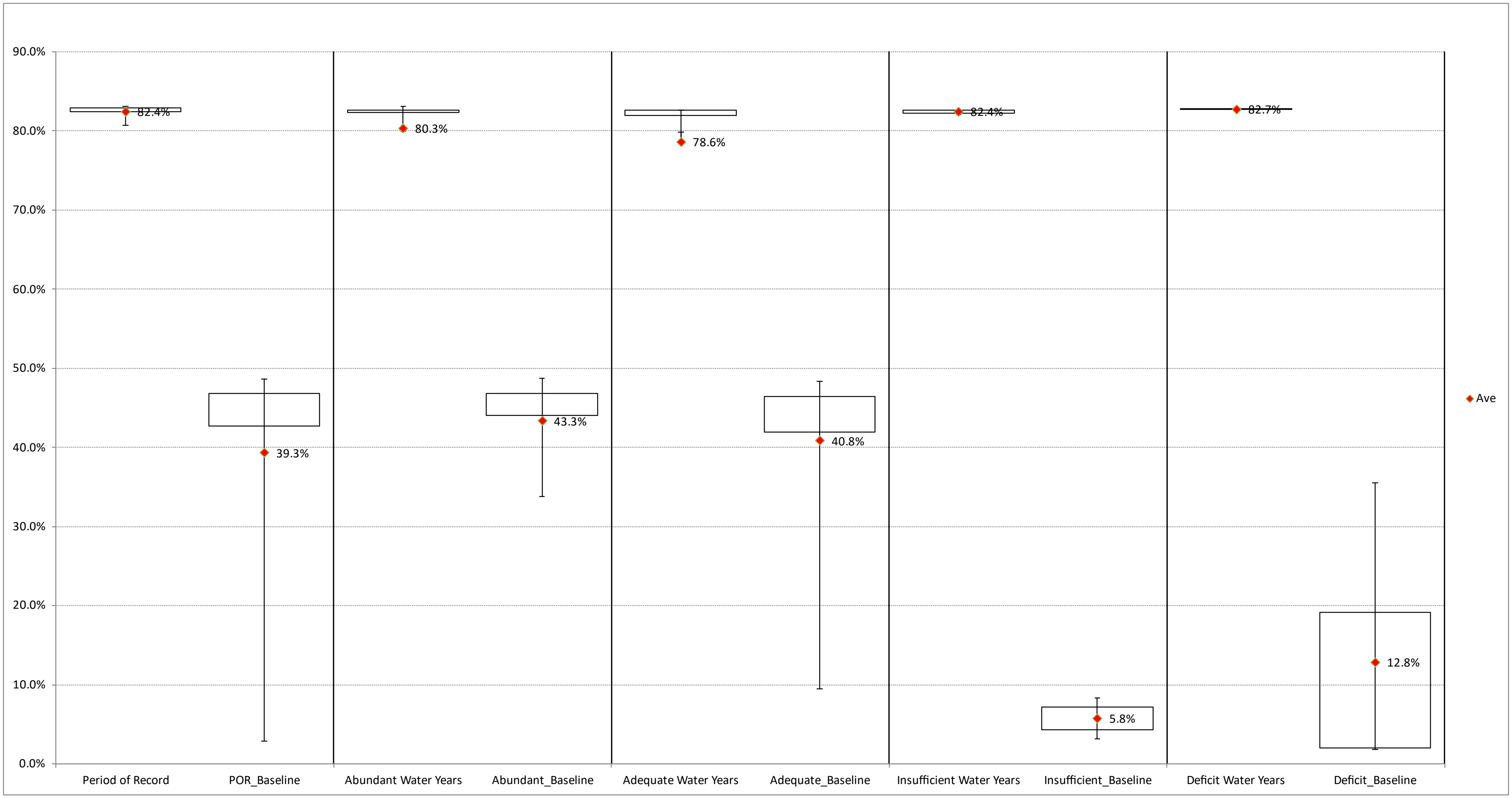

Figure 2-37. Detroit Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Detroit for juvenile spring Chinook fry under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

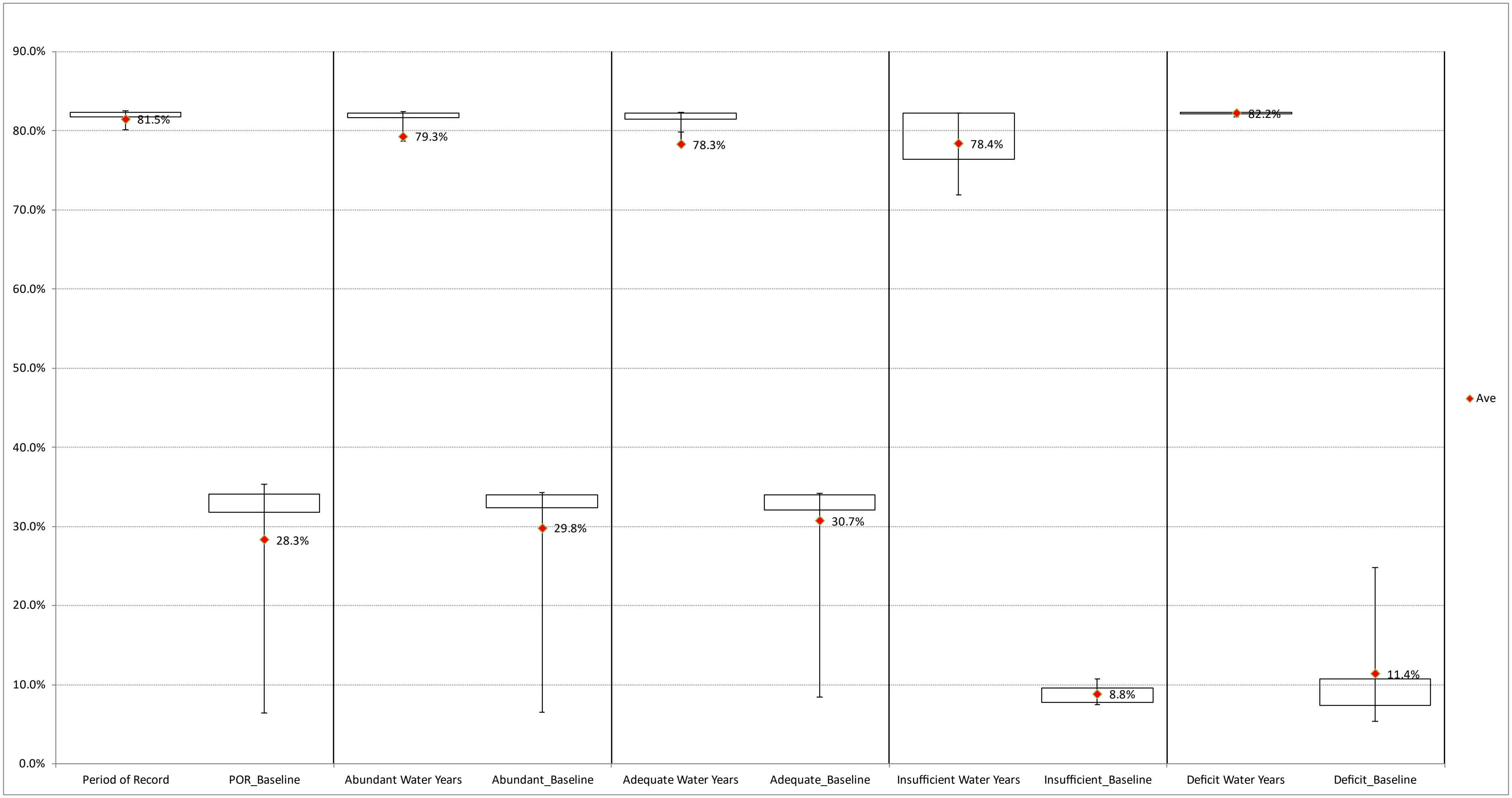

Figure 2-38. Detroit Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Detroit for juvenile spring Chinook sub-yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

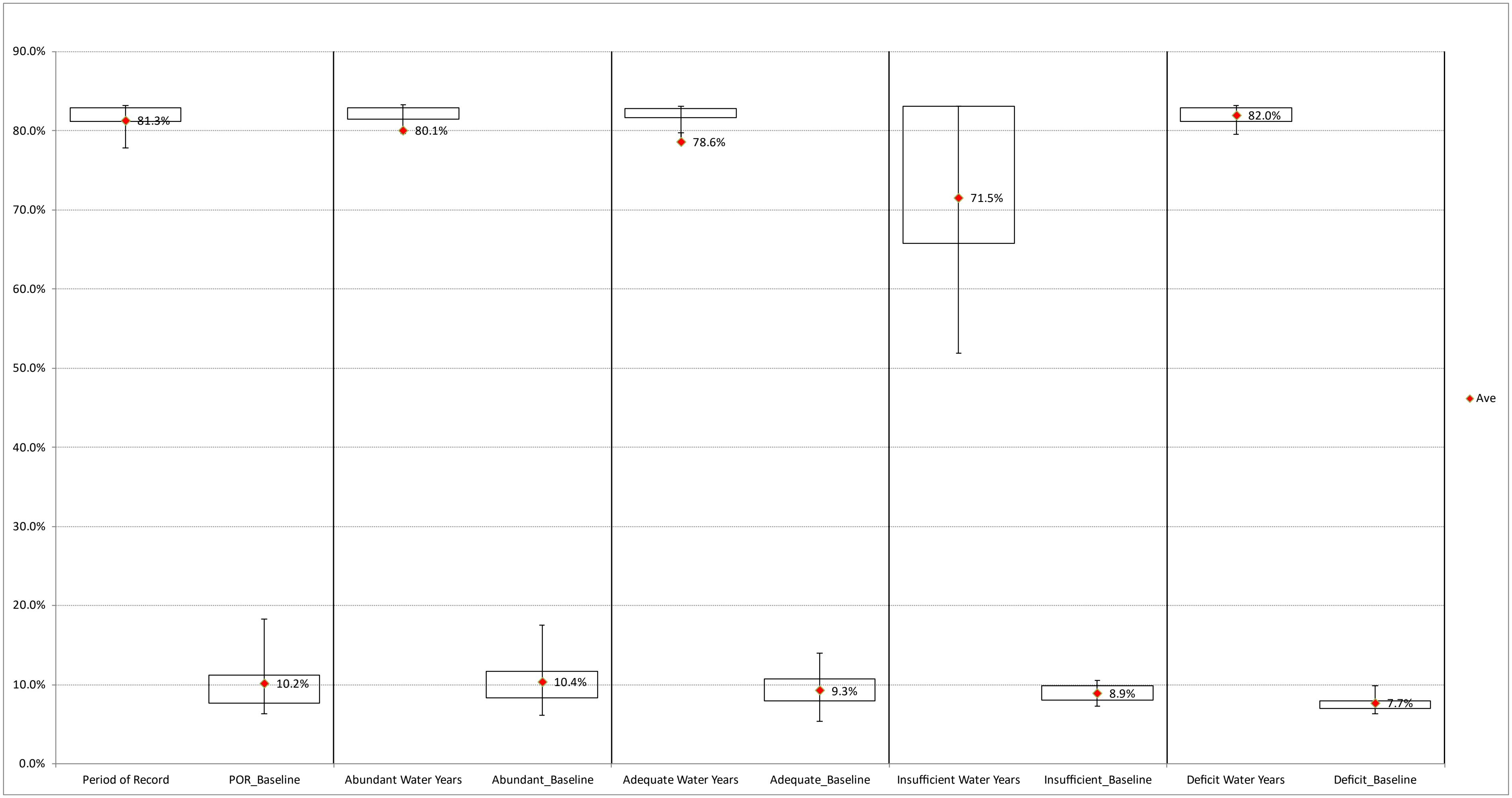

Figure 2-39. Detroit Juvenile Spring Chinook Yearlings Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Detroit for juvenile spring Chinook yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.3.2 South Santiam – Foster

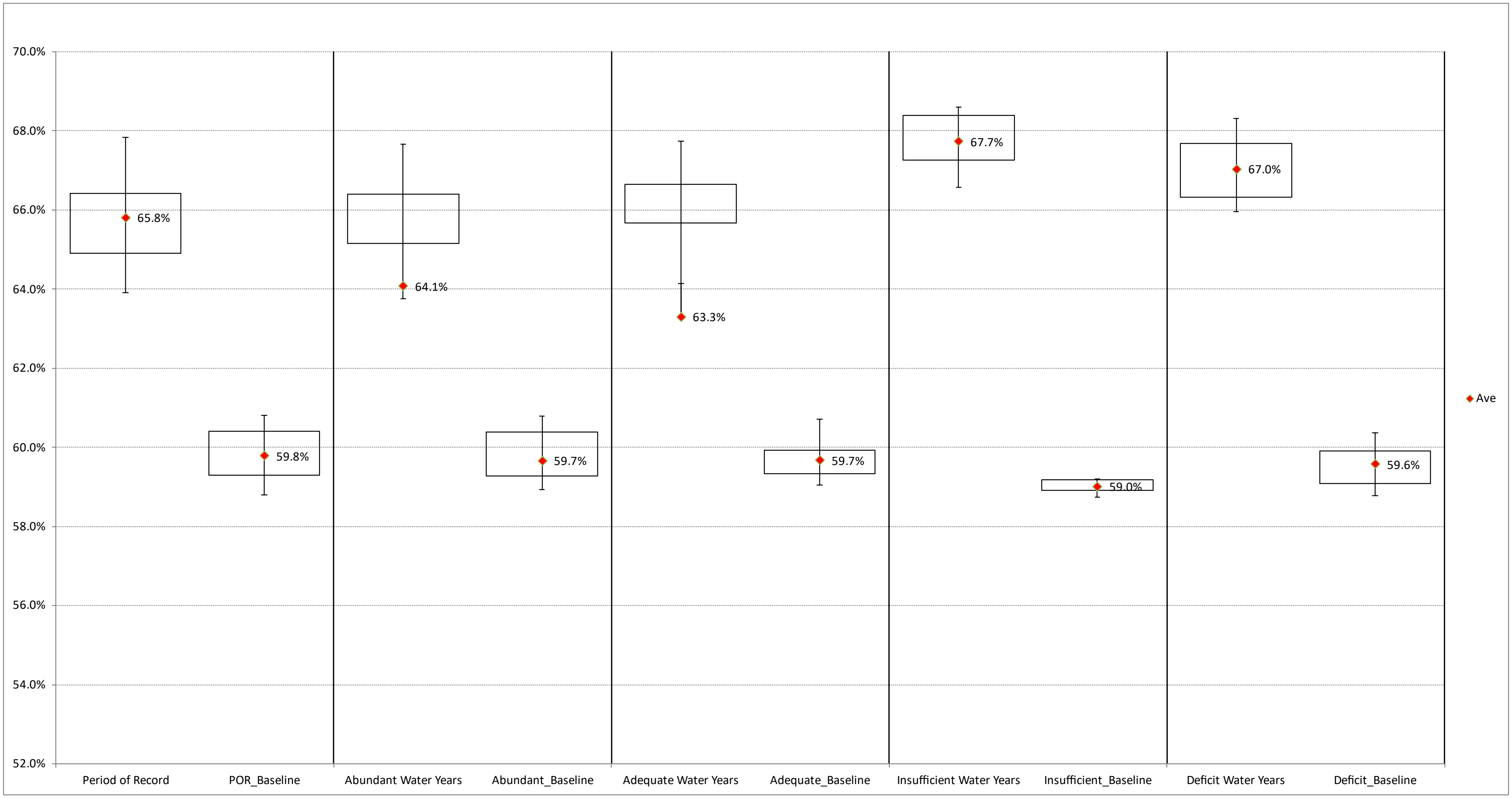

Figure 2-40. Foster Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Foster for juvenile spring Chinook fry under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

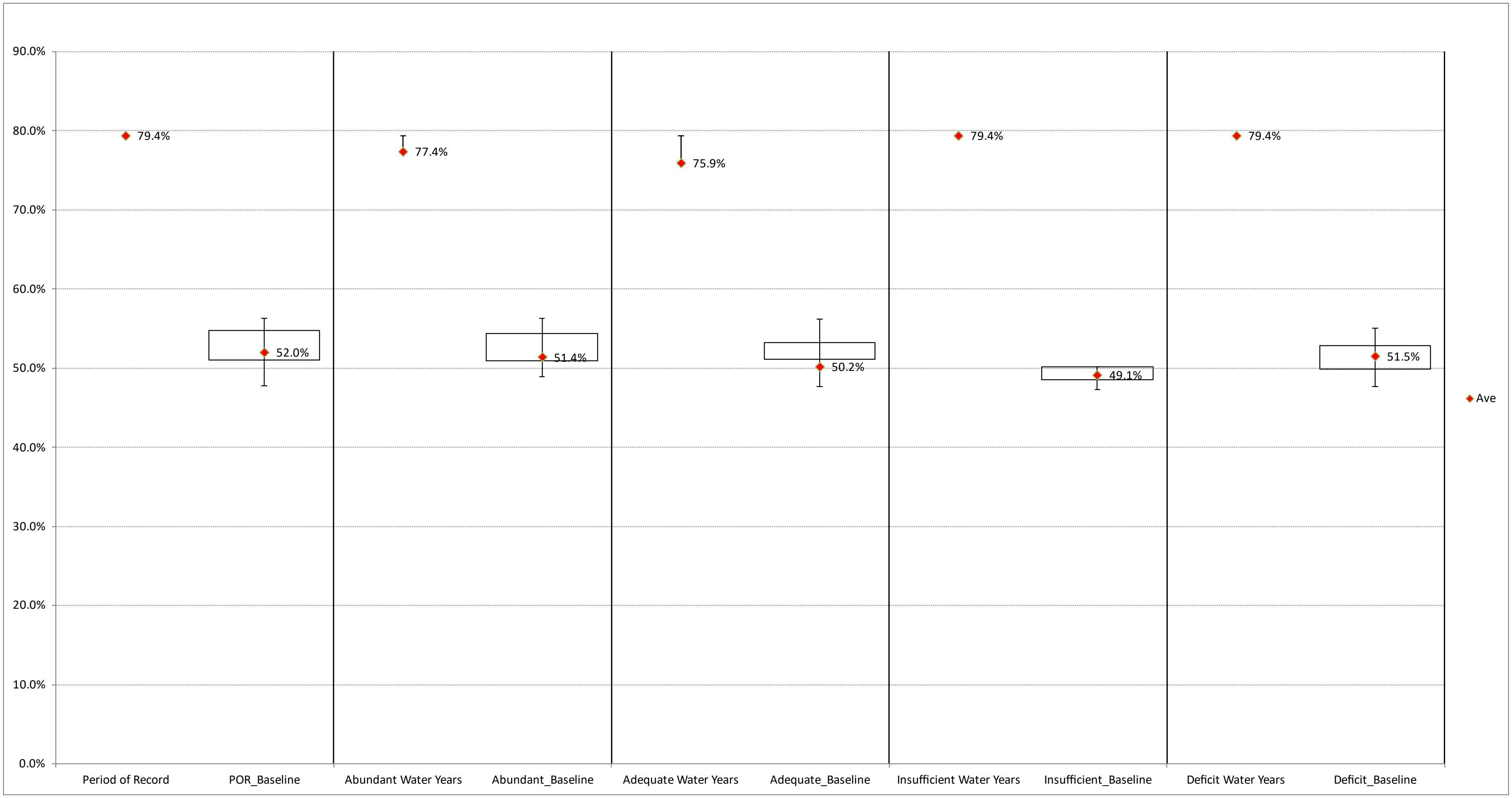

Figure 2-41. Foster Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Foster for juvenile spring Chinook sub-yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

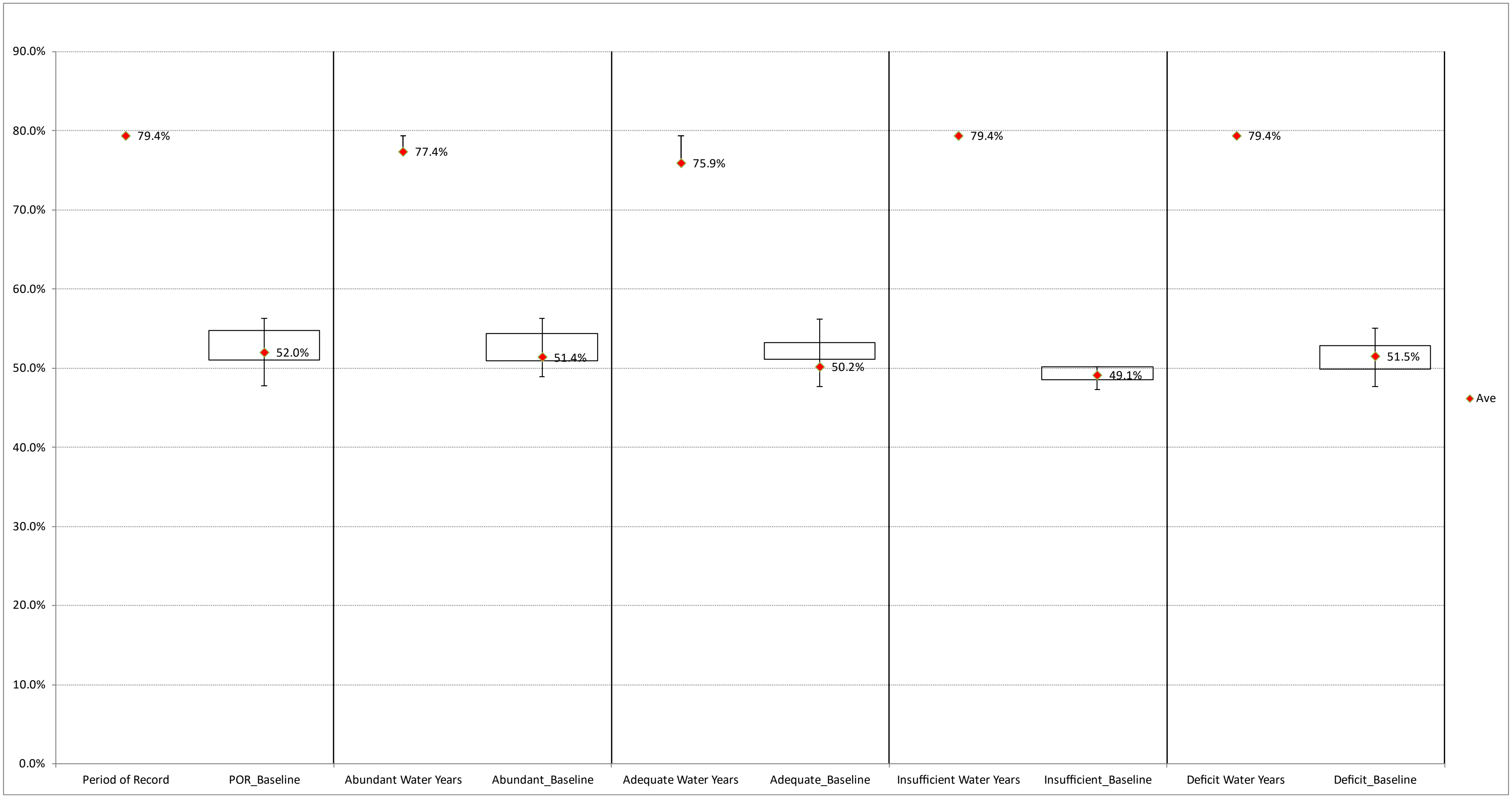

Figure 2-42. Foster Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Foster for juvenile spring Chinook yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.3.3 South Santiam – Green Peter

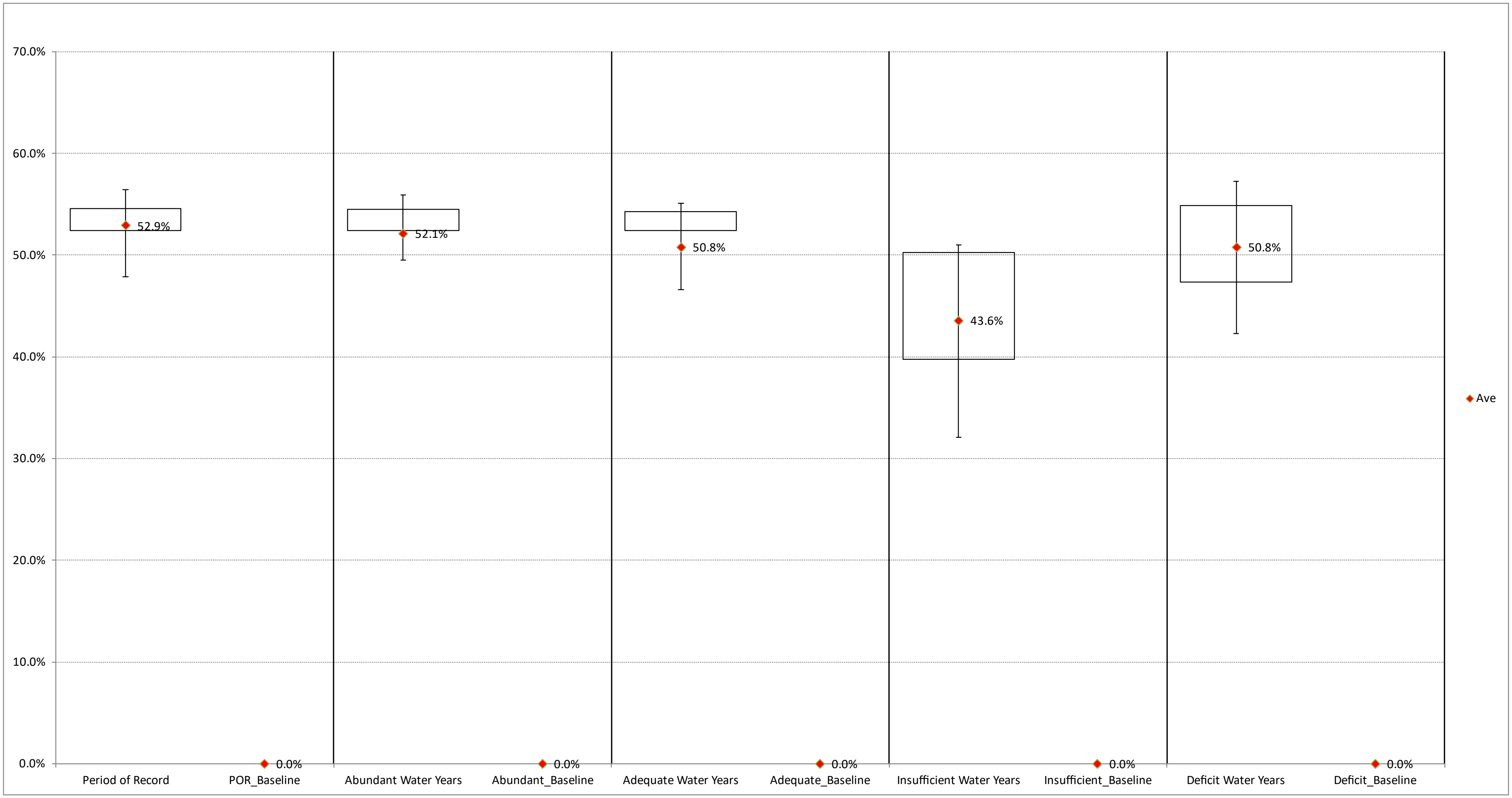

Figure 2-43. Green Peter Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Green Peter for juvenile spring Chinook fry under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

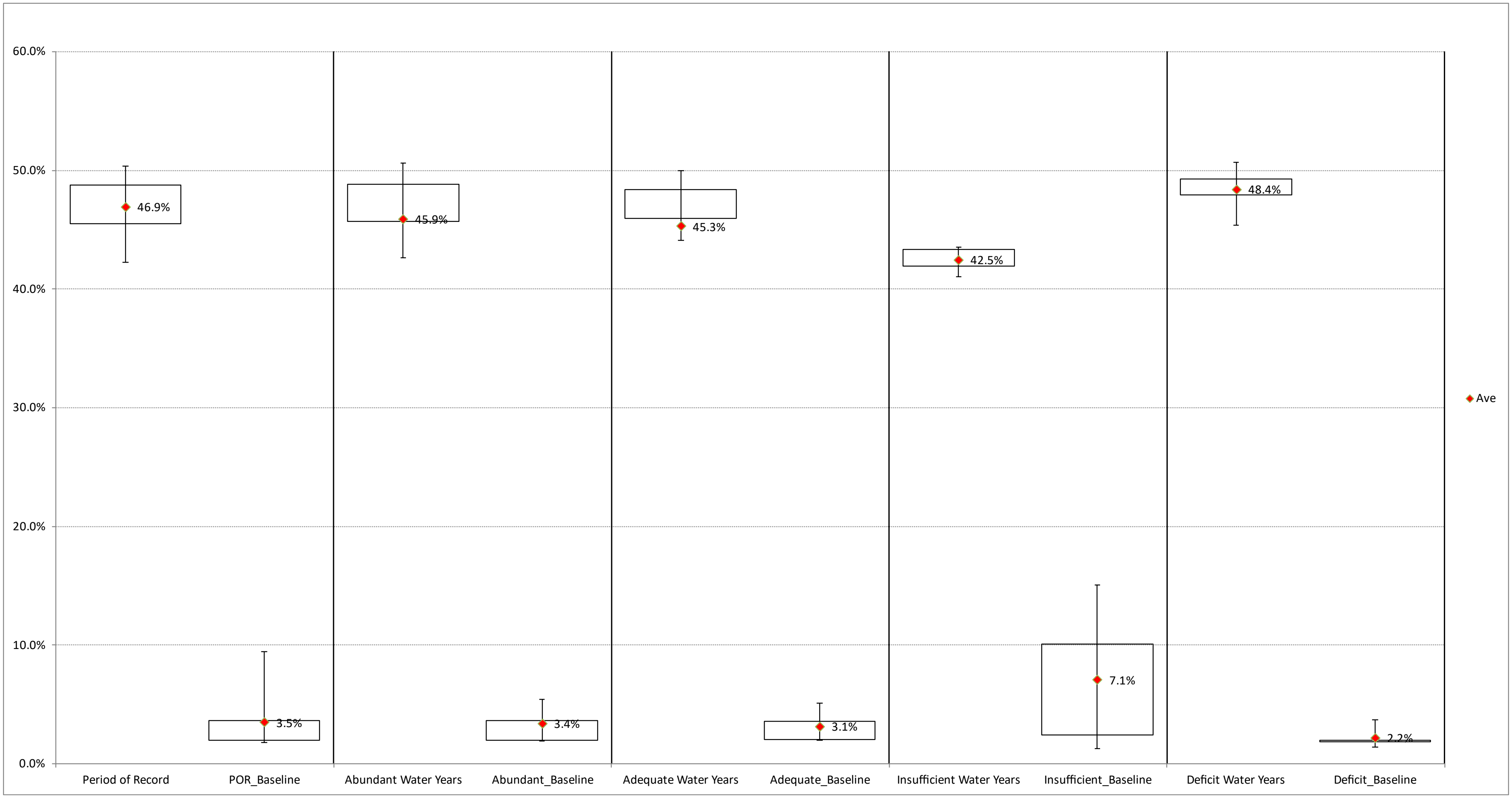

Figure 2-44. Green Peter Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Green Peter for juvenile spring Chinook sub-yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

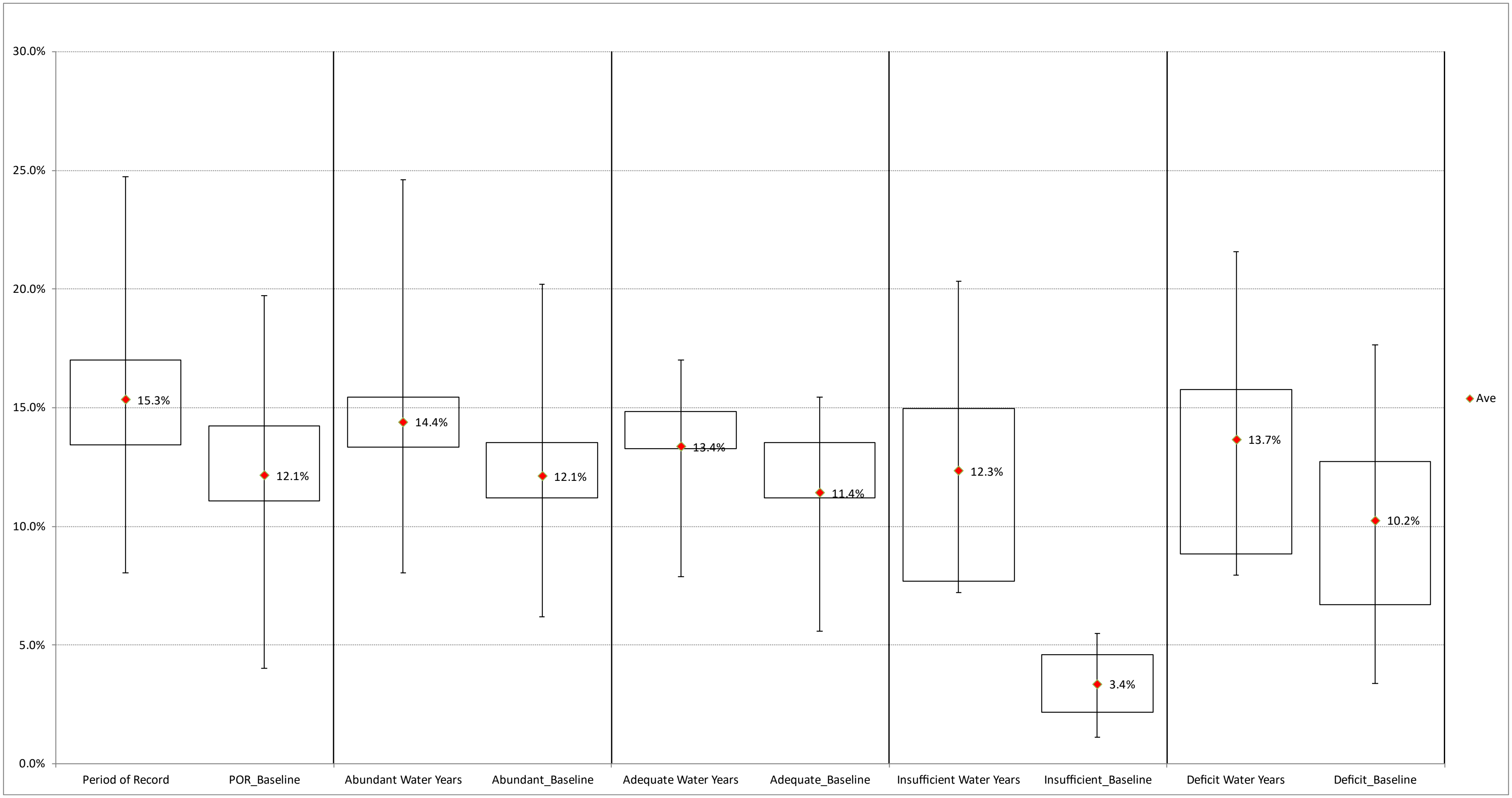

Figure 2-45. Green Peter Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Green Peter for juvenile spring Chinook yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.3.4 McKenzie - Cougar

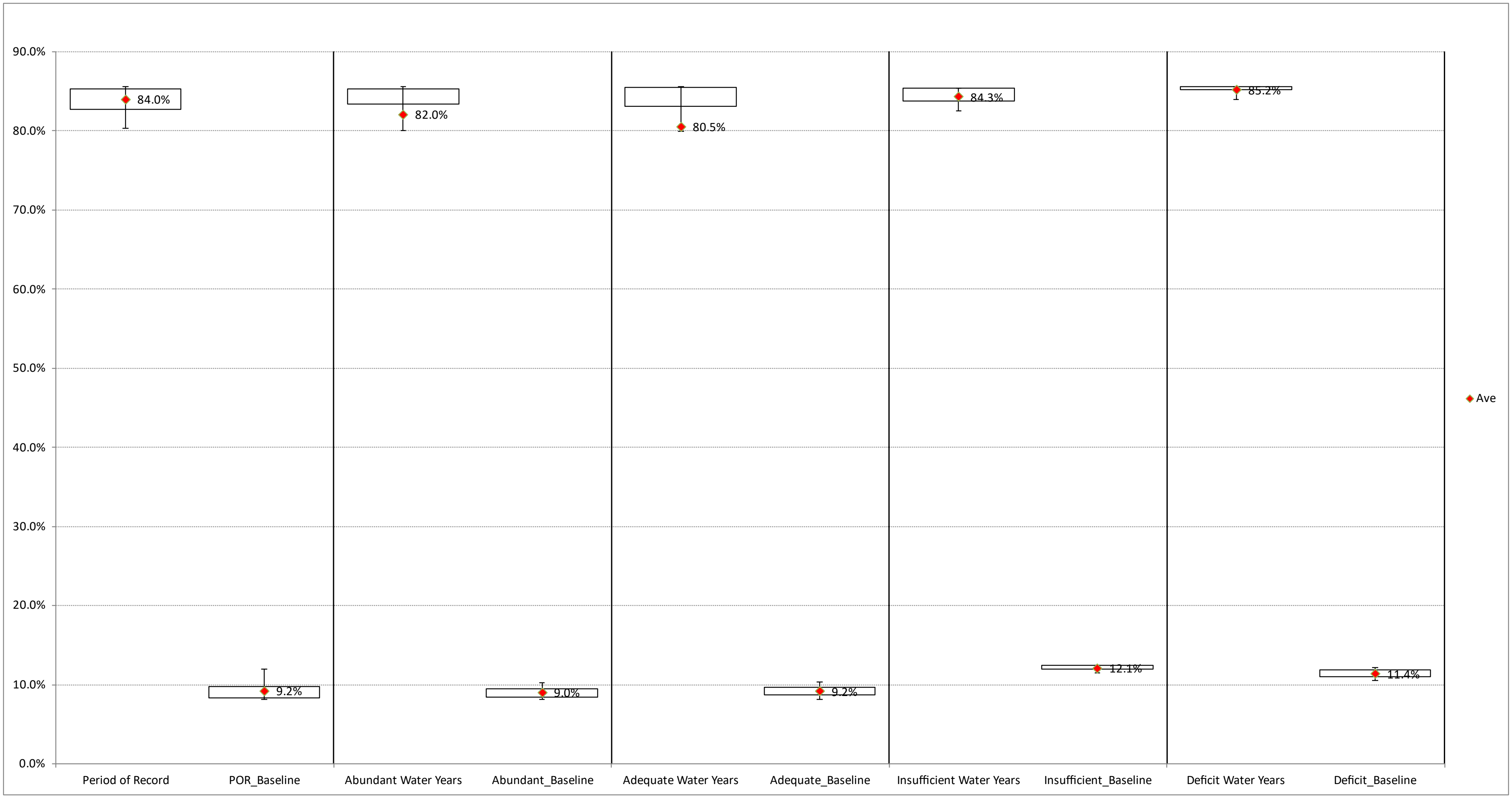

Figure 2-46. Cougar Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Cougar for juvenile spring Chinook fry under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

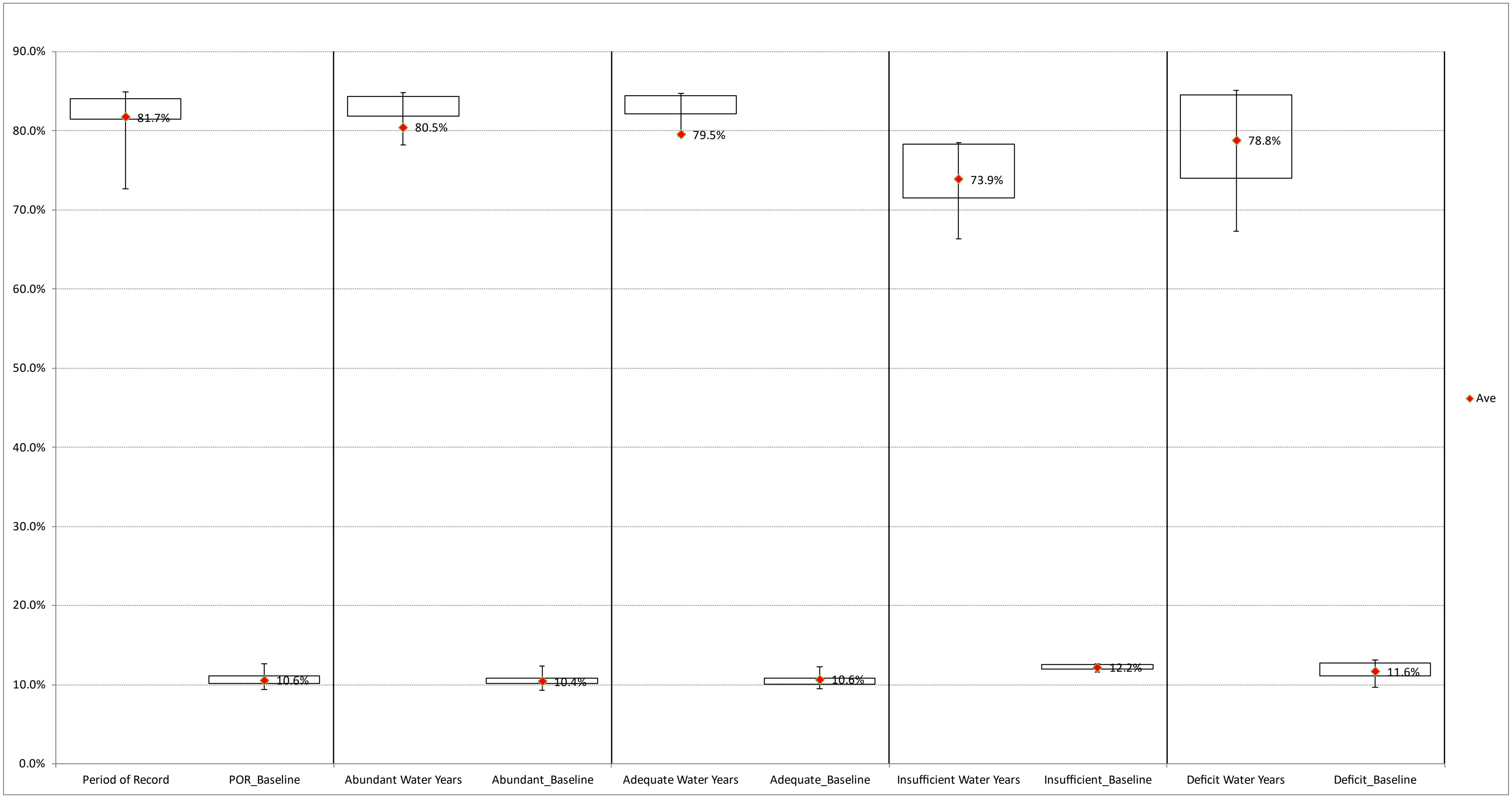

Figure 2-47. Cougar Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Cougar for juvenile spring Chinook sub-yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

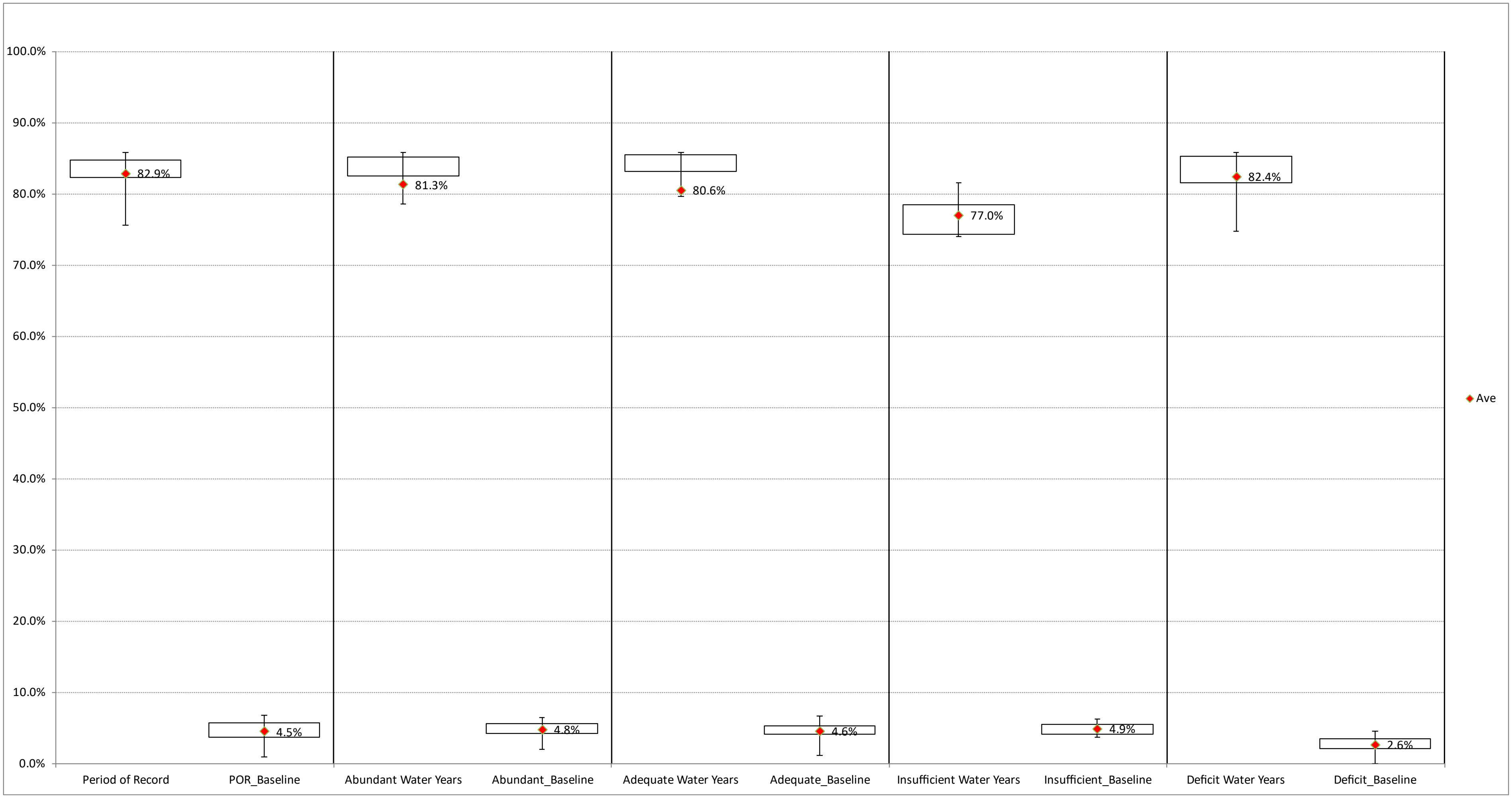

Figure 2-48. Cougar Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Cougar for juvenile spring Chinook yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.3.5 Middle Fork – Lookout Point

Figure 2-49. Lookout Point Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook fry under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

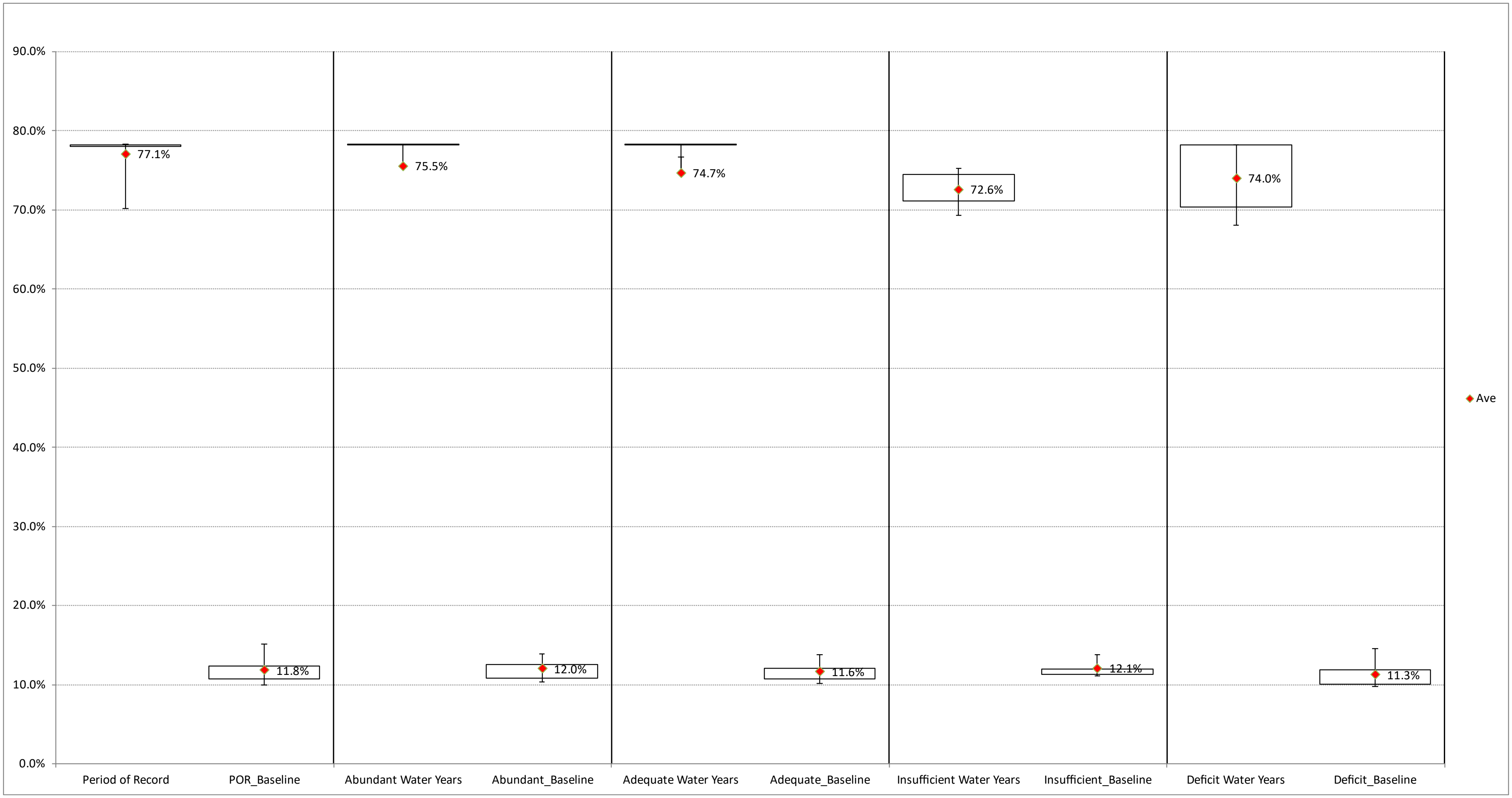

Figure 2-50. Lookout Point Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook sub-yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

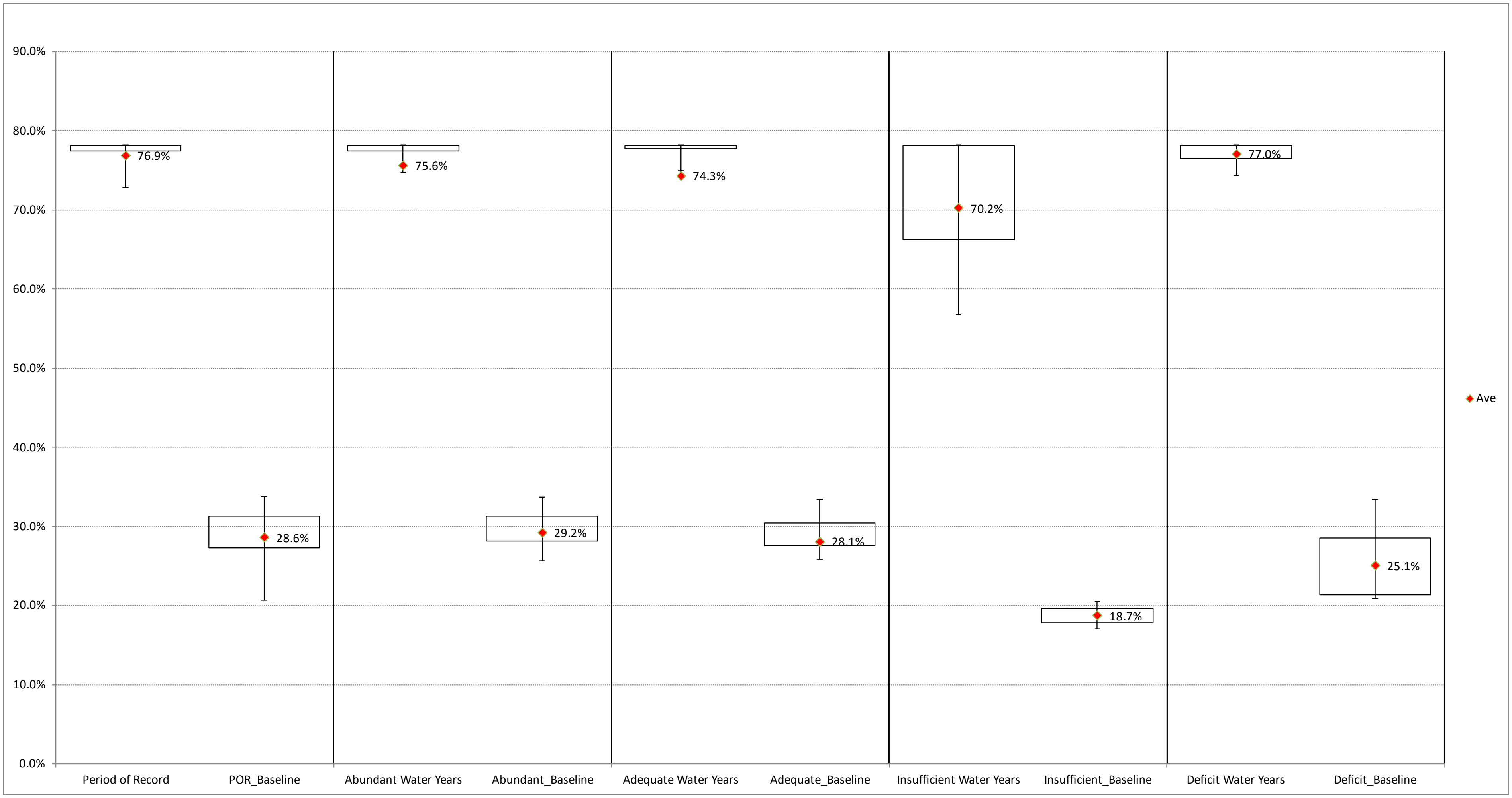

Figure 2-51. Lookout Point for juvenile spring Chinook yearling Downstream dam passage survival at s under Alternative 2a. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.4 CHINOOK SALMON ALTERNATIVE 2B

2.4.1 North Santiam – Detroit

See Alternative 2a

2.4.2 South Santiam – Foster

See Alternative 2a

2.4.3 South Santiam – Green Peter

See Alternative 2a

2.4.4 McKenzie – Cougar

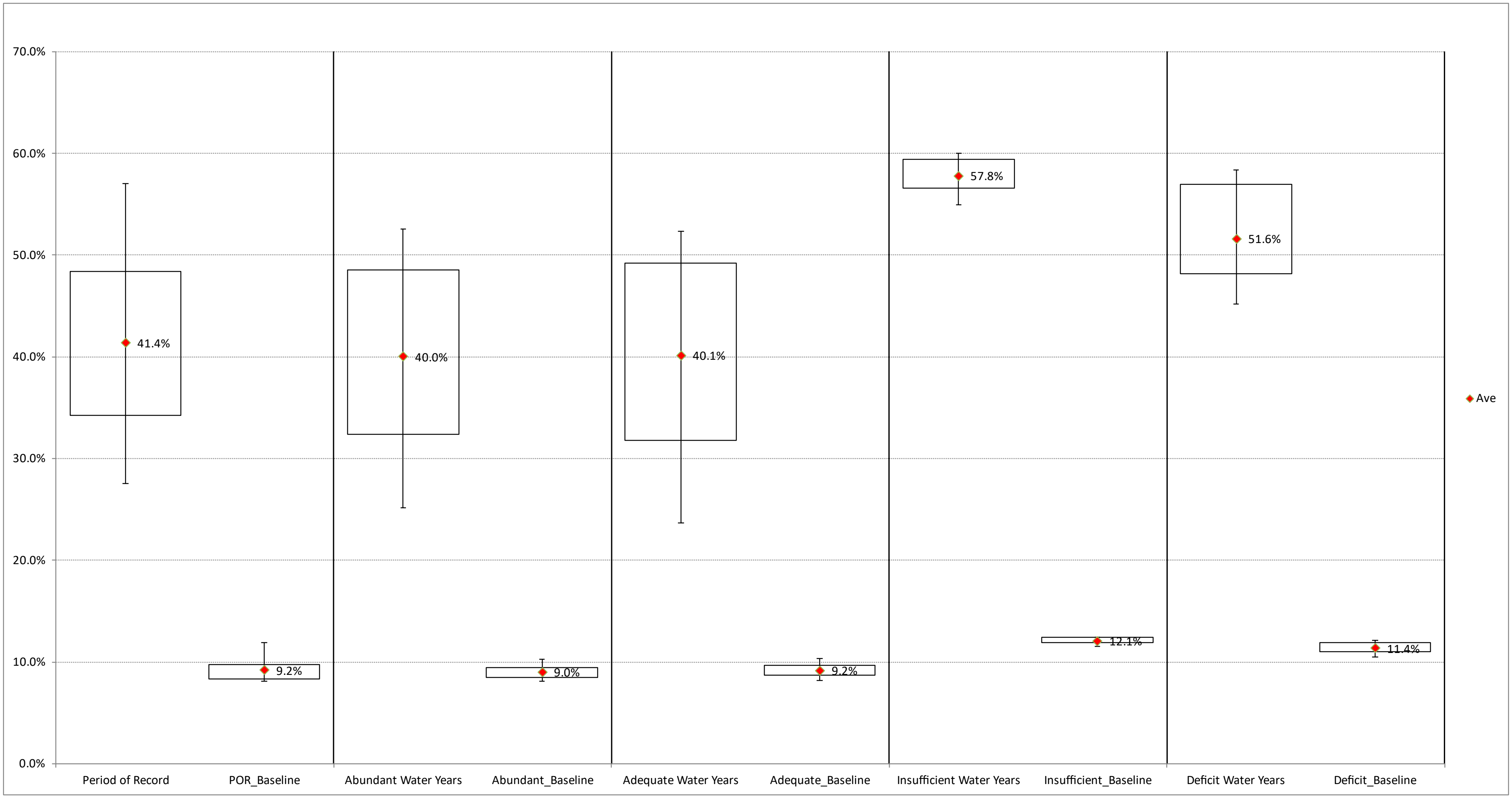

Figure 2-52. Cougar Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 2b. *Downstream dam passage survival at Cougar for juvenile spring Chinook fry under Alternative 2b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

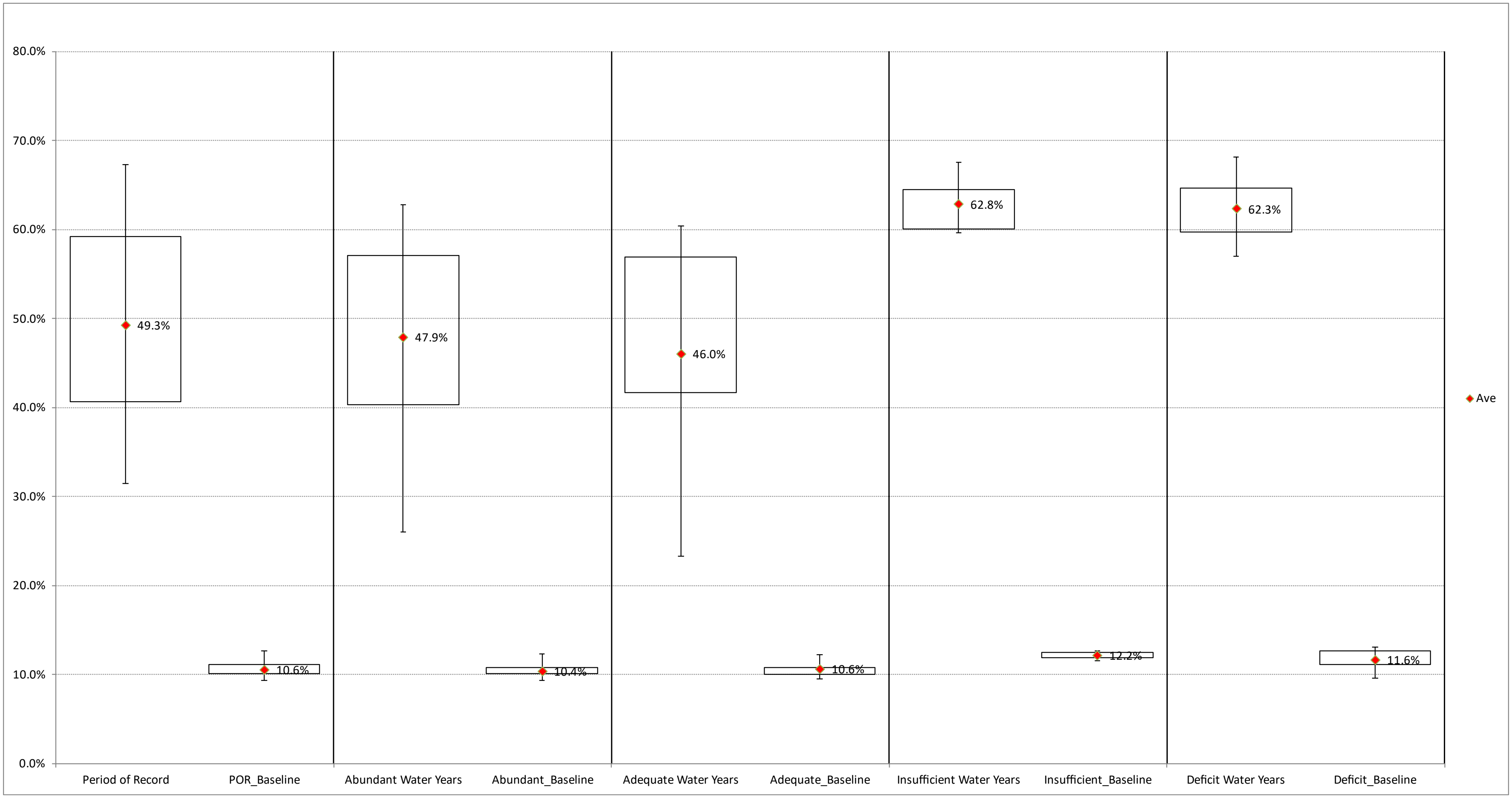

Figure 0 52. Cougar Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 2b. *The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

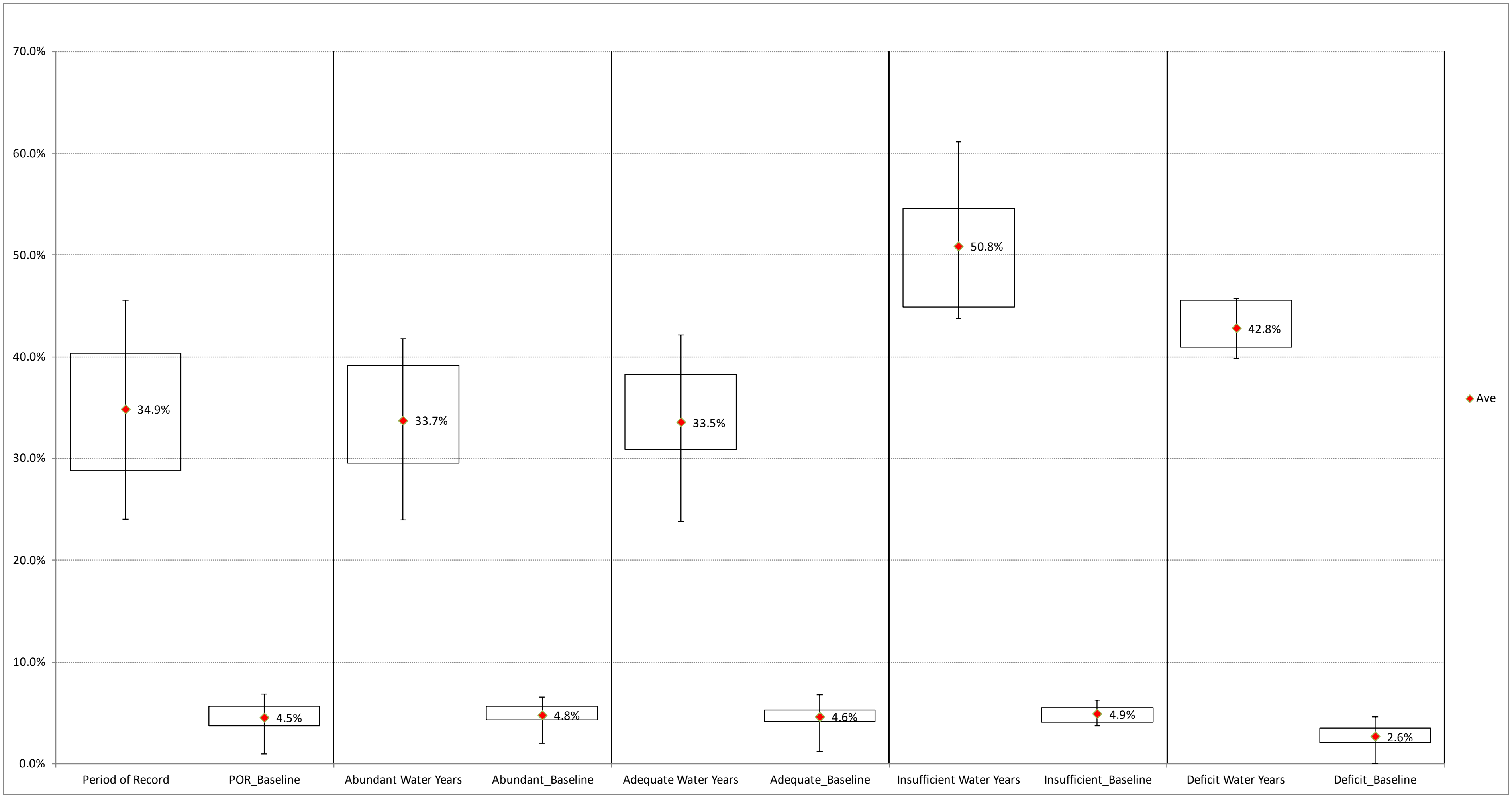

Figure 0 53. Downstream dam passage survival at Cougar for juvenile spring Chinook yearlings under Alternative 2b*. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.4.5 Middle Fork – Lookout Point

See Alternative 2a

2.5 CHINOOK SALMON ALTERNATIVE 3A

2.5.1 North Santiam – Detroit

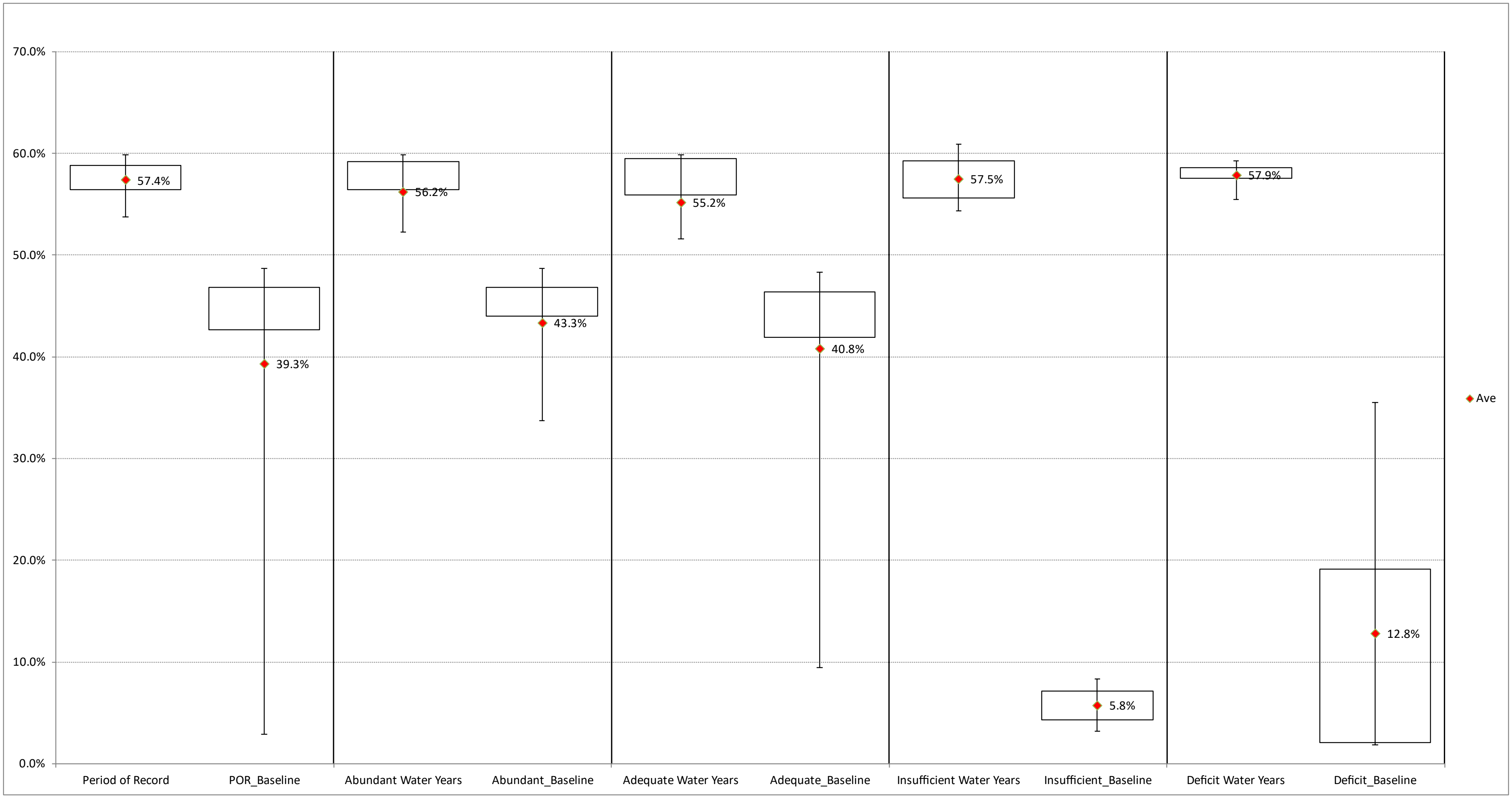

Figure 2-53. Detroit Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Detroit for juvenile spring Chinook fry under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

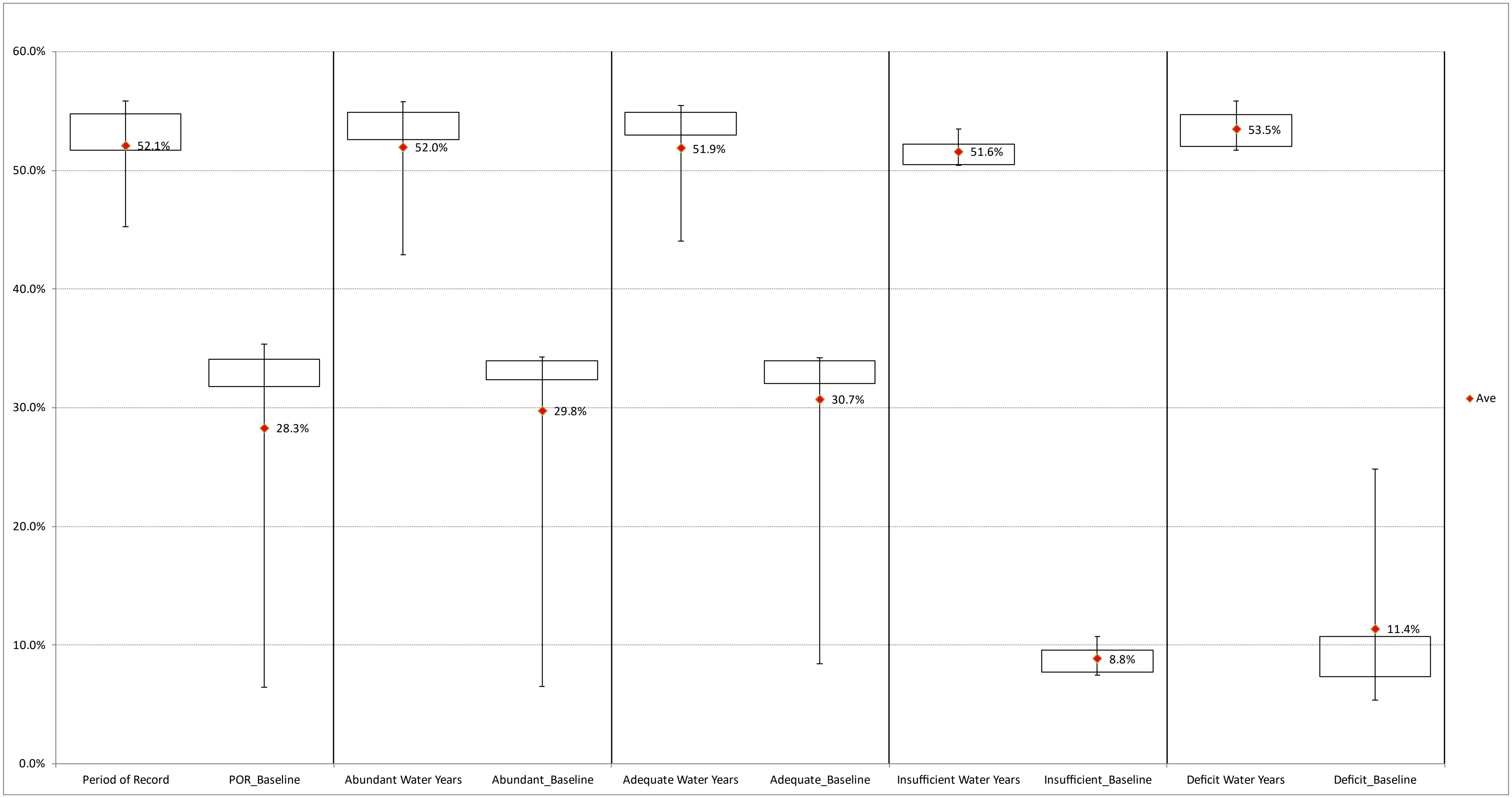

Figure 2-54. Detroit Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Detroit for juvenile spring Chinook sub-yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

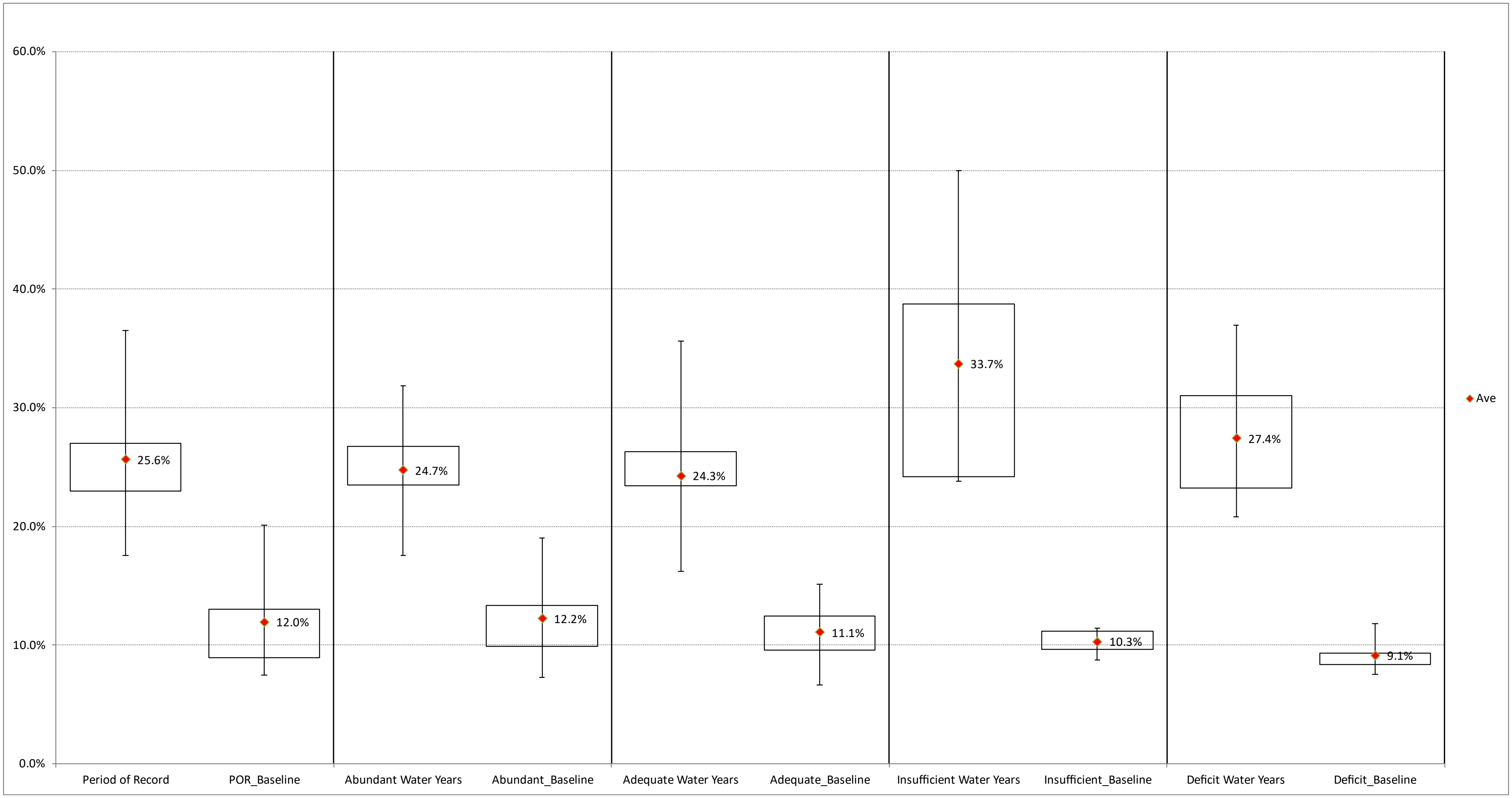

Figure 2-55. Detroit Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Detroit for juvenile spring Chinook yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.5.2 South Santiam - Foster

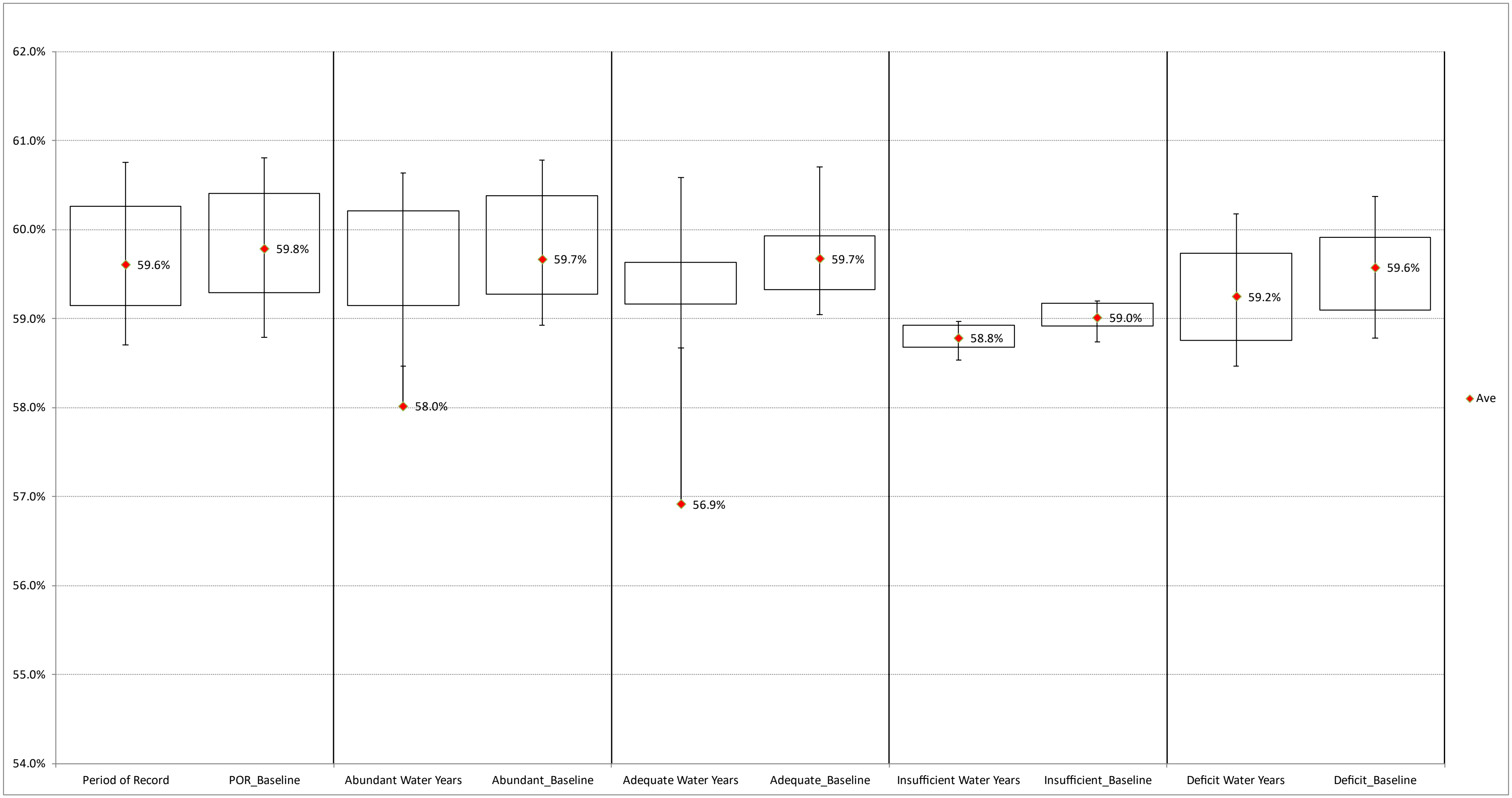

Figure 2-56. Foster Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Foster for juvenile spring Chinook fry under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

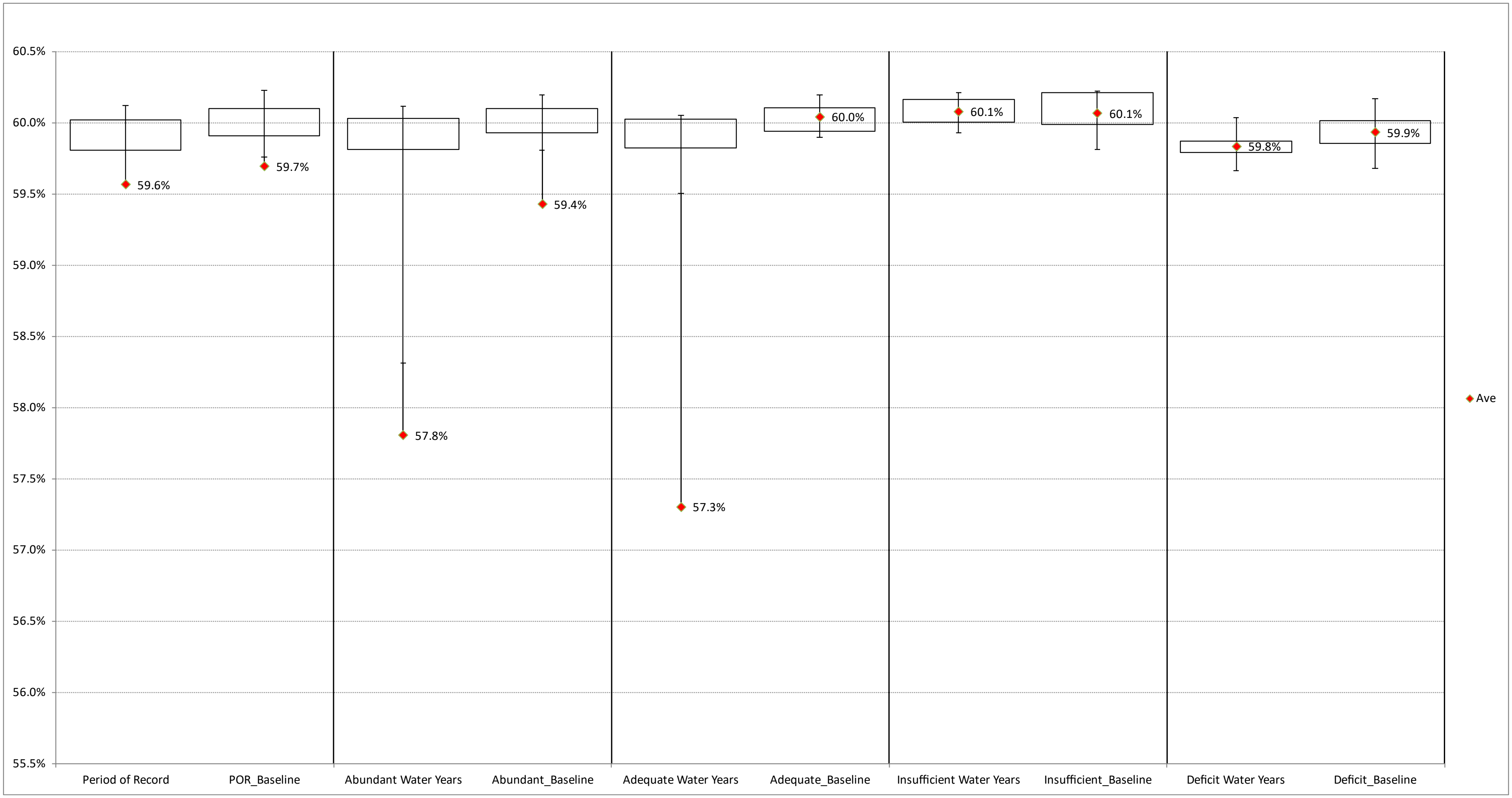

Figure 2-57. Foster Juvenile Spring Chinook Sub-Yearlings Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Foster for juvenile spring Chinook sub-yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

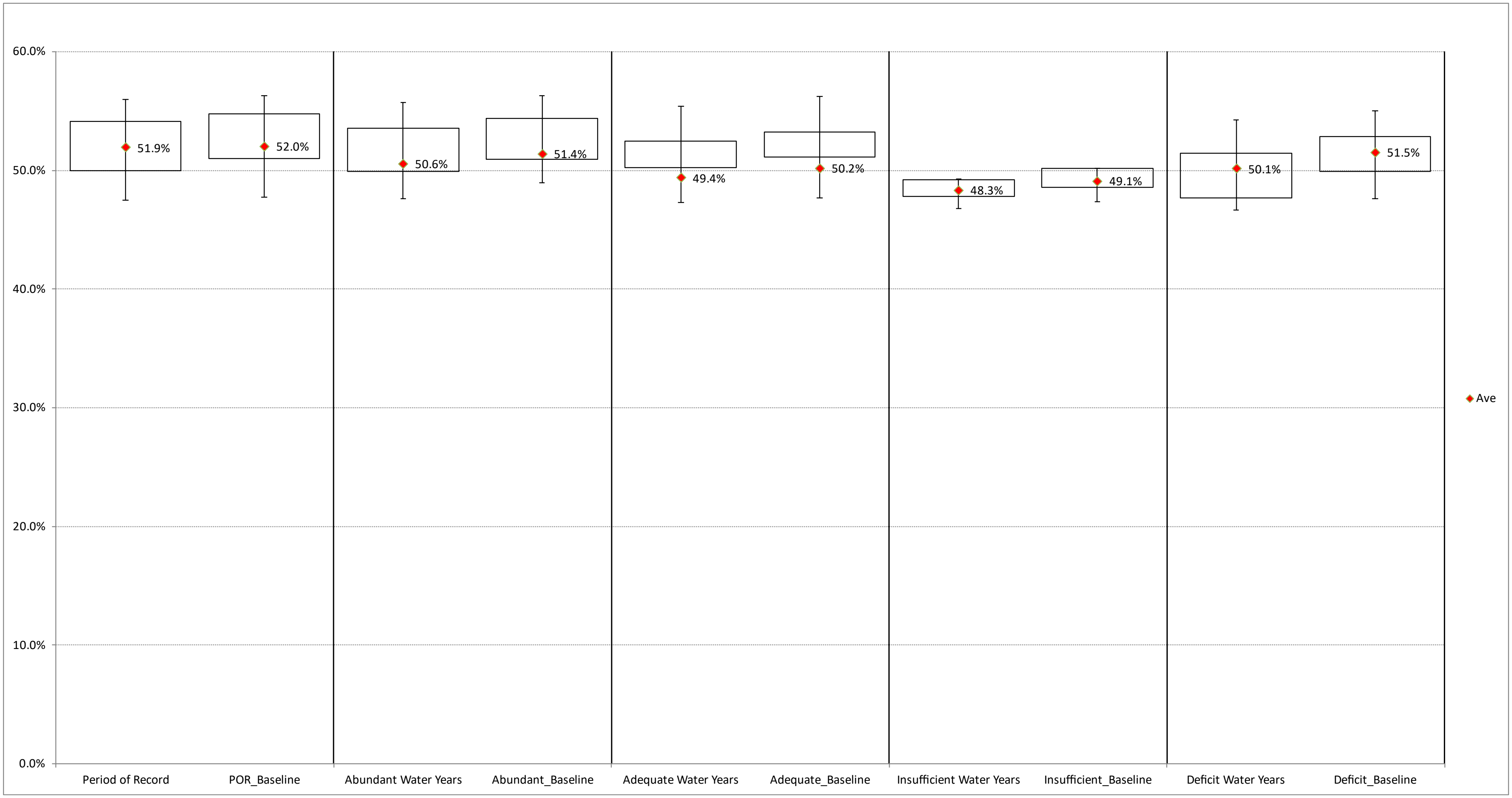

Figure 2-58. Foster For Juvenile Spring Chinook Yearlings Downstream Dam Passage Survival At Under Alternative 3a. *Downstream dam passage survival at Foster for juvenile spring Chinook yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.5.3 South Santiam – Green Peter

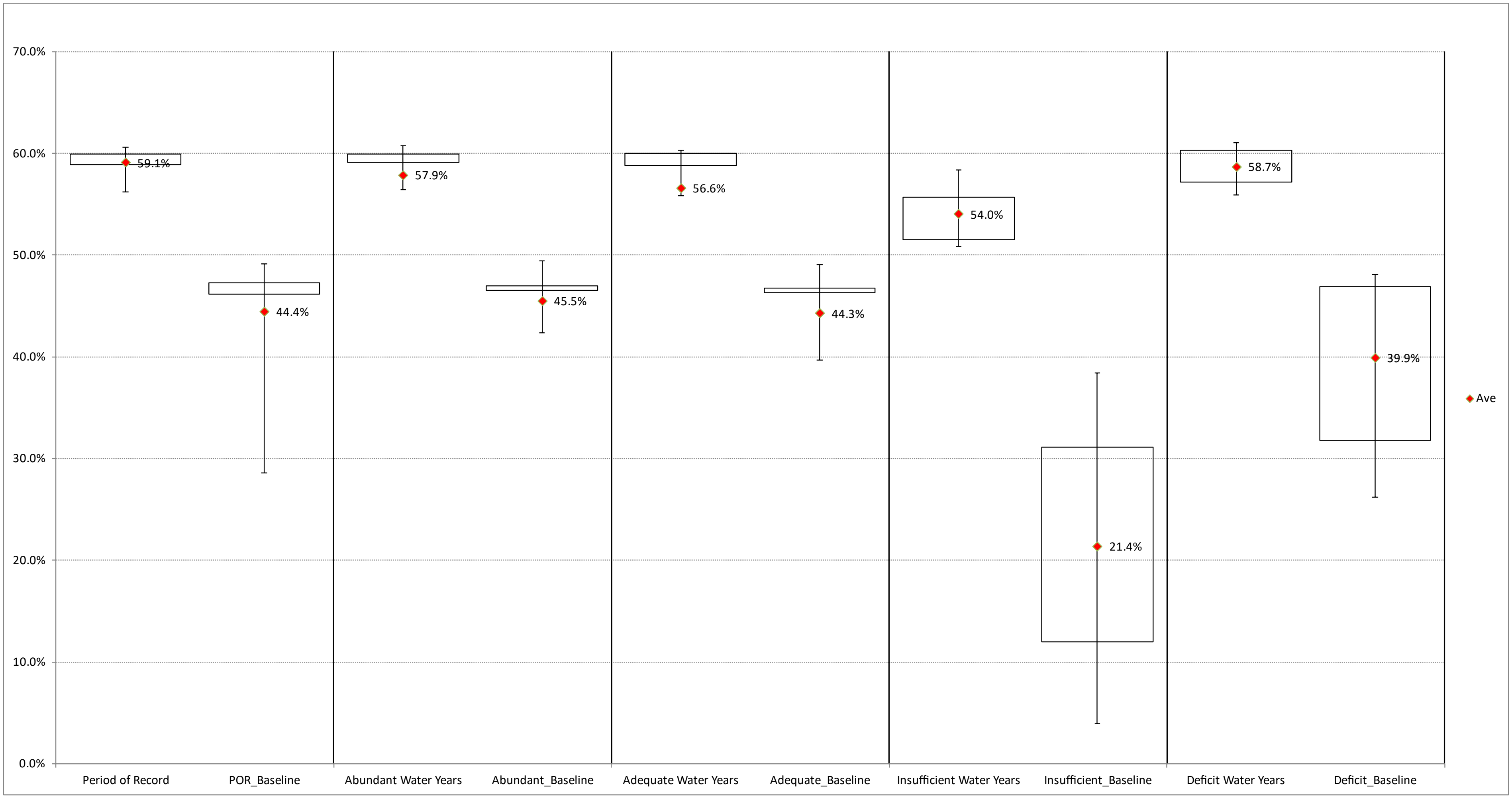

Figure 2-59. Green Peter Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Green Peter for juvenile spring Chinook fry under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

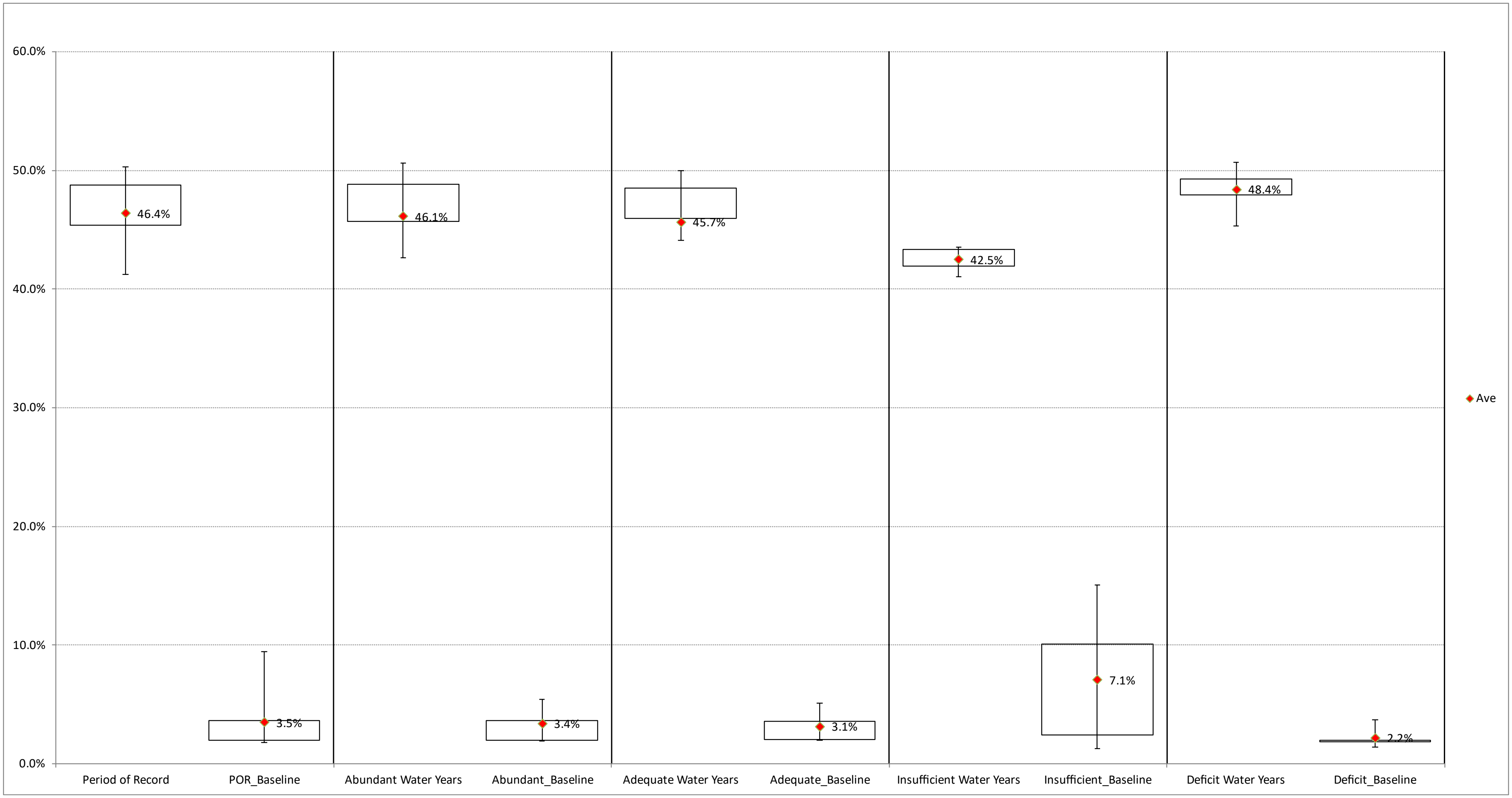

Figure 2-60. Green Peter Juvenile Spring Chinook Sub-Yearlings Downstream Dam Passage Survival Under Alternative 3a.
Downstream dam passage survival at Green Peter for juvenile spring Chinook sub-yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.

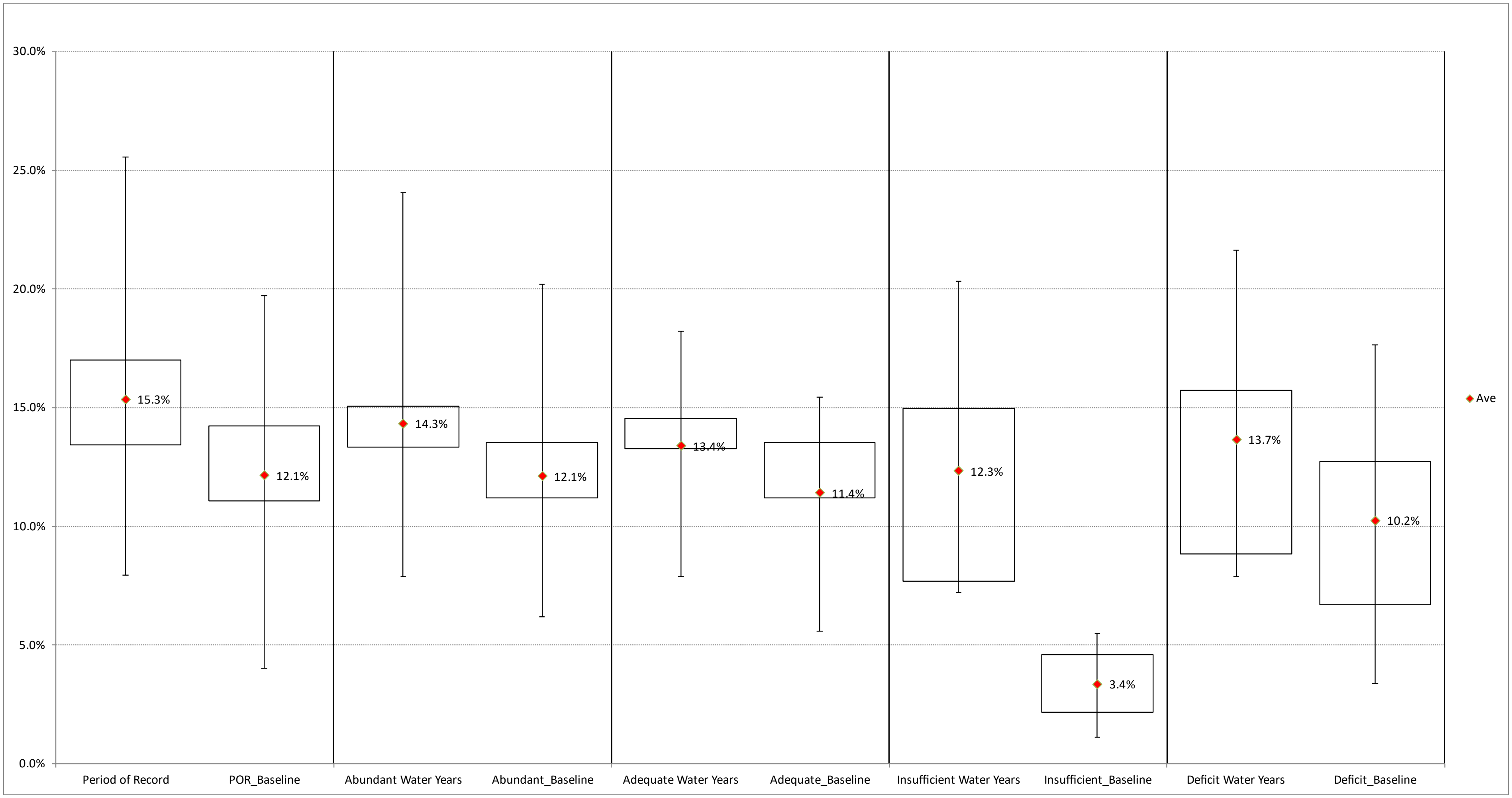

Figure 2-61. Green Peter Juvenile Spring Chinook Yearlings Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Green Peter for juvenile spring Chinook yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.5.4 McKenzie - Cougar

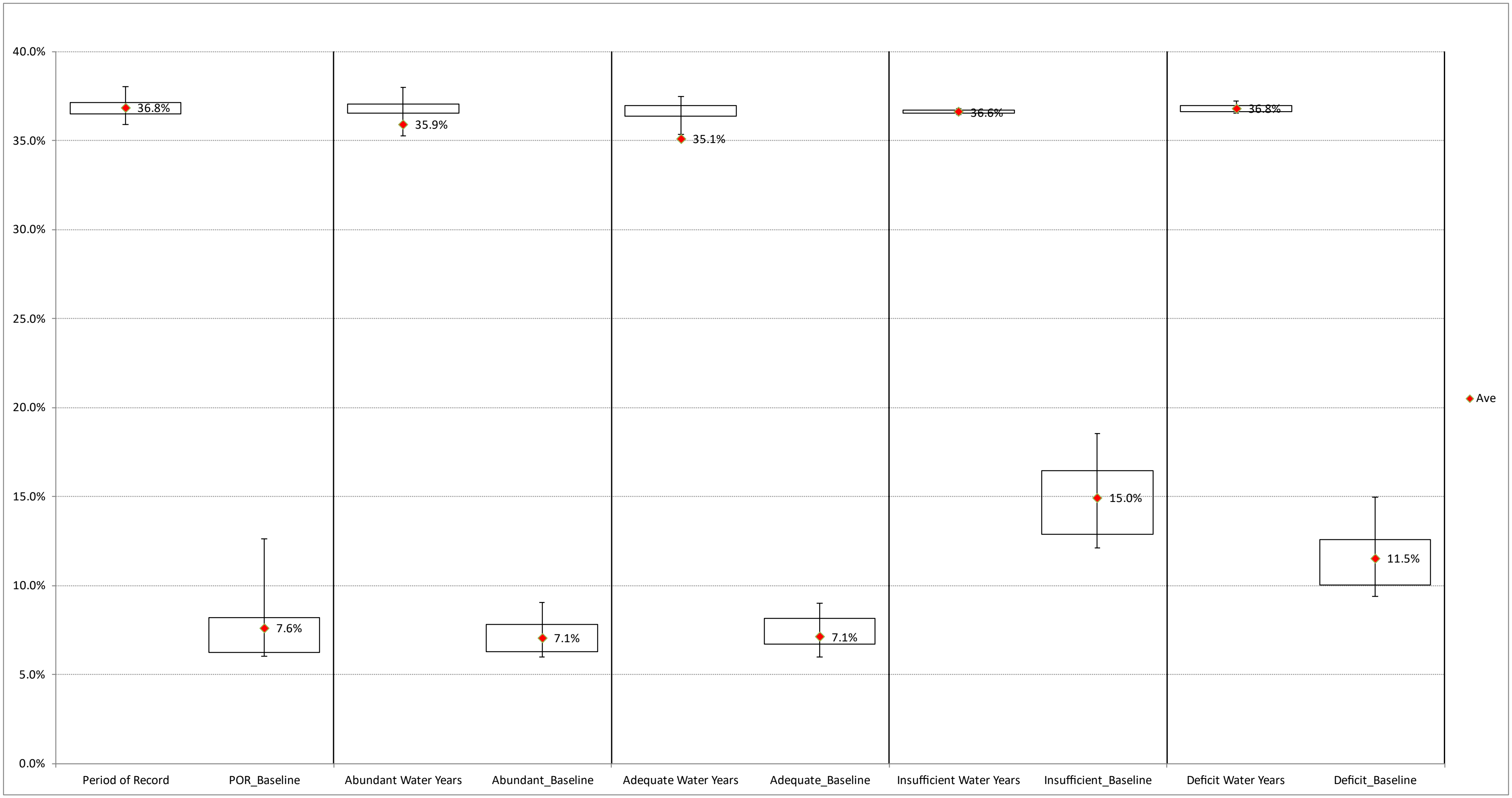

Figure 2-62. Cougar Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Cougar for juvenile spring Chinook fry under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

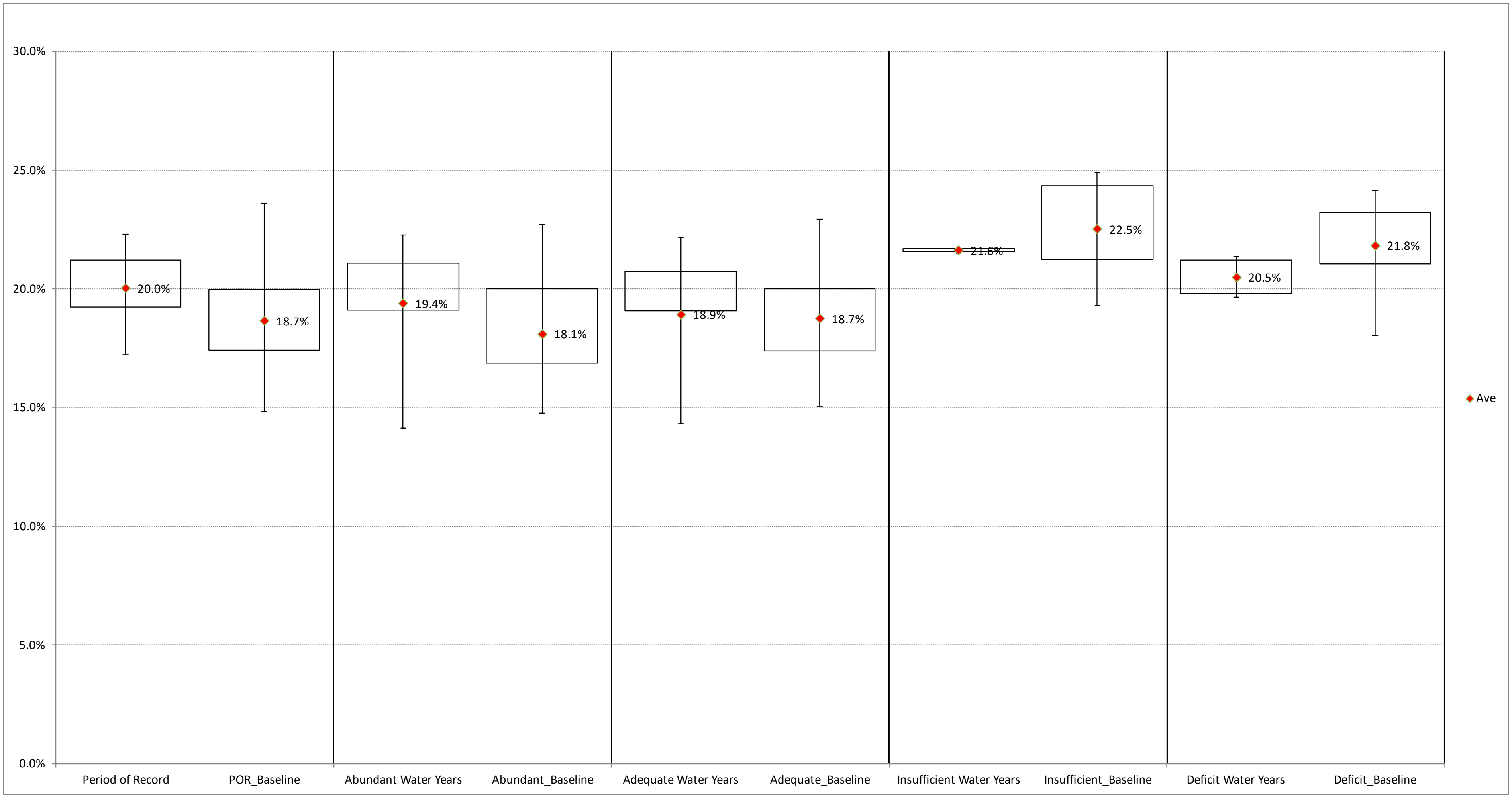

Figure 2-63. Cougar Juvenile Spring Chinook Sub-Yearlings Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Cougar for juvenile spring Chinook sub-yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

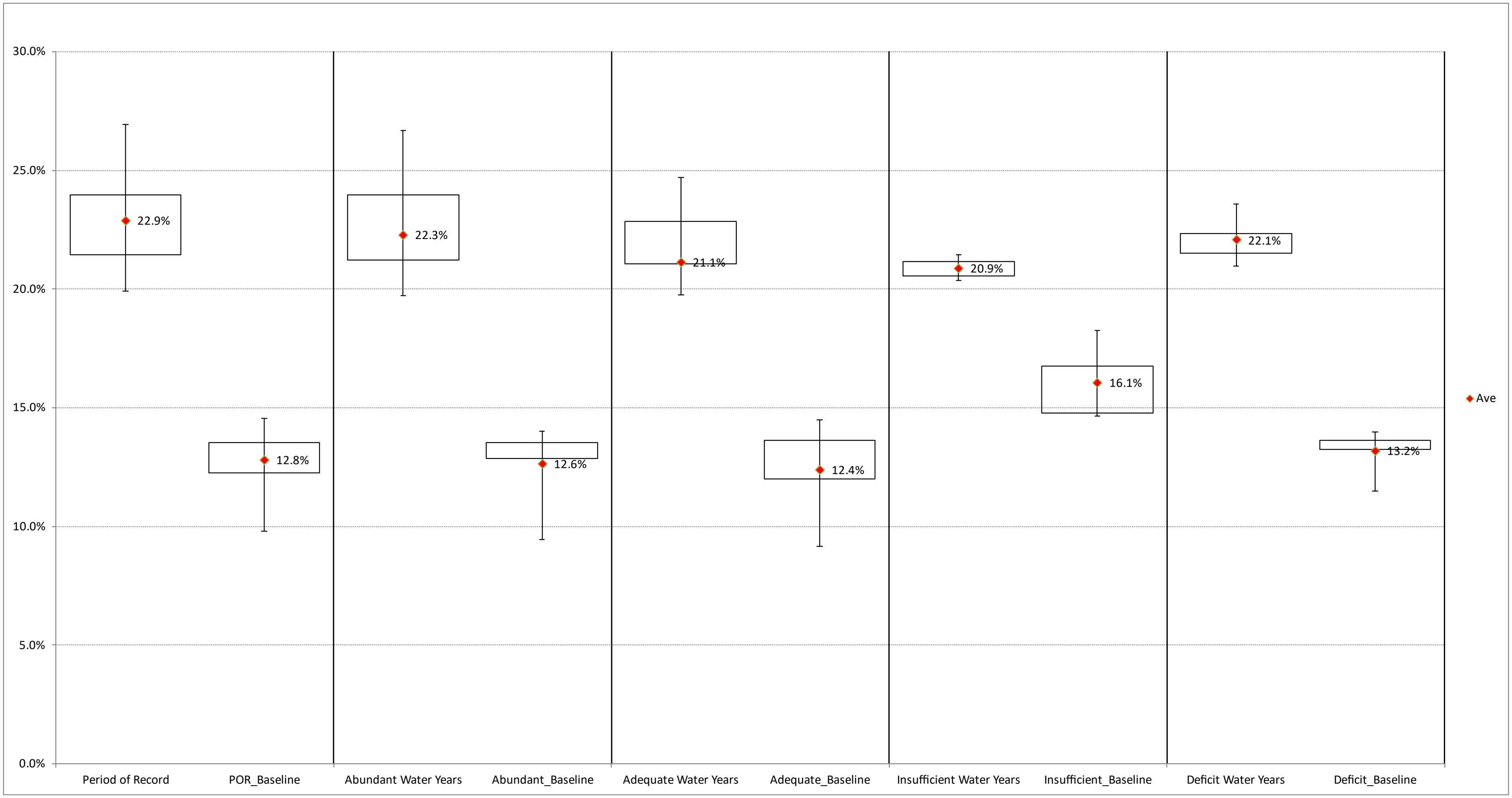

Figure 2-64. Cougar Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Cougar for juvenile spring Chinook yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.5.5 Middle Fork – Lookout Point

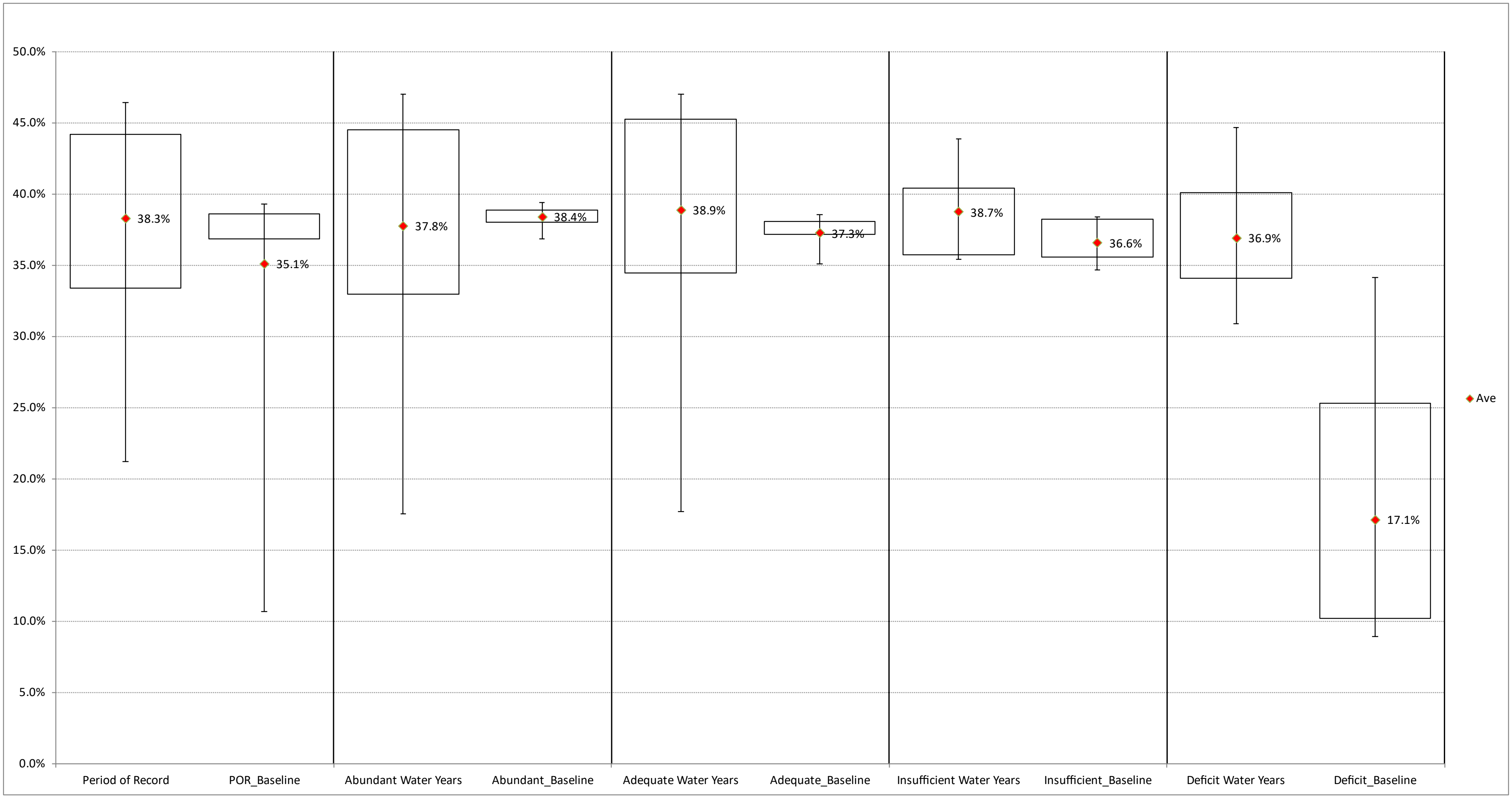

Figure 2-65. Lookout Point Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook fry under Alternative 3a. The mean is given by the point estimate*

(filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.

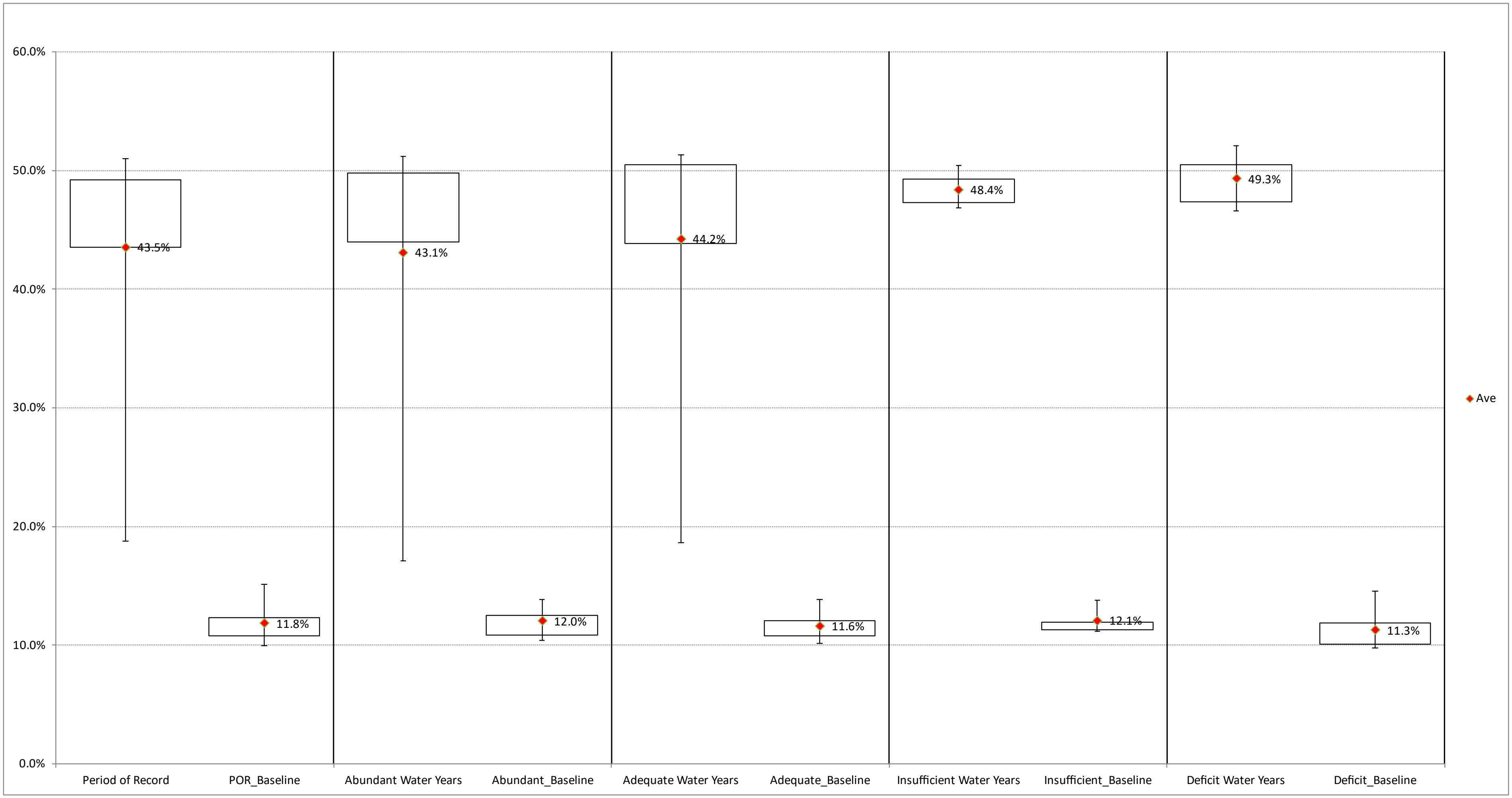

Figure 2-66. Lookout Point Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 3a.
Downstream dam passage survival at Lookout Point for juvenile spring Chinook sub-yearlings under Alternative 3a. The mean is given

by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.

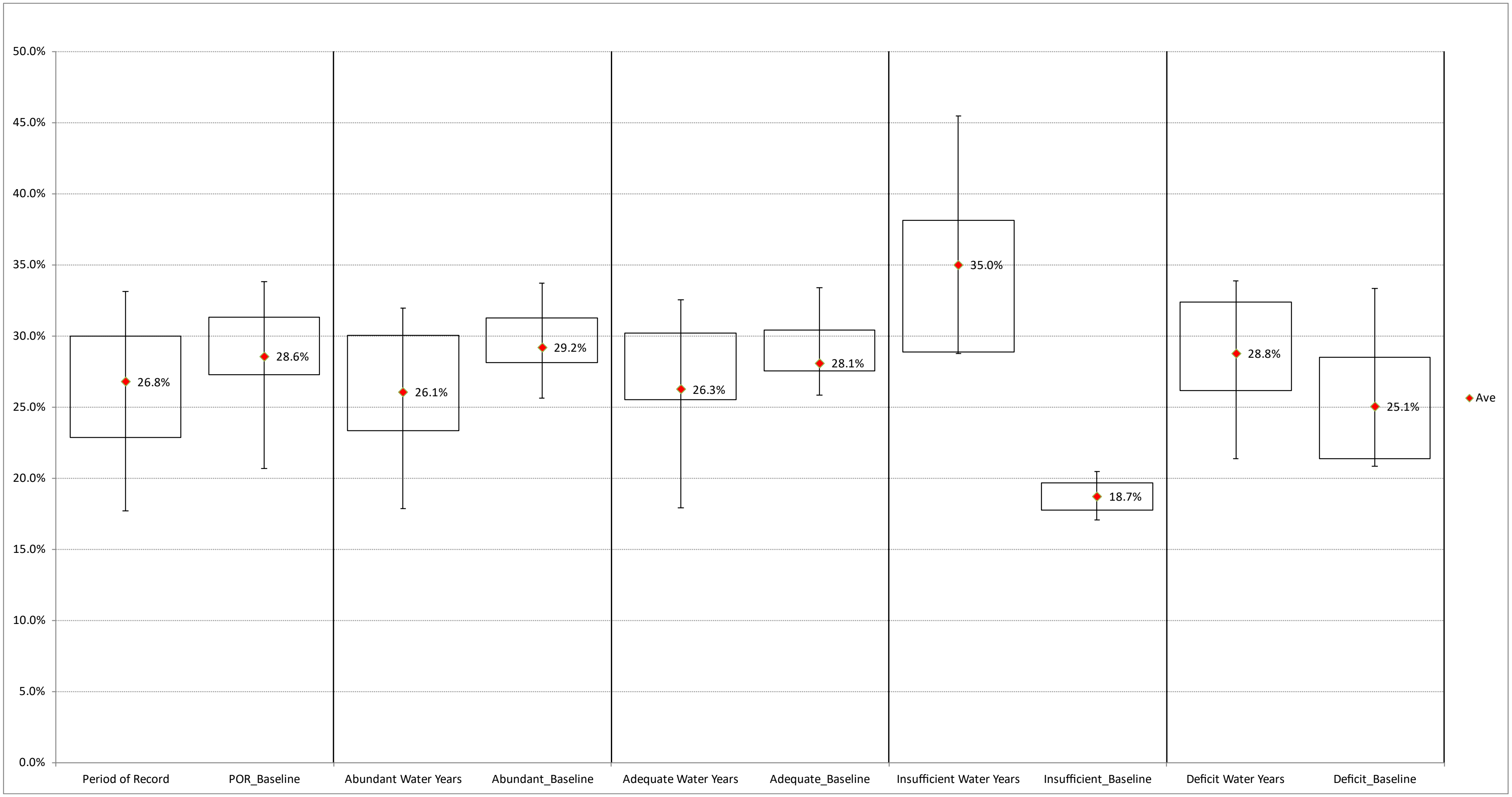

Figure 2-67. Lookout Point Juvenile Spring Chinook Yearlings Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

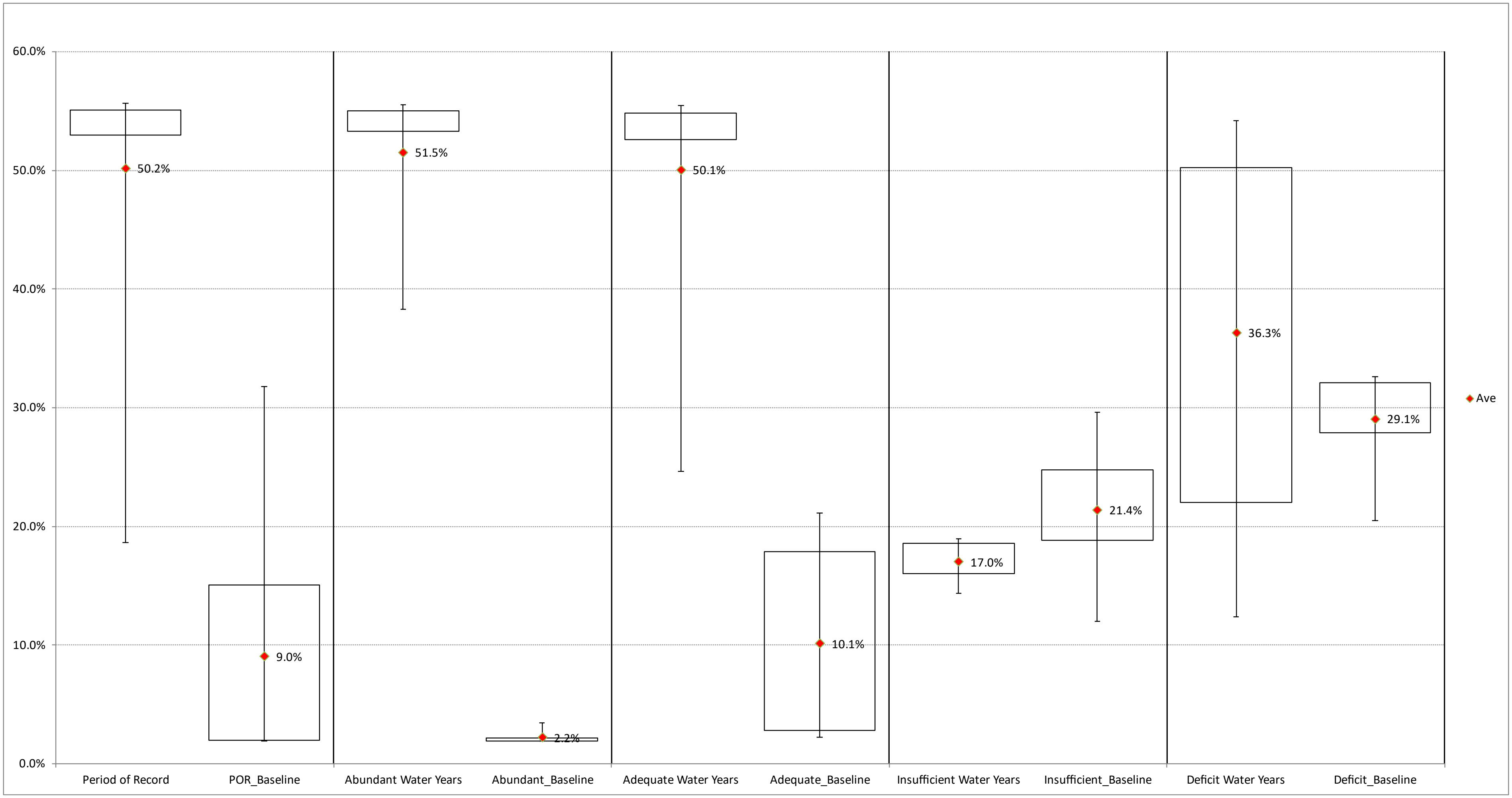

Figure 2-68. Hills Creek Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook fry under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

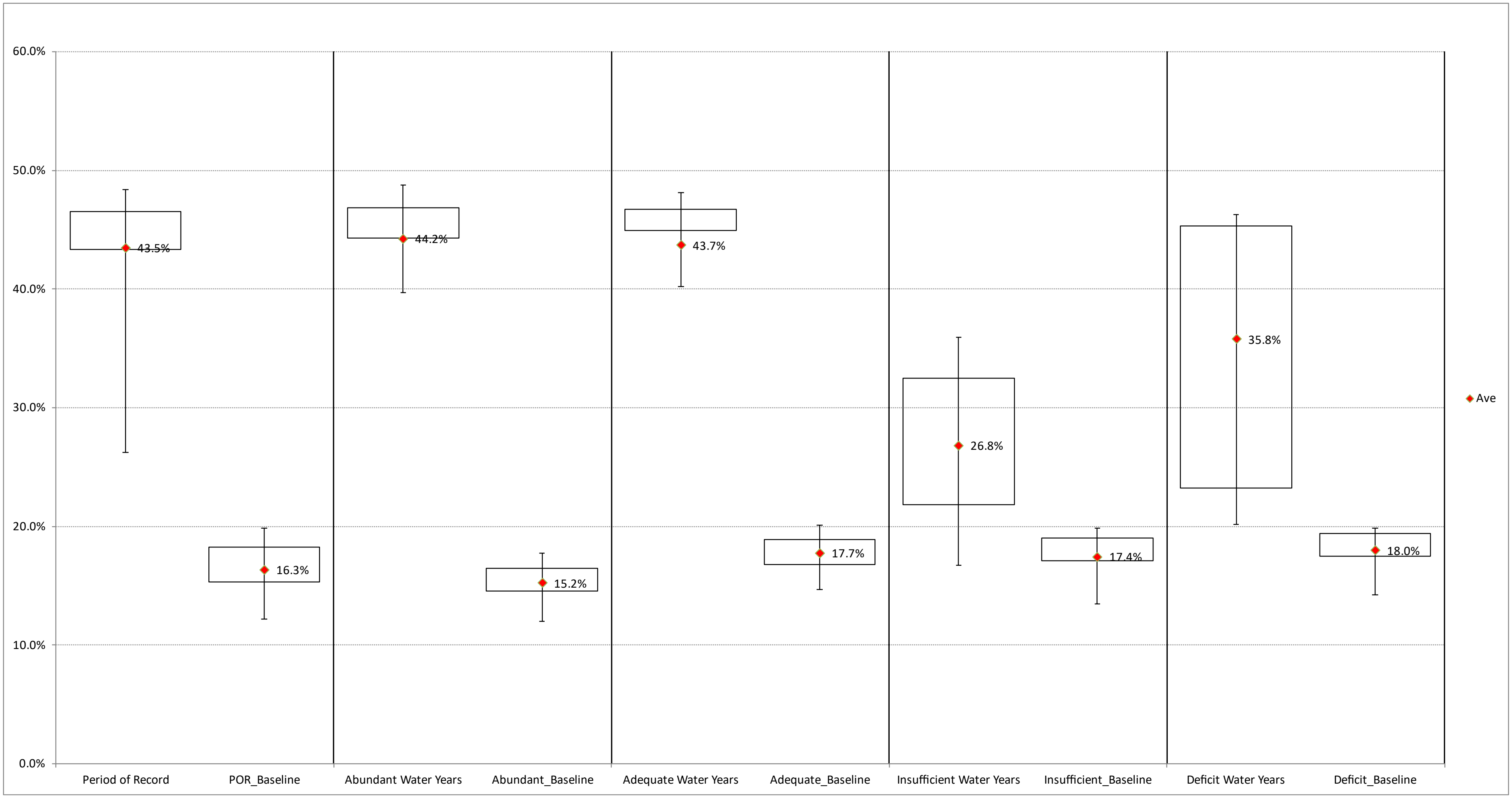

Figure 2-69. Hills Creek Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 3a.
Downstream dam passage survival at Hills Creek for juvenile spring Chinook sub-yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.

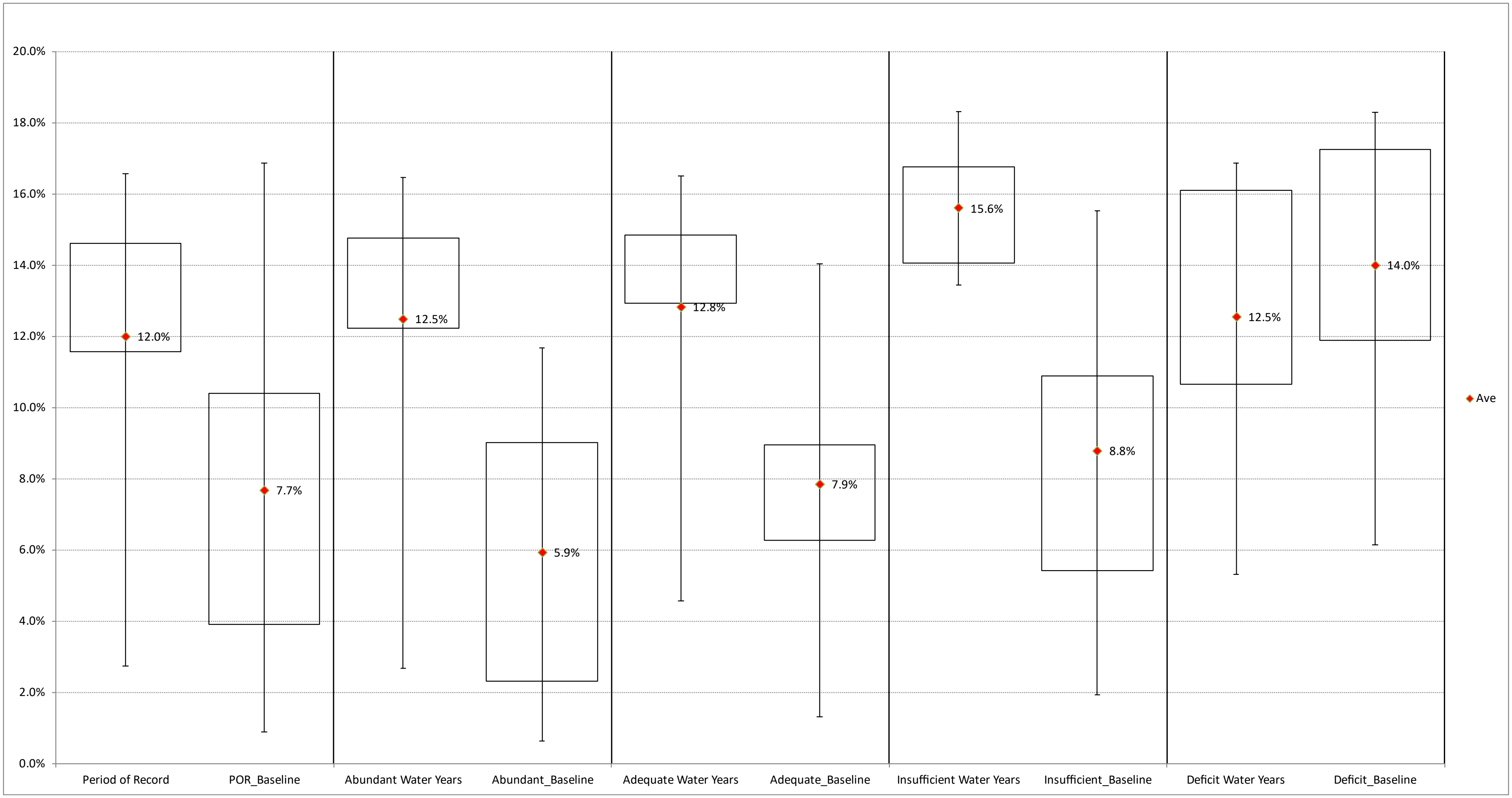

Figure 2-70.Downstream dam passage survival at Hills Creek for juvenile spring Chinook yearlings under Alternative 3a. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.6 CHINOOK SALMON ALTERNATIVE 3B

2.6.1 North Santiam – Detroit

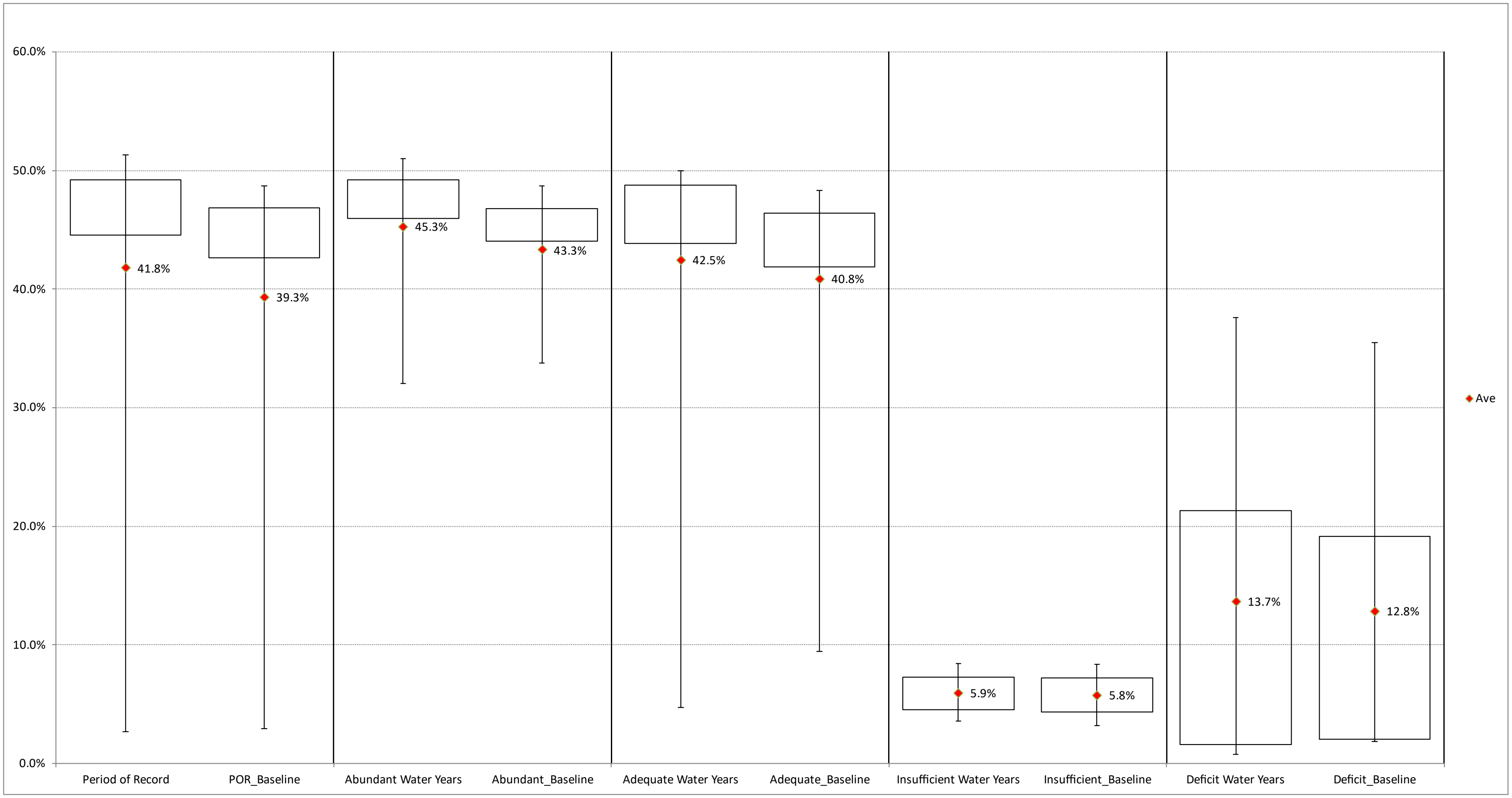

Figure 2-71. Detroit Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Detroit for juvenile spring Chinook fry under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

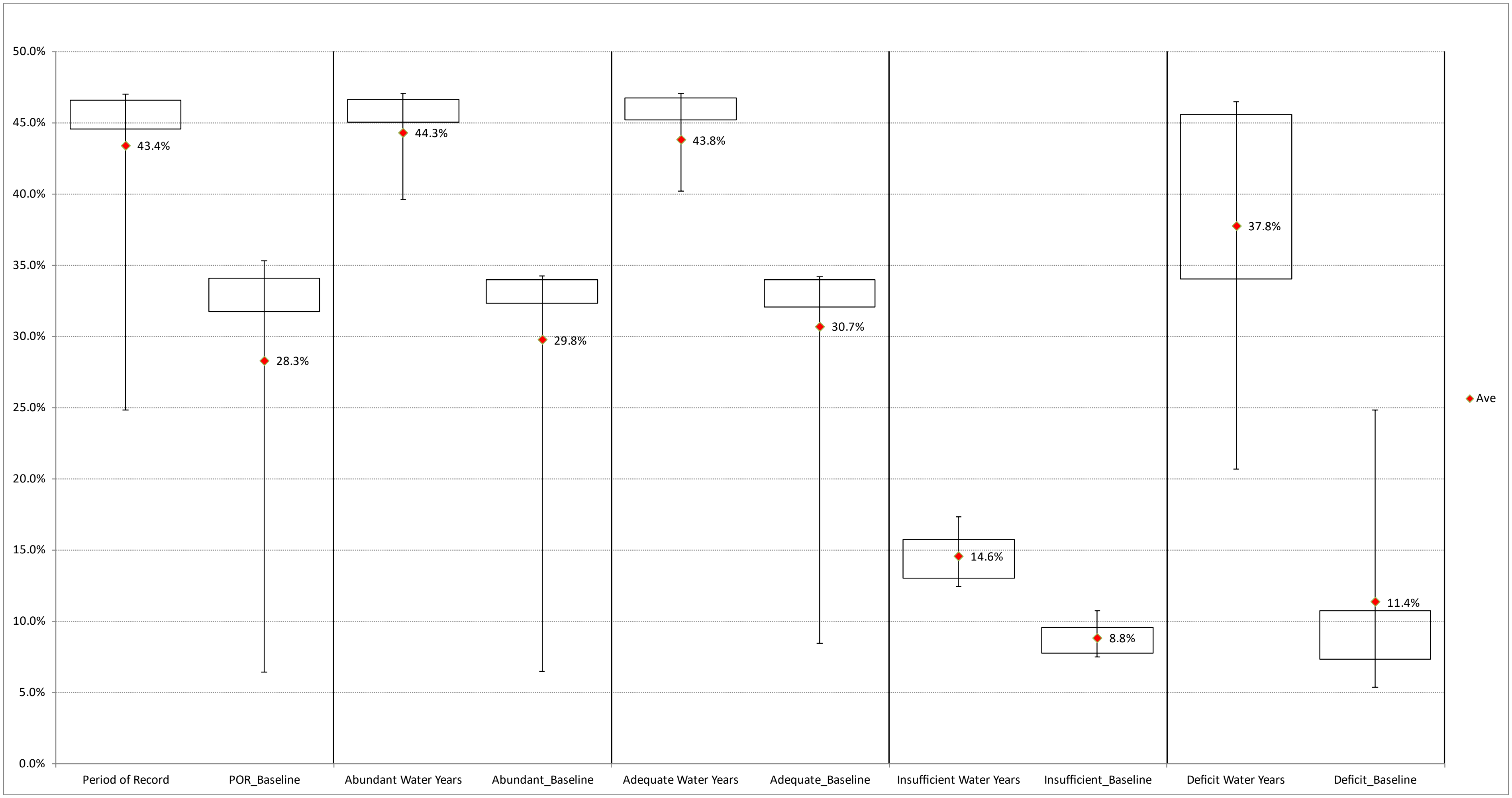

Figure 2-72. Detroit Juvenile Spring Chinook Sub-Yearlings Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Detroit for juvenile spring Chinook sub-yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

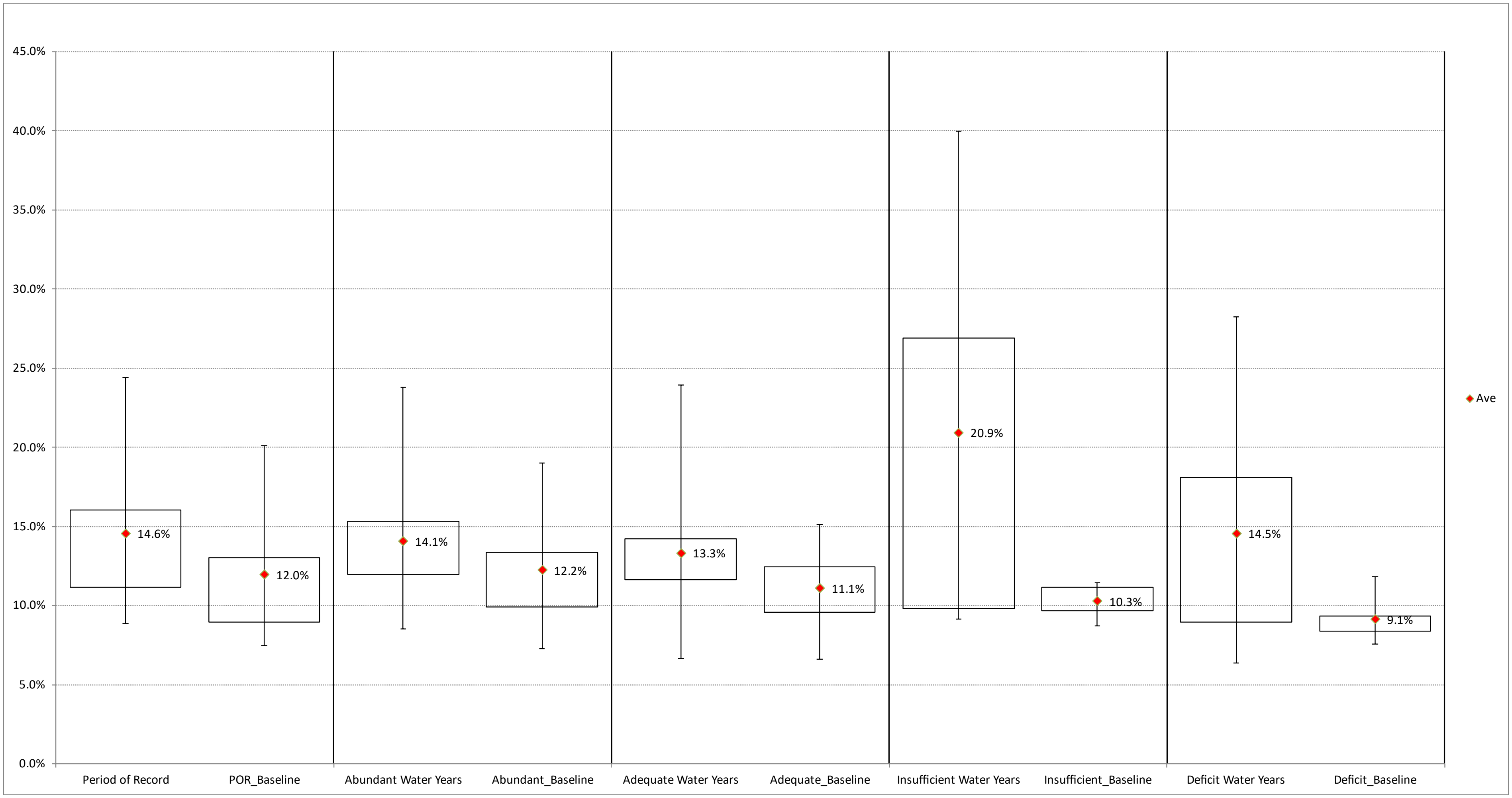

Figure 2-73. Detroit Juvenile Spring Chinook Yearlings Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Detroit for juvenile spring Chinook yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.6.2 South Santiam – Foster

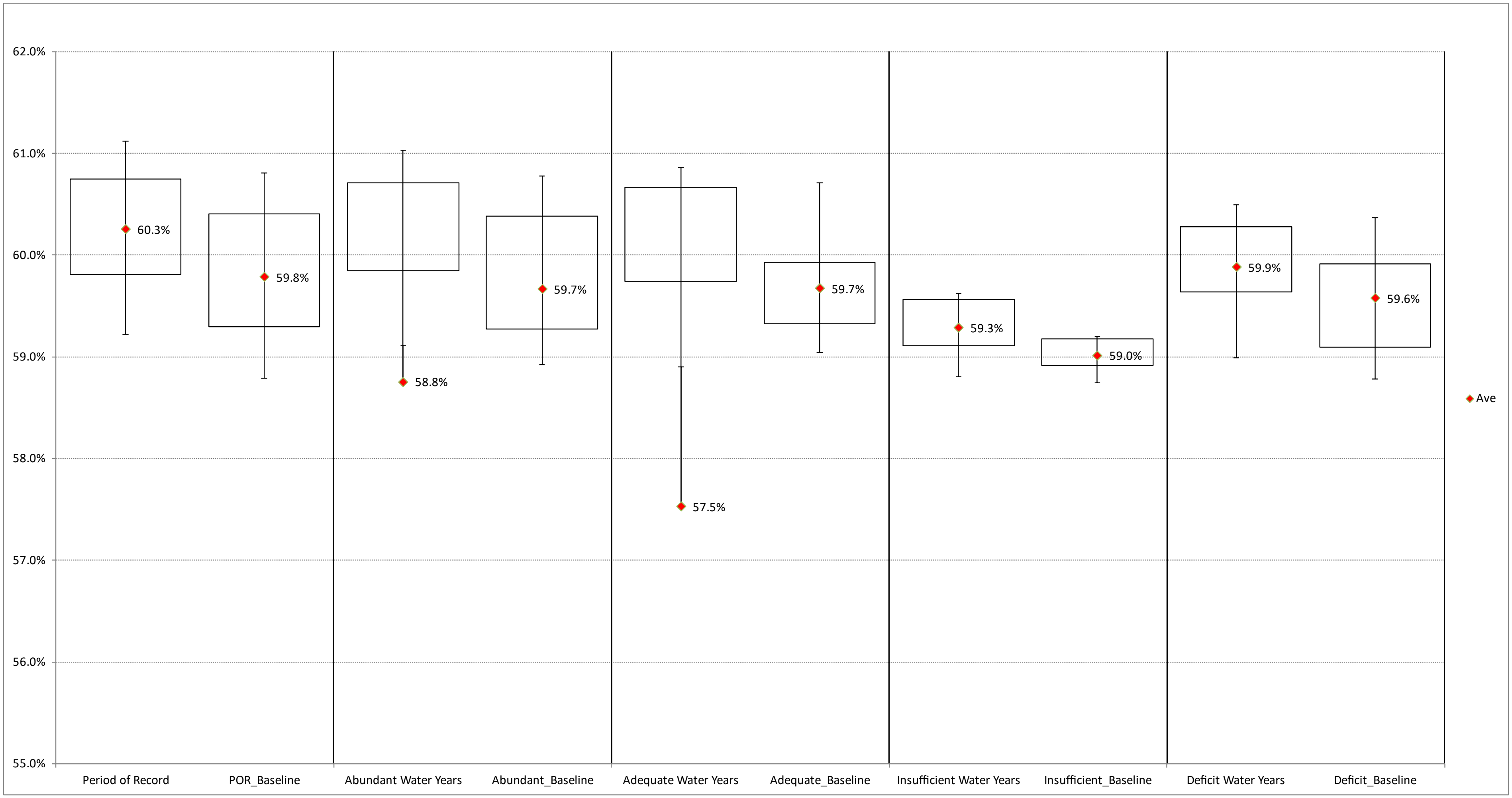

Figure 2-74. Foster Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Foster for juvenile spring Chinook fry under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

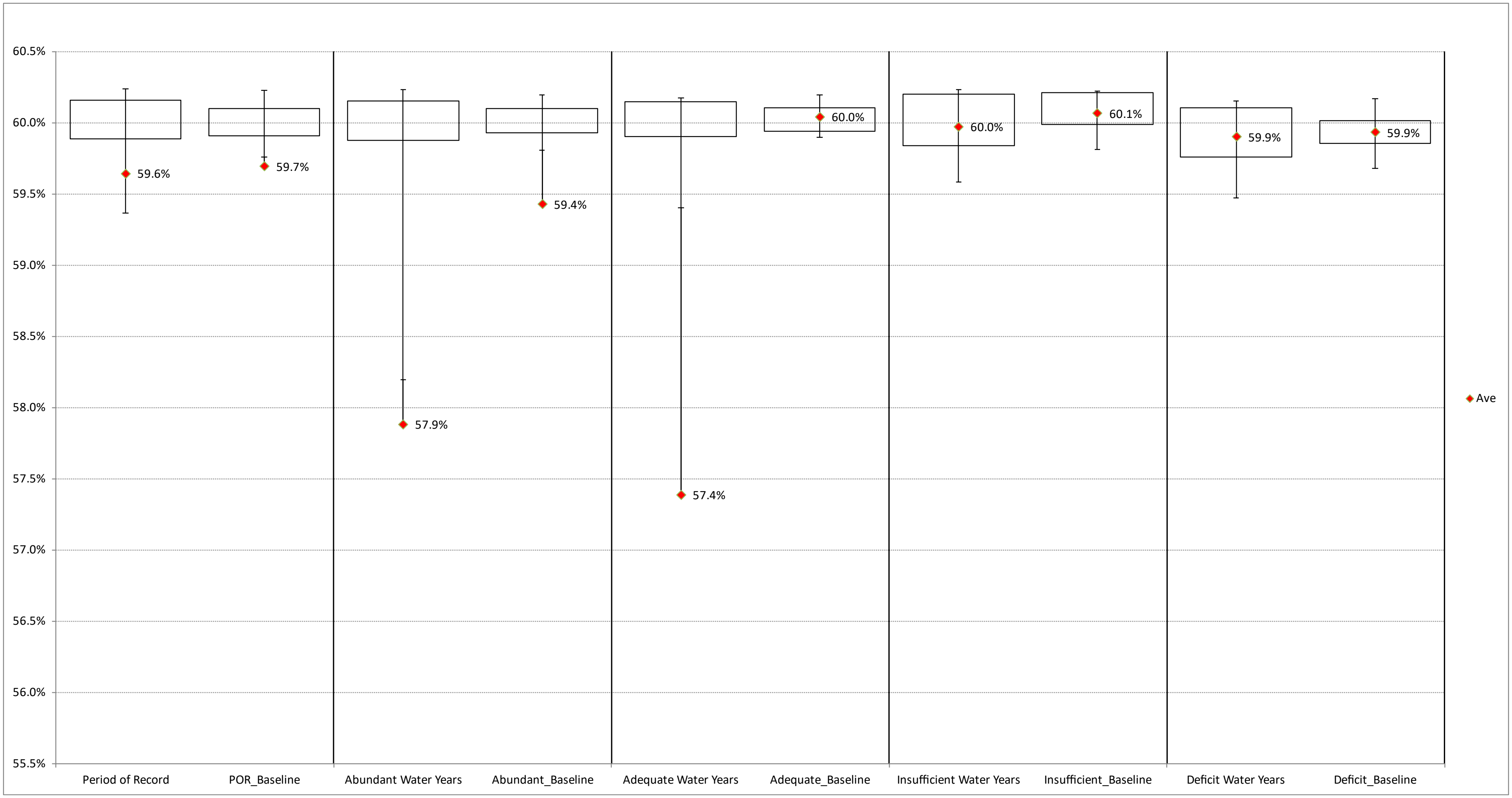

Figure 2-75. Foster Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Foster for juvenile spring Chinook sub-yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

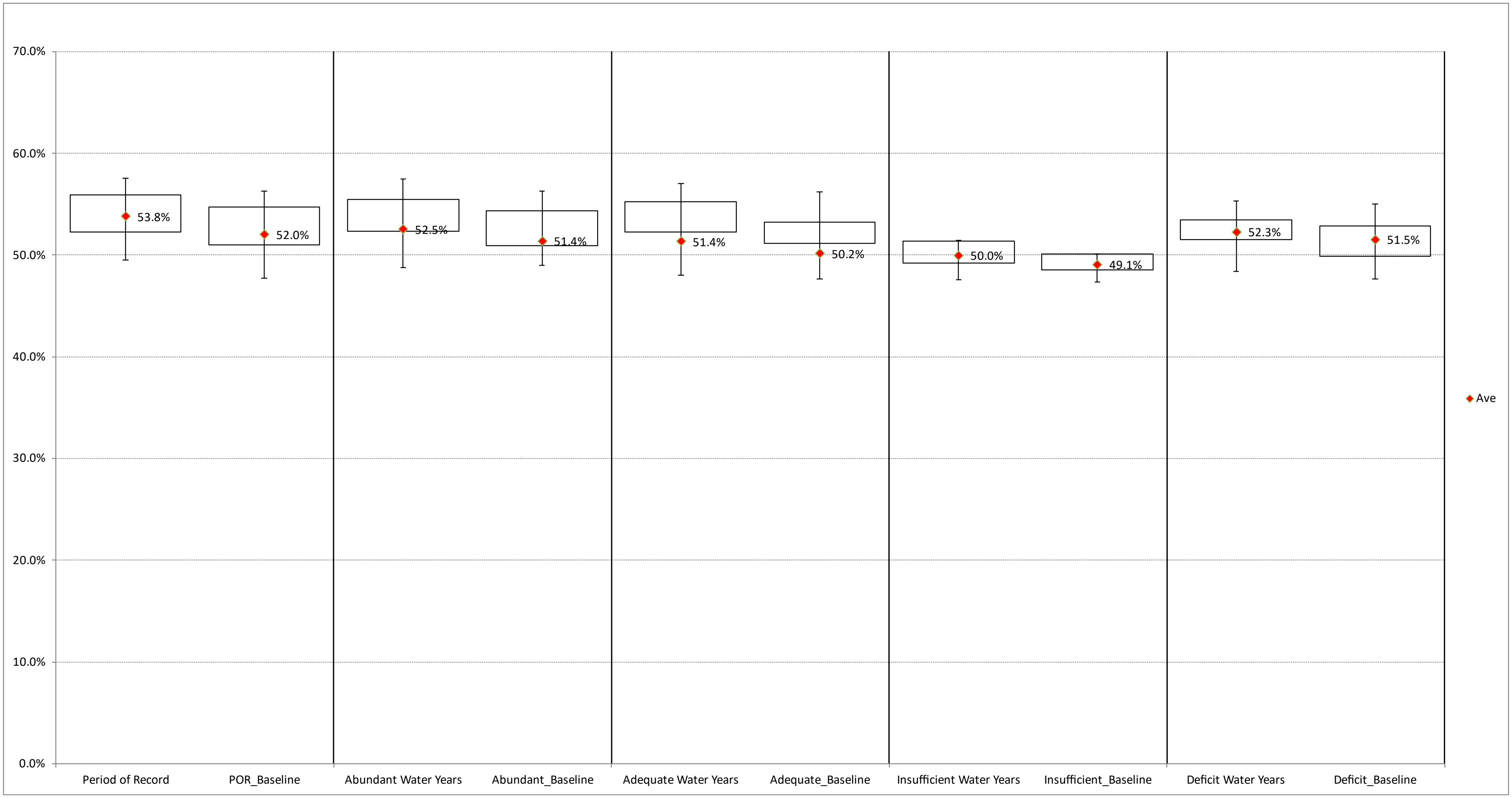

Figure 2-76. Downstream dam passage survival at Foster for juvenile spring Chinook yearlings under Alternative 3b. *Downstream dam passage survival at Foster for juvenile spring Chinook yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.6.3 McKenzie – Cougar

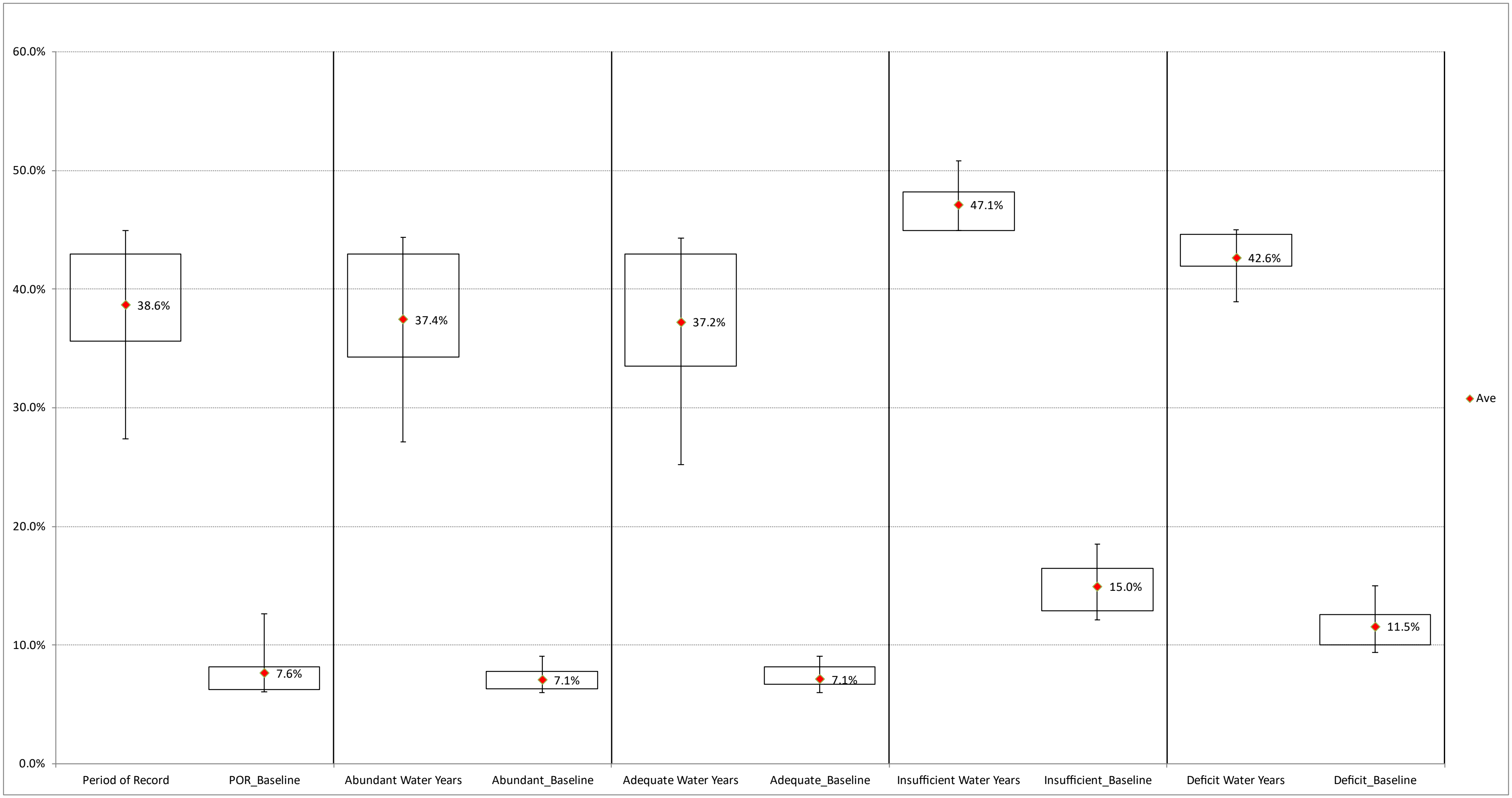

Figure 2-77. Cougar Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Cougar for juvenile spring Chinook fry under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

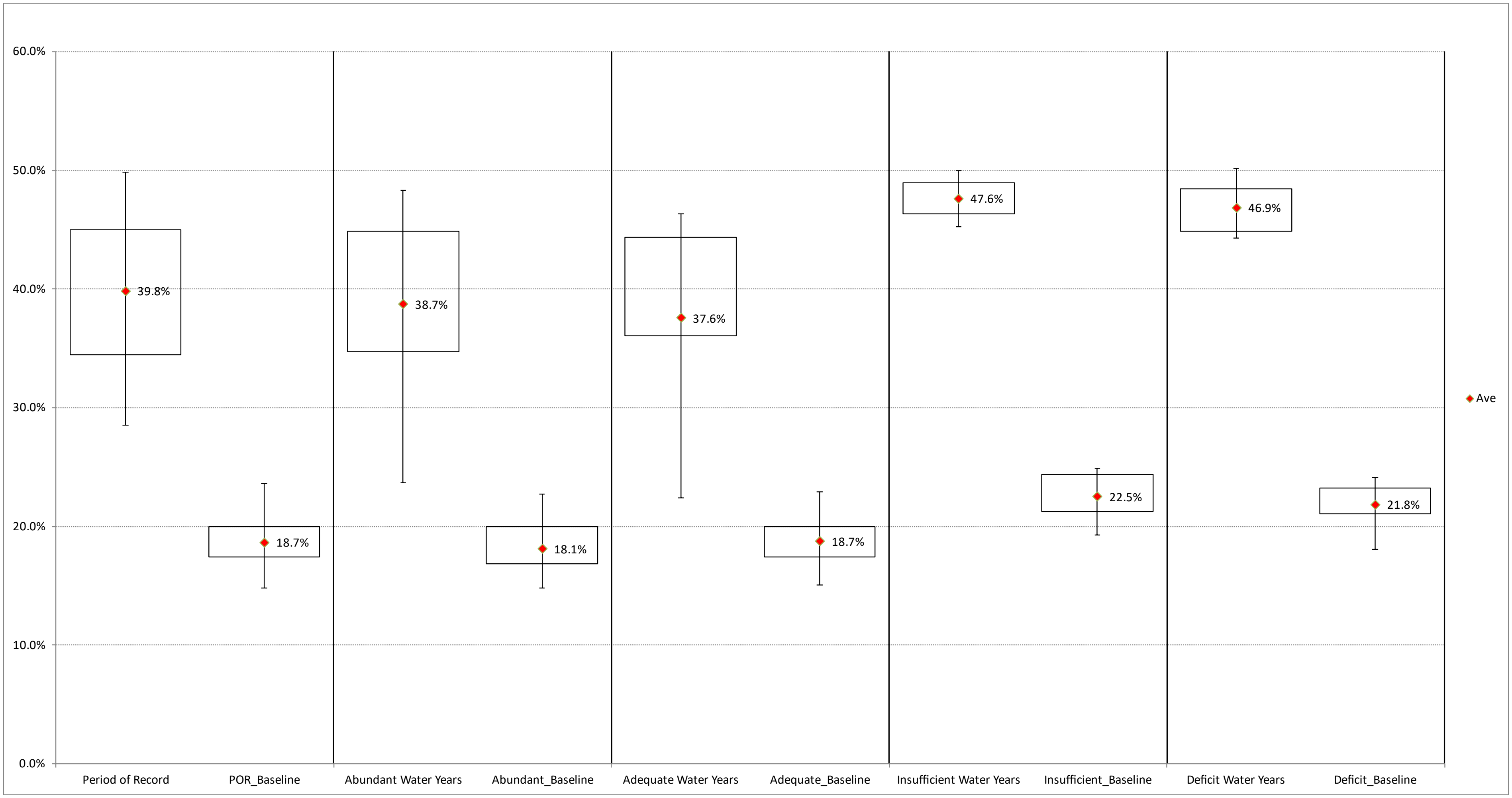

Figure 2-78. Cougar Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Cougar for juvenile spring Chinook sub-yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

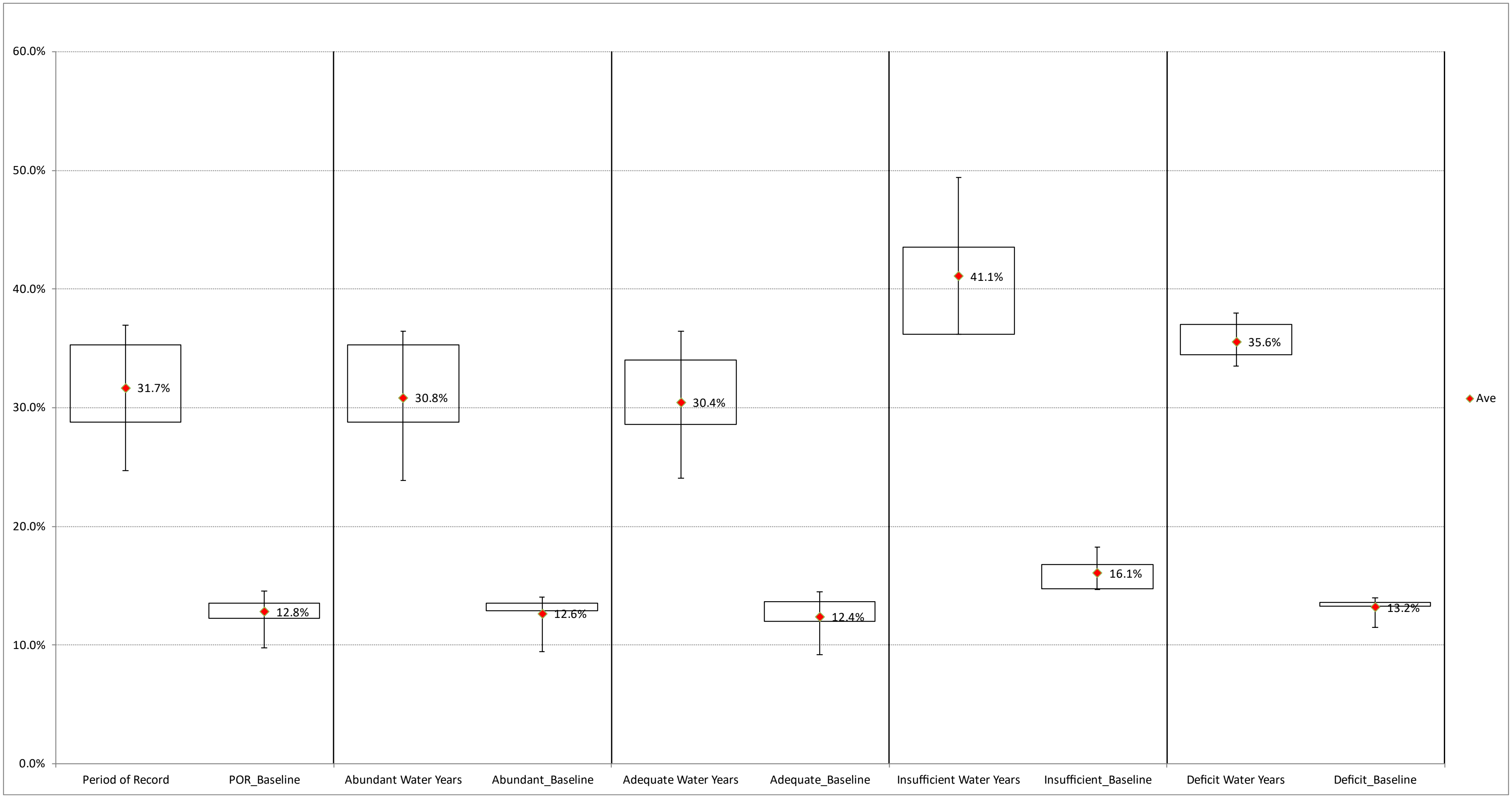

Figure 2-79. Cougar Juvenile Spring Chinook Yearlings Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Cougar for juvenile spring Chinook yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.6.4 Middle Fork – Lookout Point

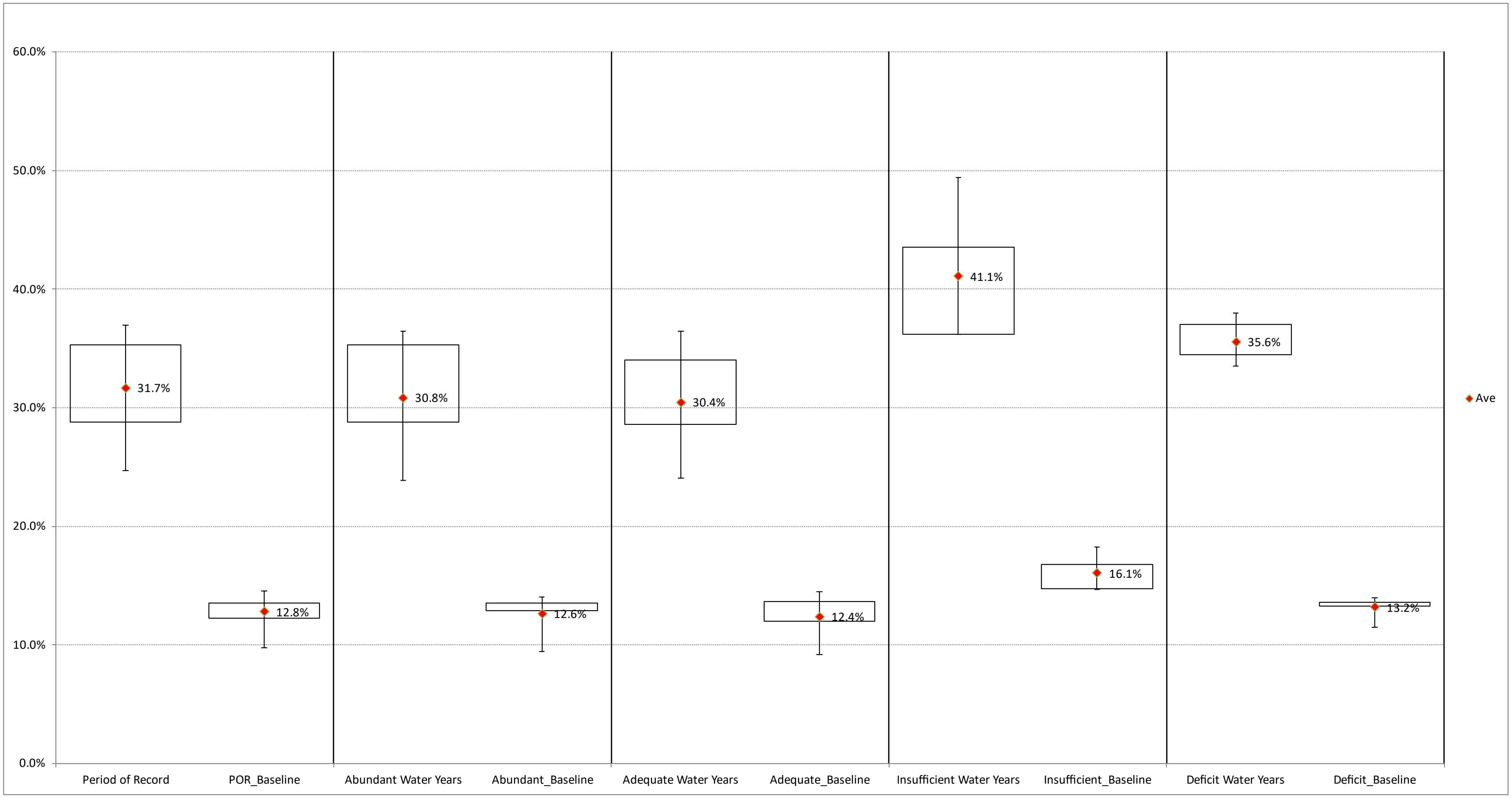

Figure 2-80. Lookout Point Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook fry under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

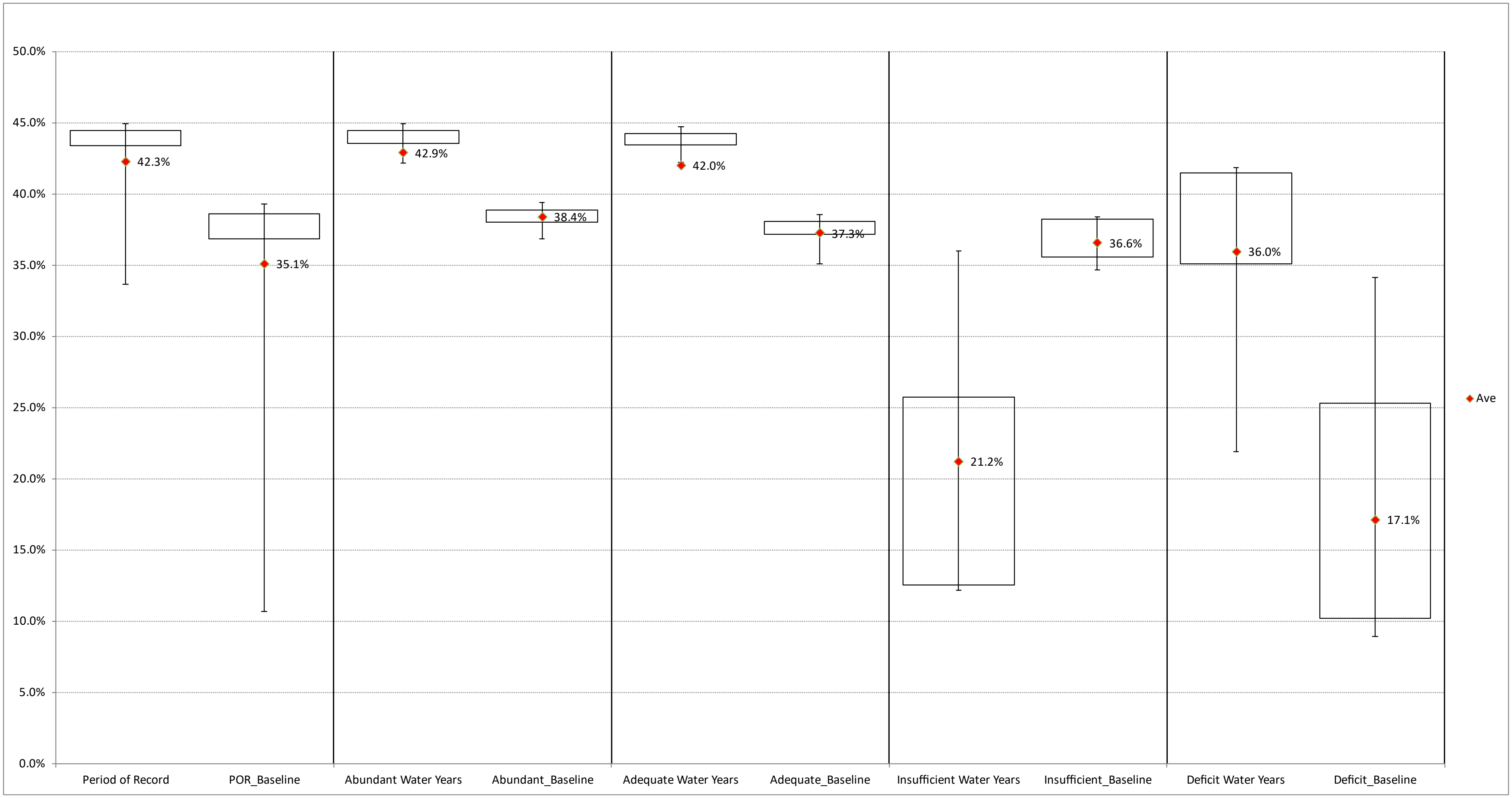

Figure 2-81. Lookout Point Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook sub-yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

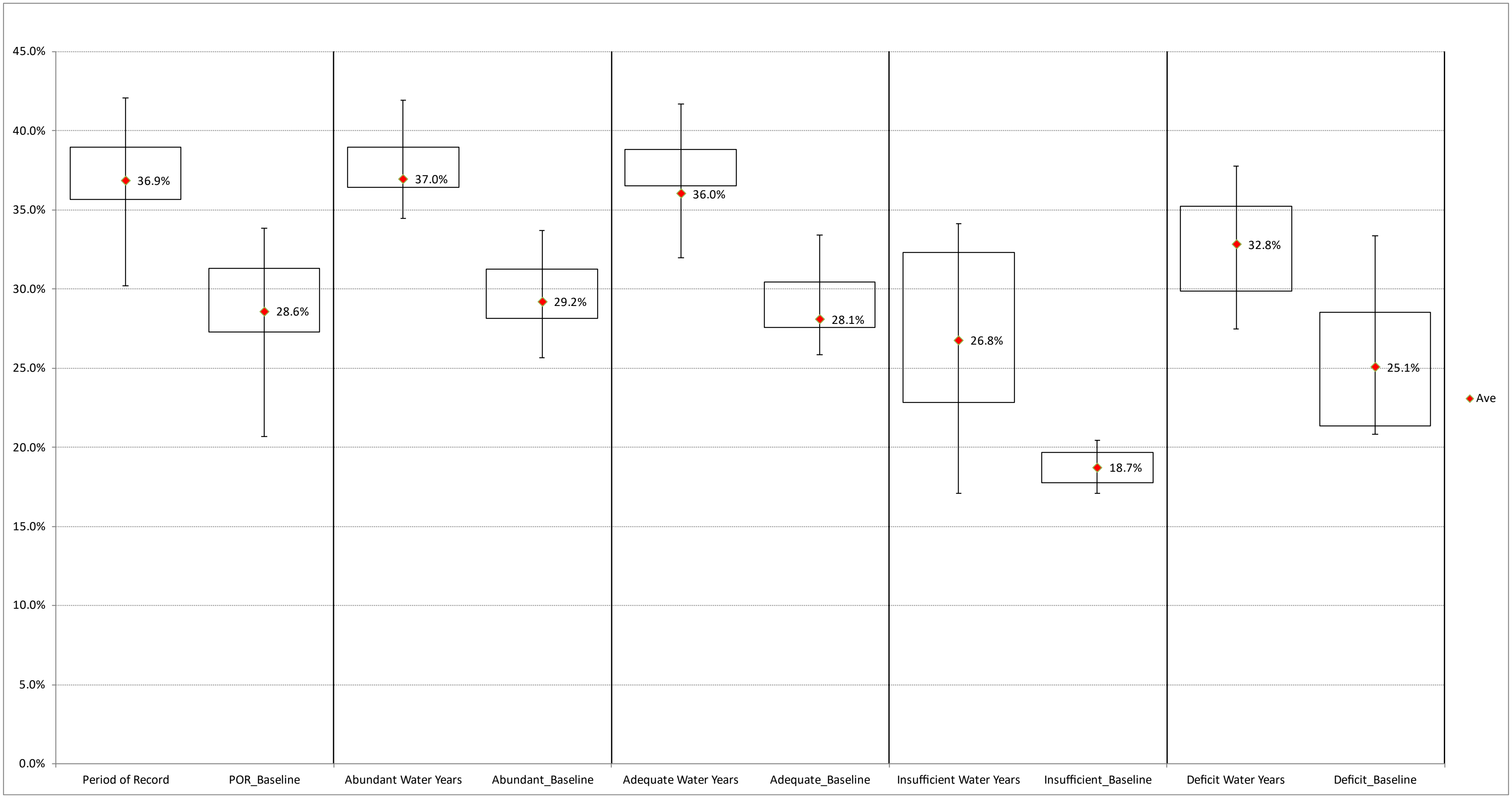

Figure 2-82. Lookout Point for juvenile spring Chinook yearling Downstream dam passage survival under Alternative 3b. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

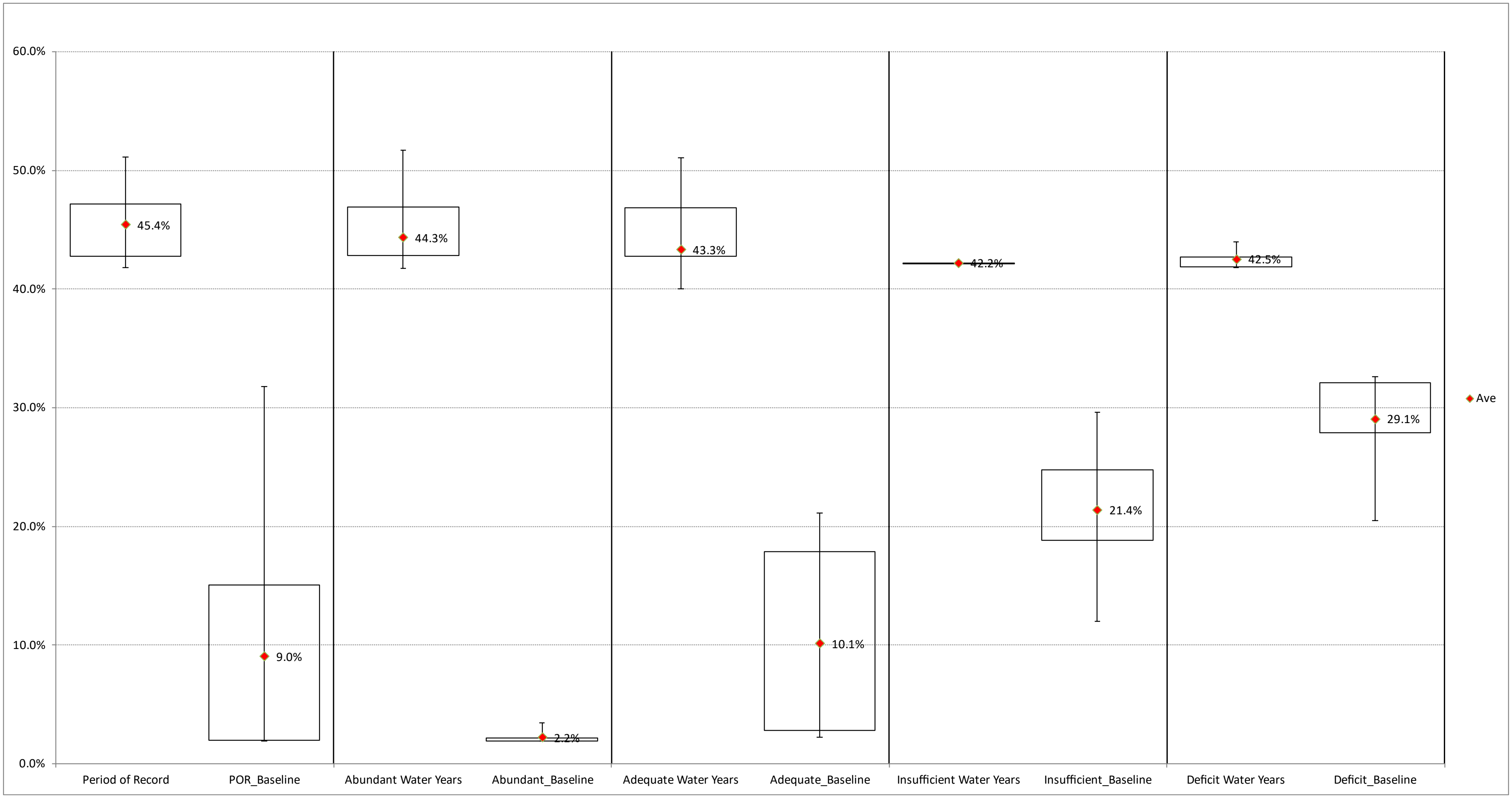

Figure 2-83. Hills Creek Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook fry under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

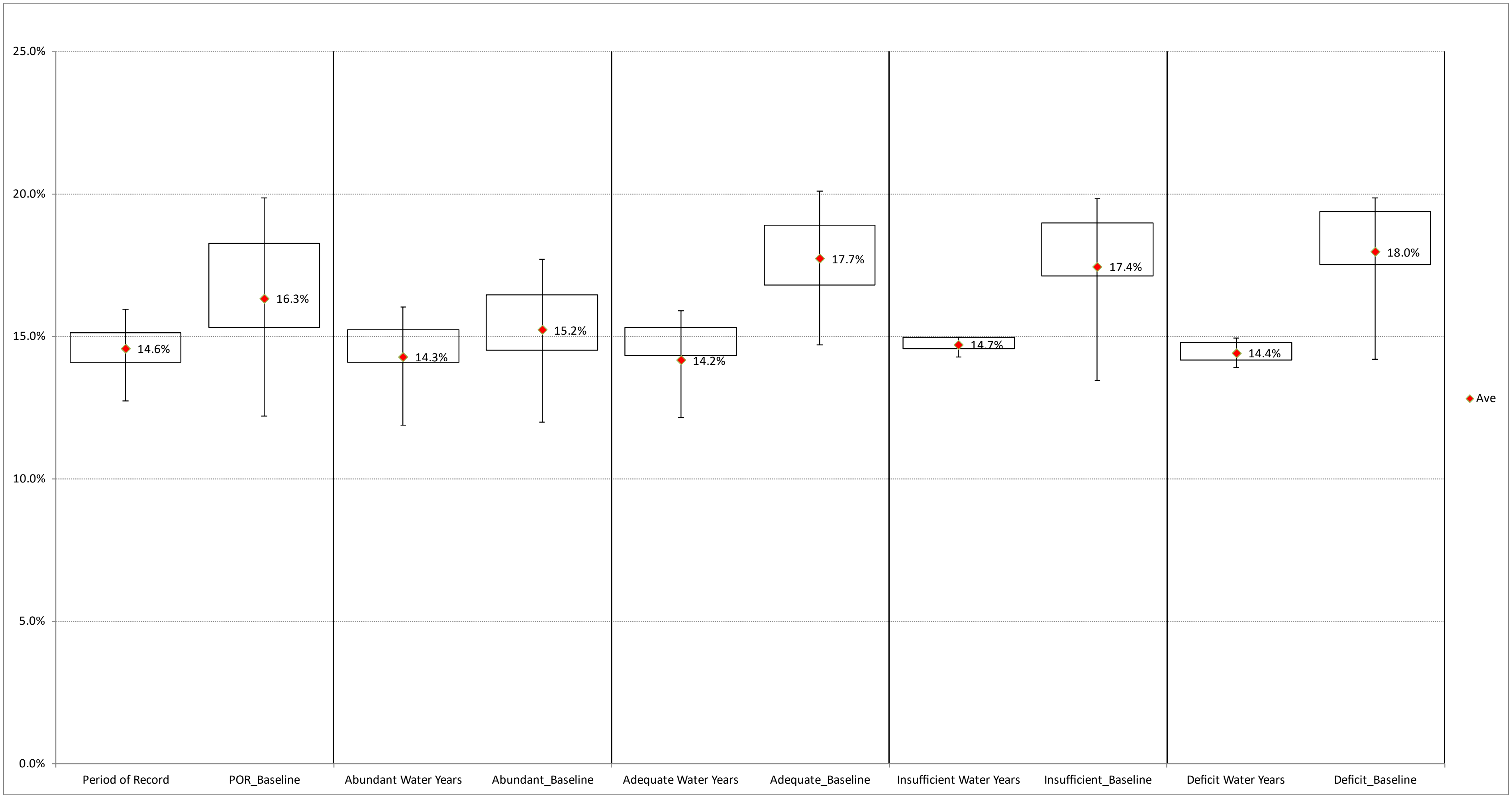

Figure 2-84. Hills Creek For Juvenile Spring Chinook Sub-Yearlings Downstream Dam Passage Survival At Under Alternative 3b. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook sub-yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

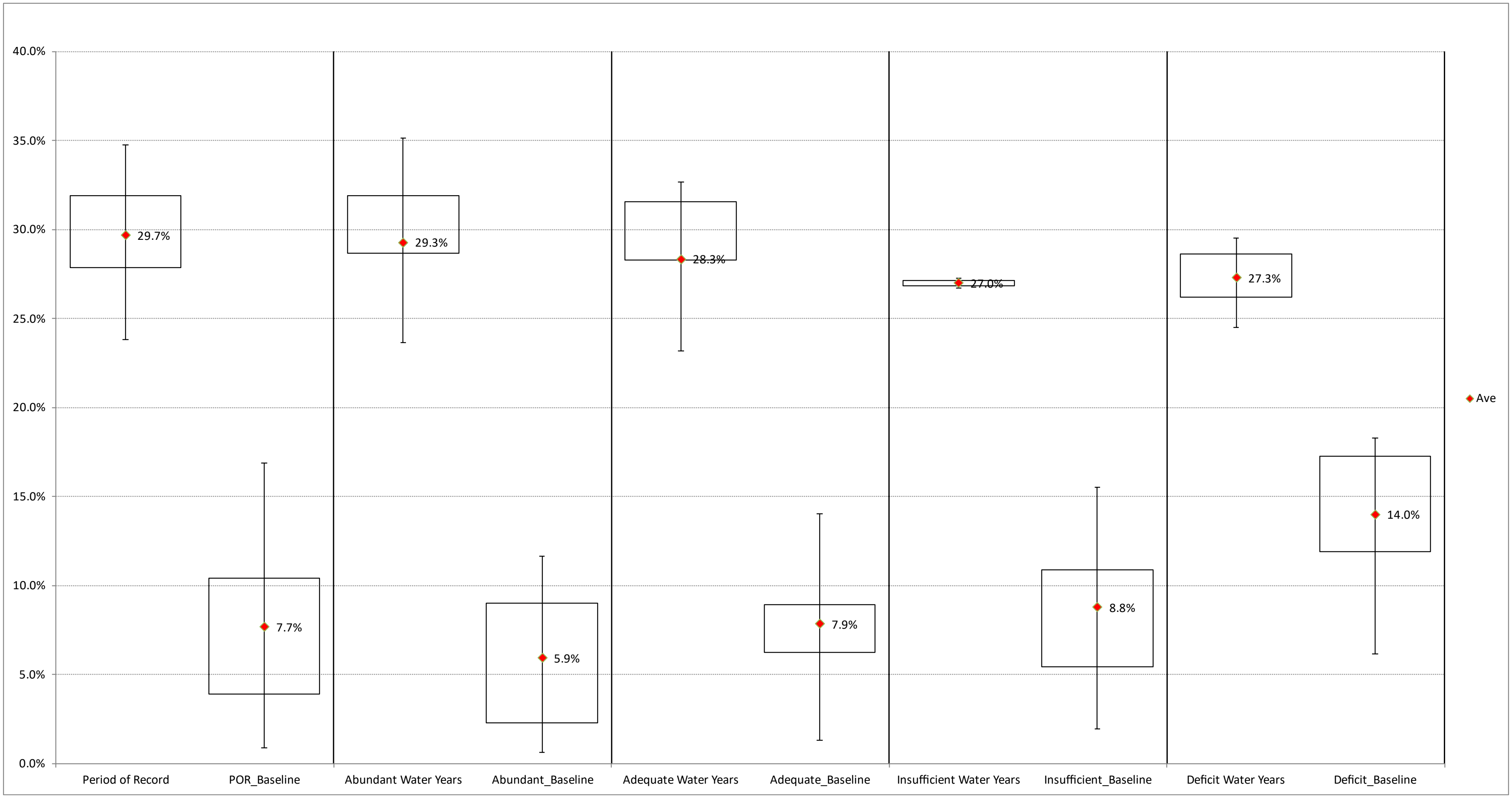

Figure 2-85. Hills Creek Juvenile Spring Chinook Yearlings Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.7 CHINOOK SALMON ALTERNATIVE 4

2.7.1 North Santiam – Detroit

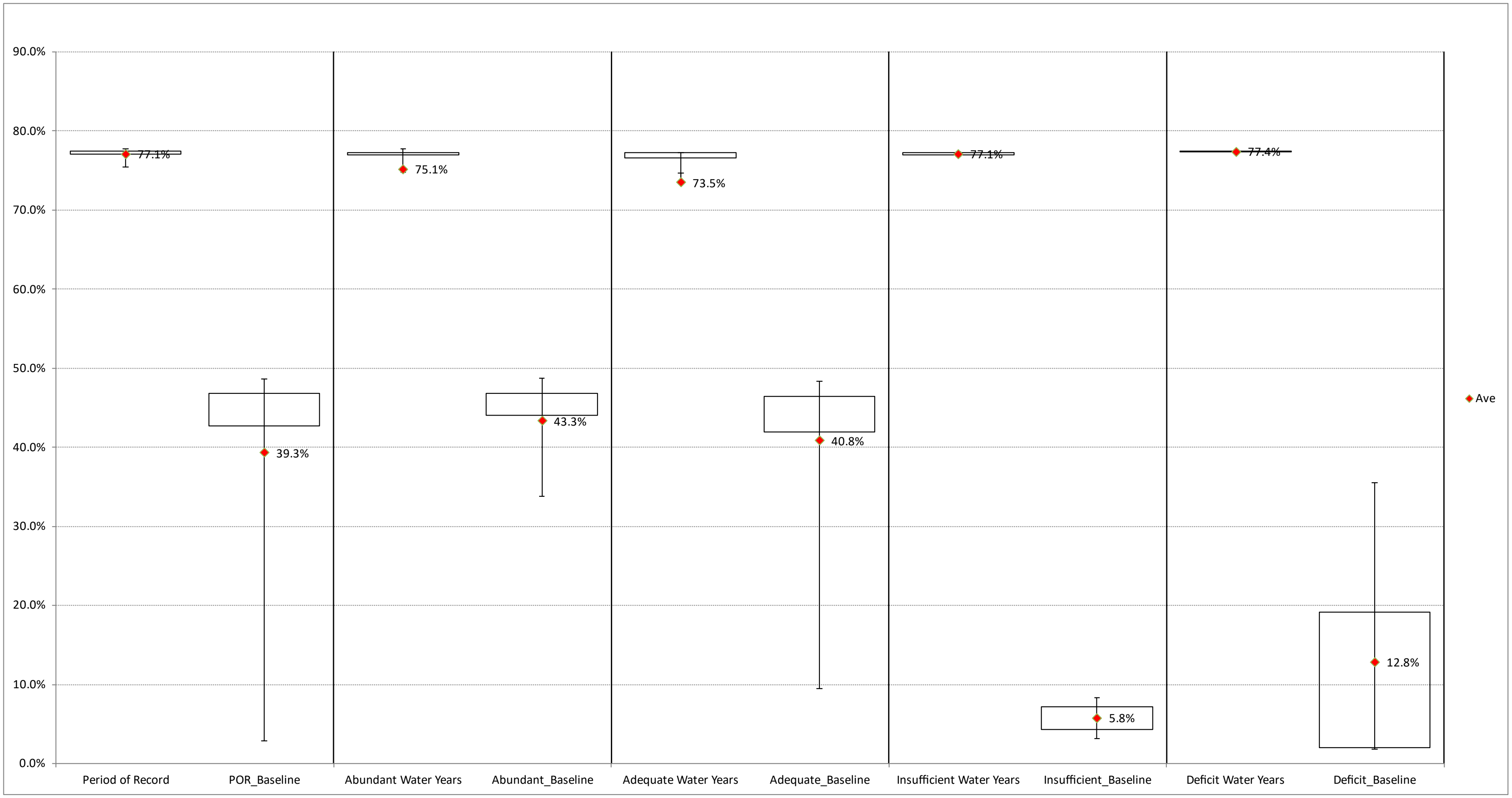

Figure 2-86. Detroit Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Detroit for juvenile spring Chinook fry under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

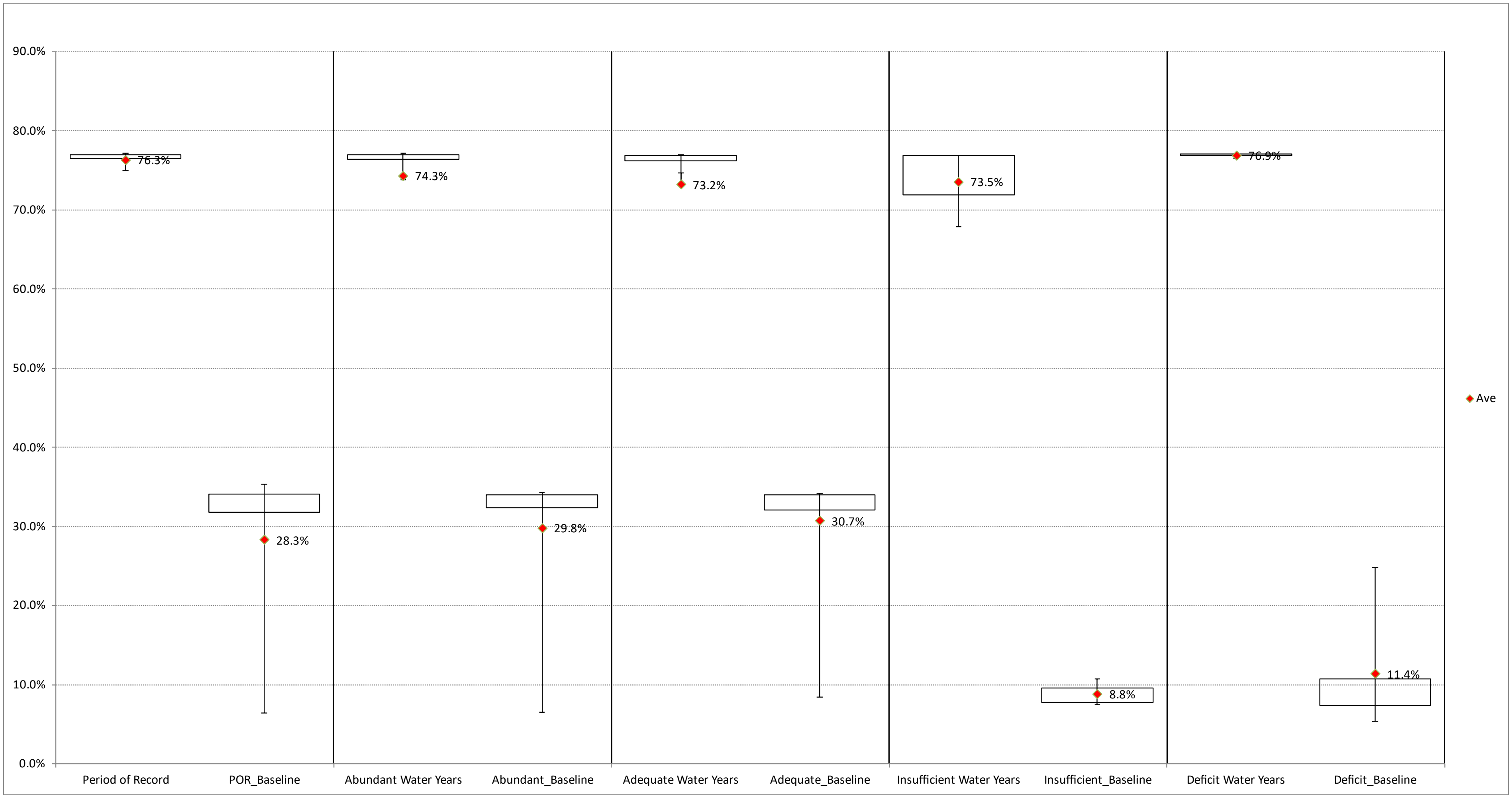

Figure 2-87. Detroit Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Detroit for juvenile spring Chinook sub-yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

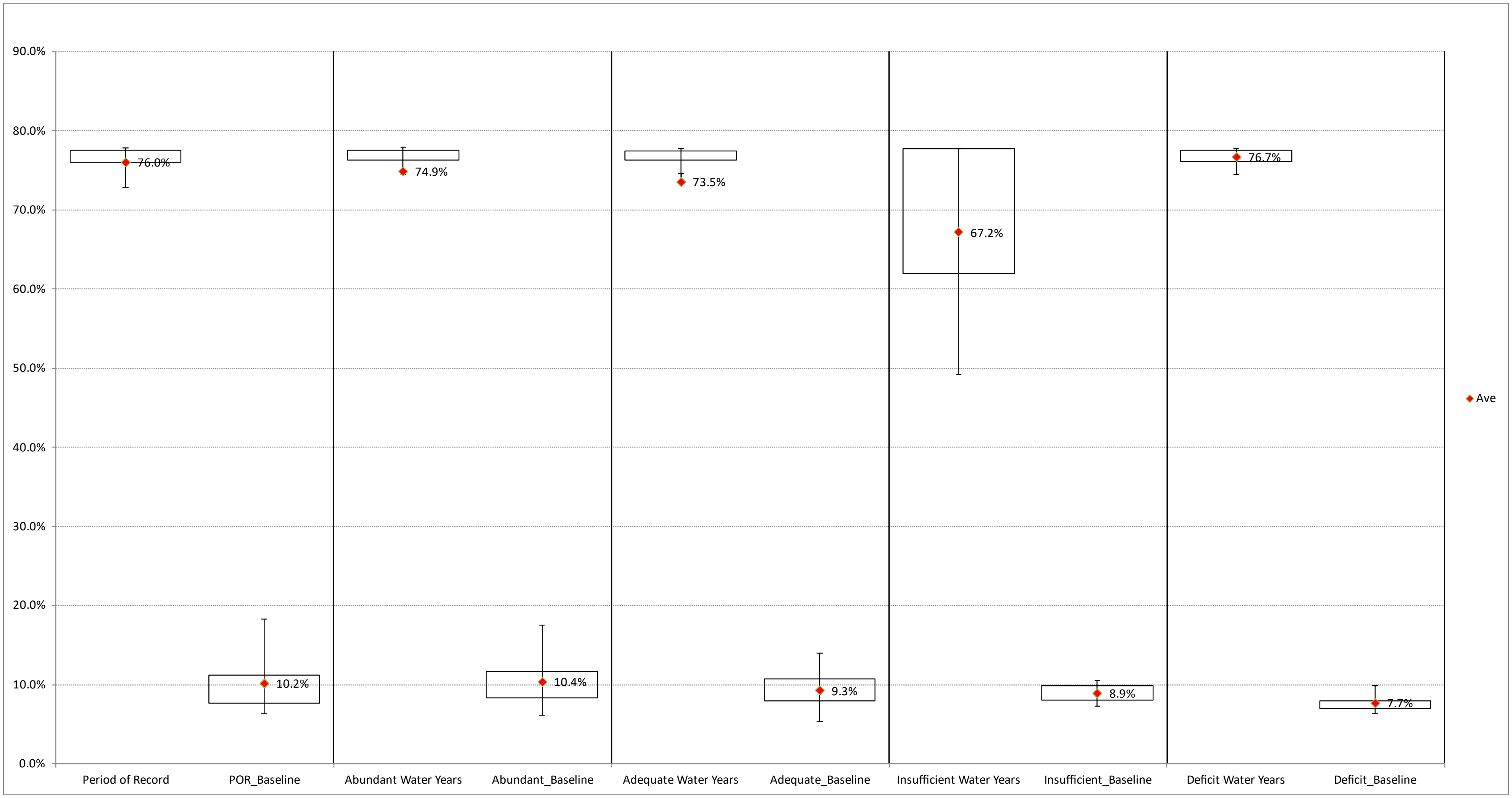

Figure 2-88. Downstream dam passage survival at Detroit for juvenile spring Chinook yearlings under Alternative 4. *Downstream dam passage survival at Detroit for juvenile spring Chinook yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.7.2 South Santiam – Foster

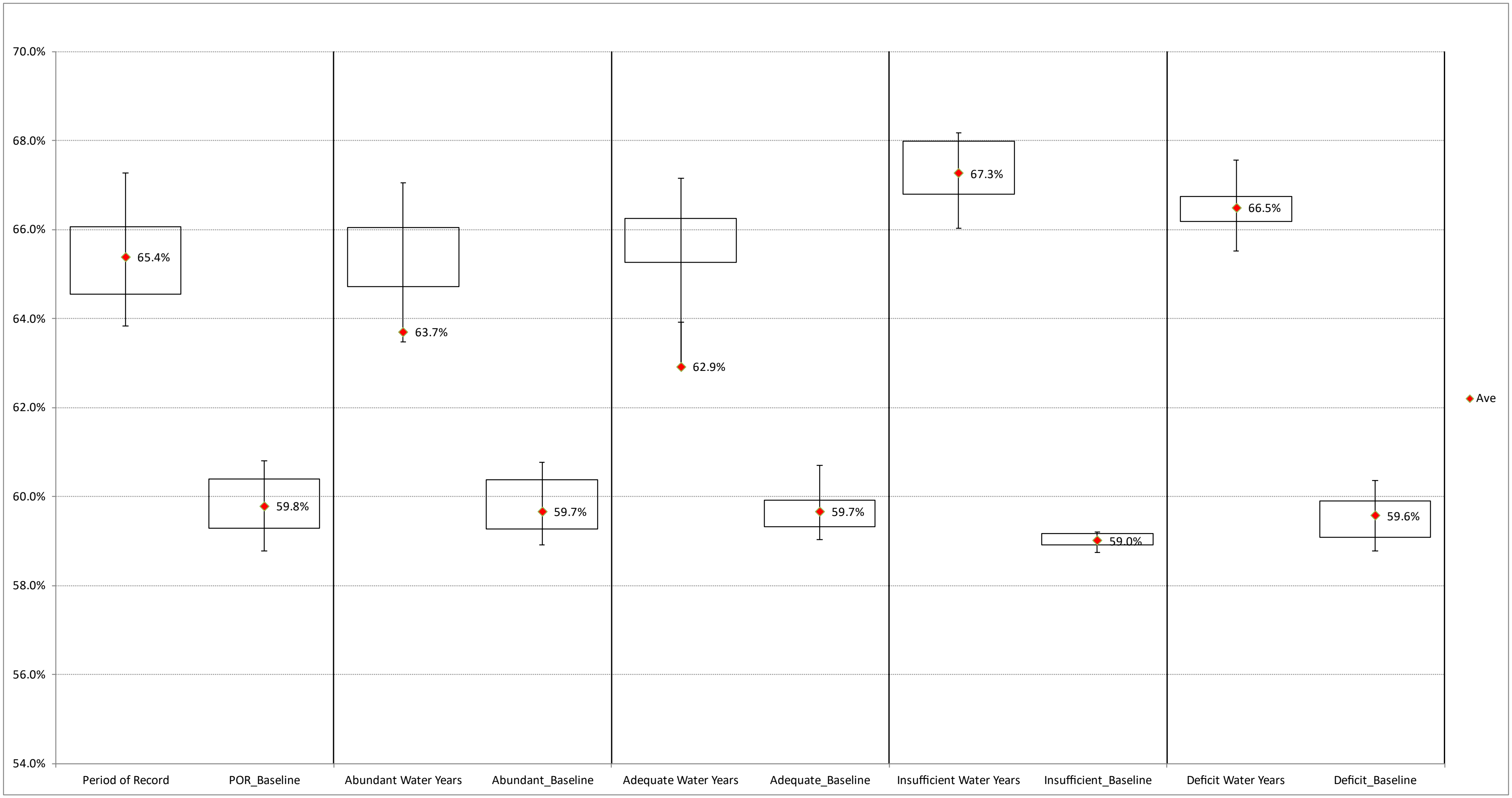

Figure 2-89.Downstream dam passage survival at Foster for juvenile spring Chinook fry under Alternative 4. *Downstream dam passage survival at Foster for juvenile spring Chinook fry under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

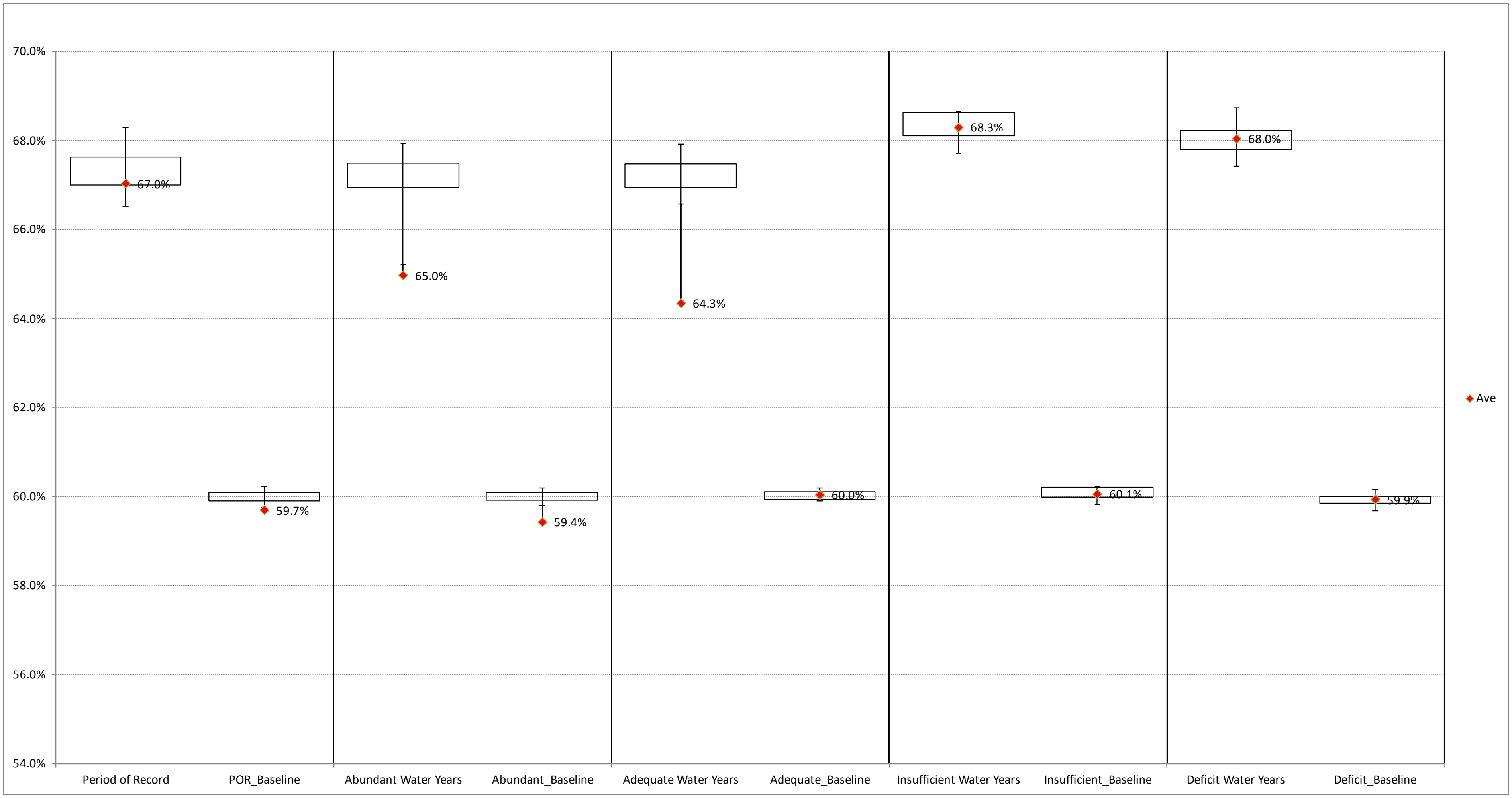

Figure 2-90. Foster Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Foster for juvenile spring Chinook sub-yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

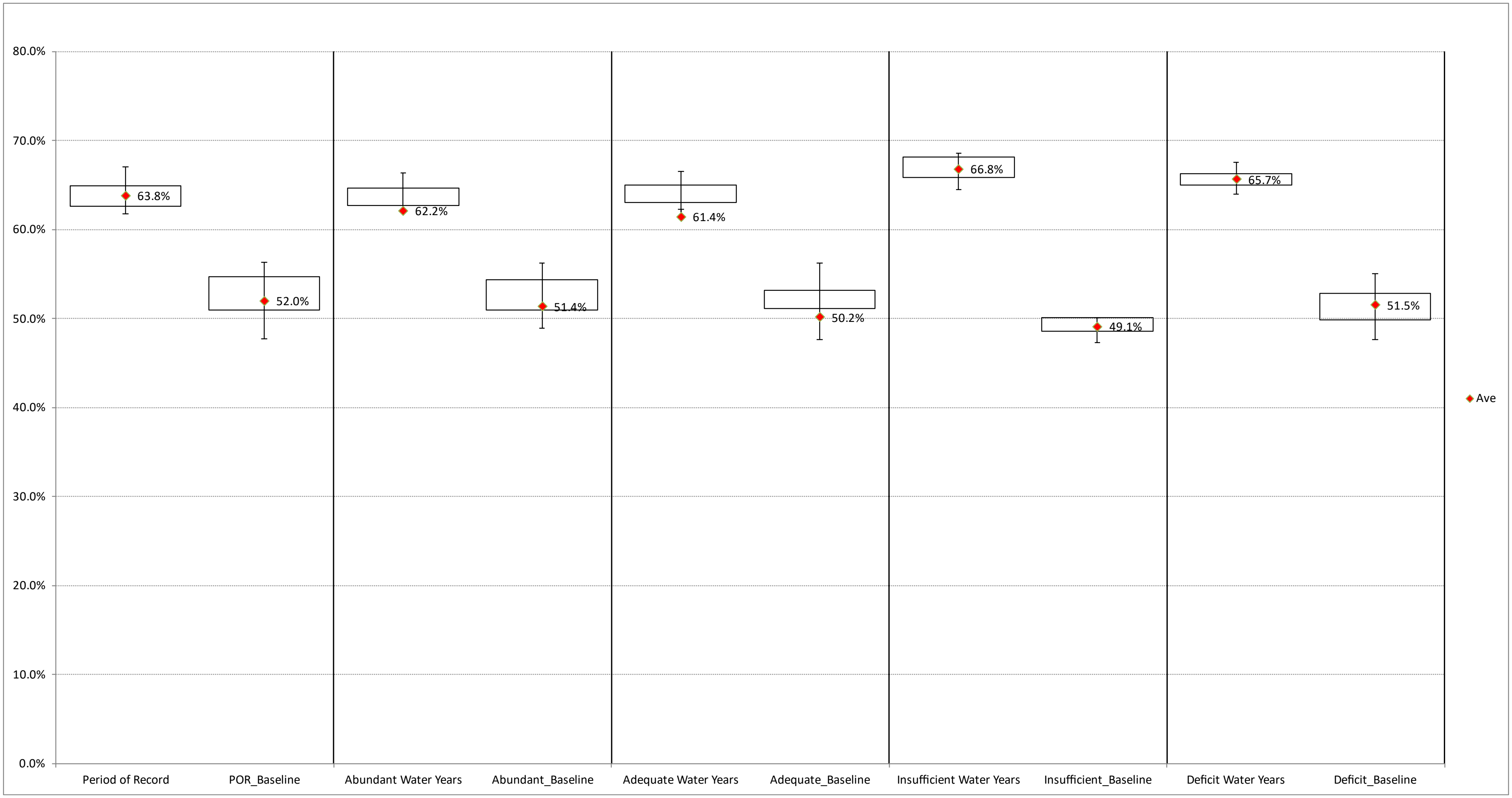

Figure 2-91. Foster Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Foster for juvenile spring Chinook yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.7.3 South Santiam – Green Peter

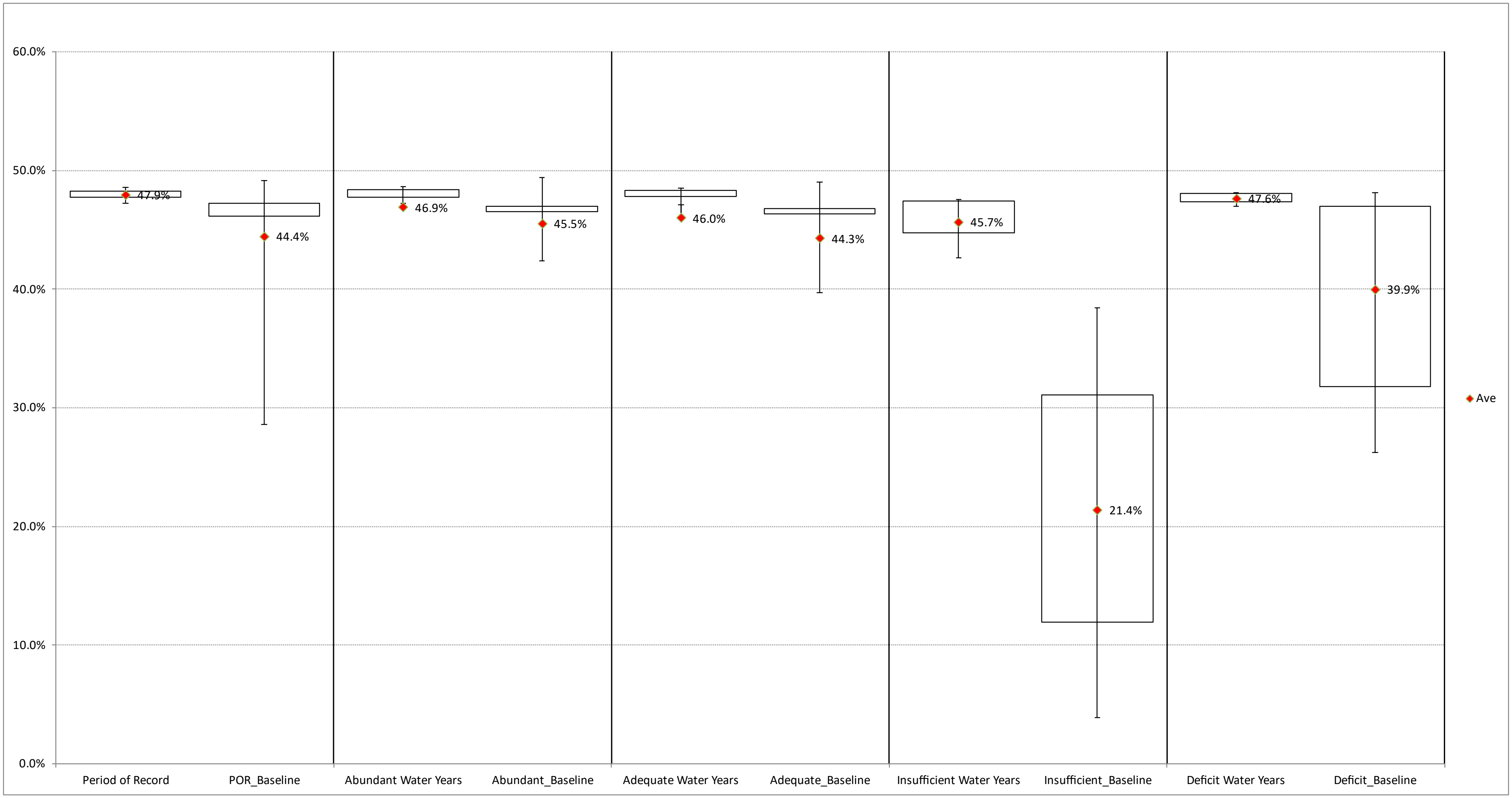

Figure 2-92. Green Peter Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Green Peter for juvenile spring Chinook fry under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

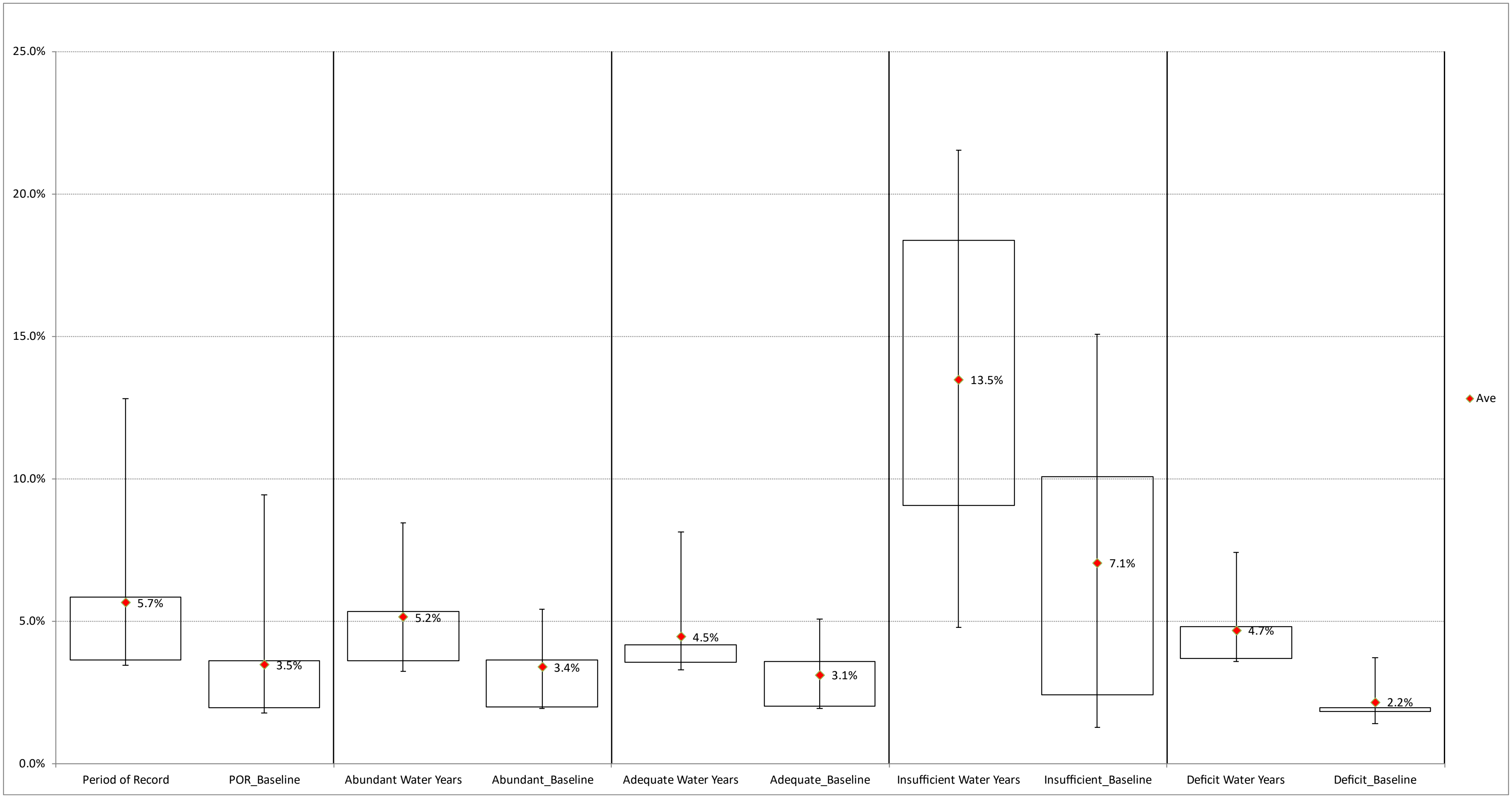

Figure 2-93.Downstream dam passage survival at Green Peter for juvenile spring Chinook sub-yearlings under Alternative 4.
Downstream dam passage survival at Green Peter for juvenile spring Chinook sub-yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.

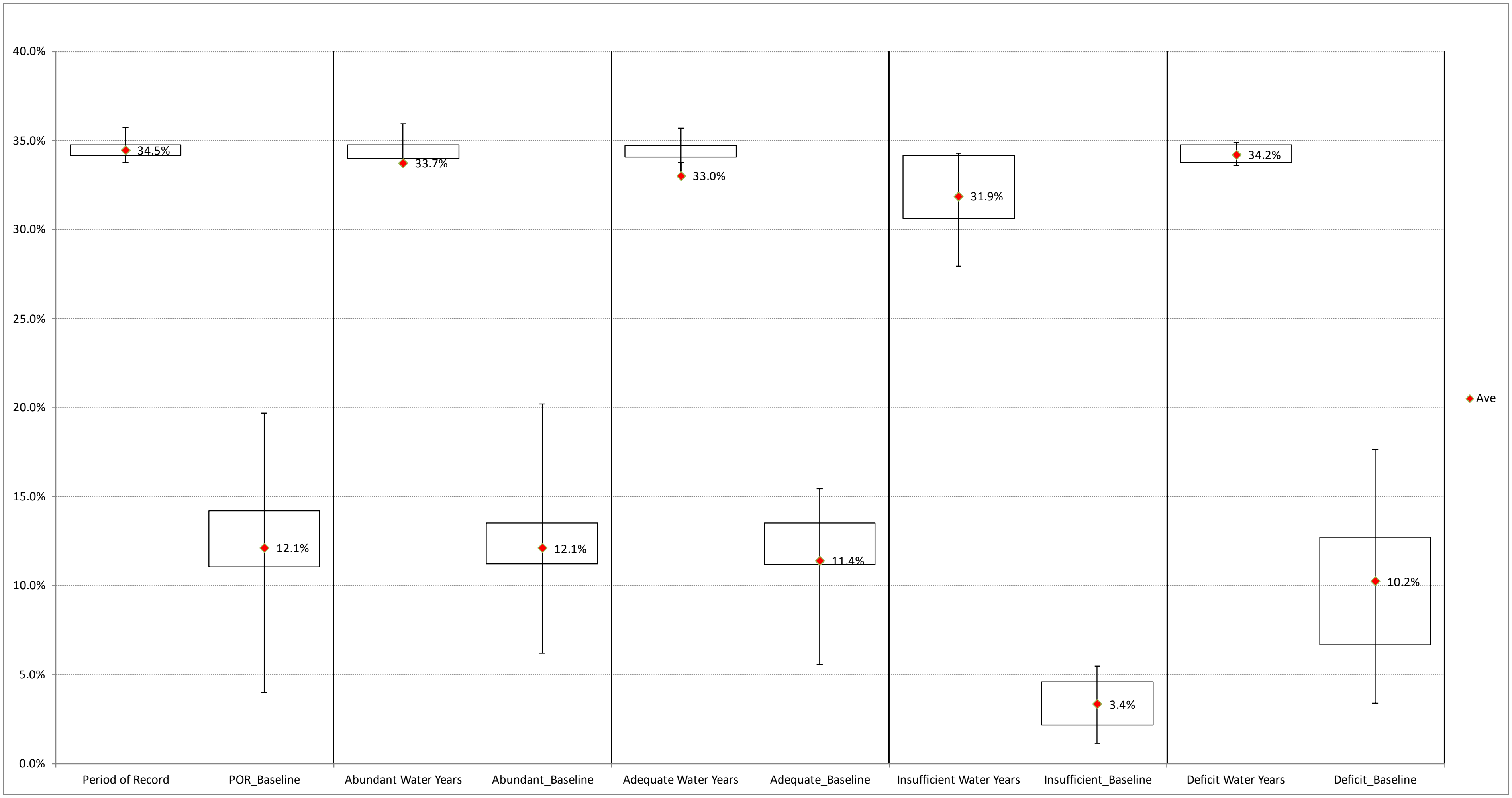

Figure 2-94. Green Peter Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Green Peter for juvenile spring Chinook sub-yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.7.4 McKenzie - Cougar

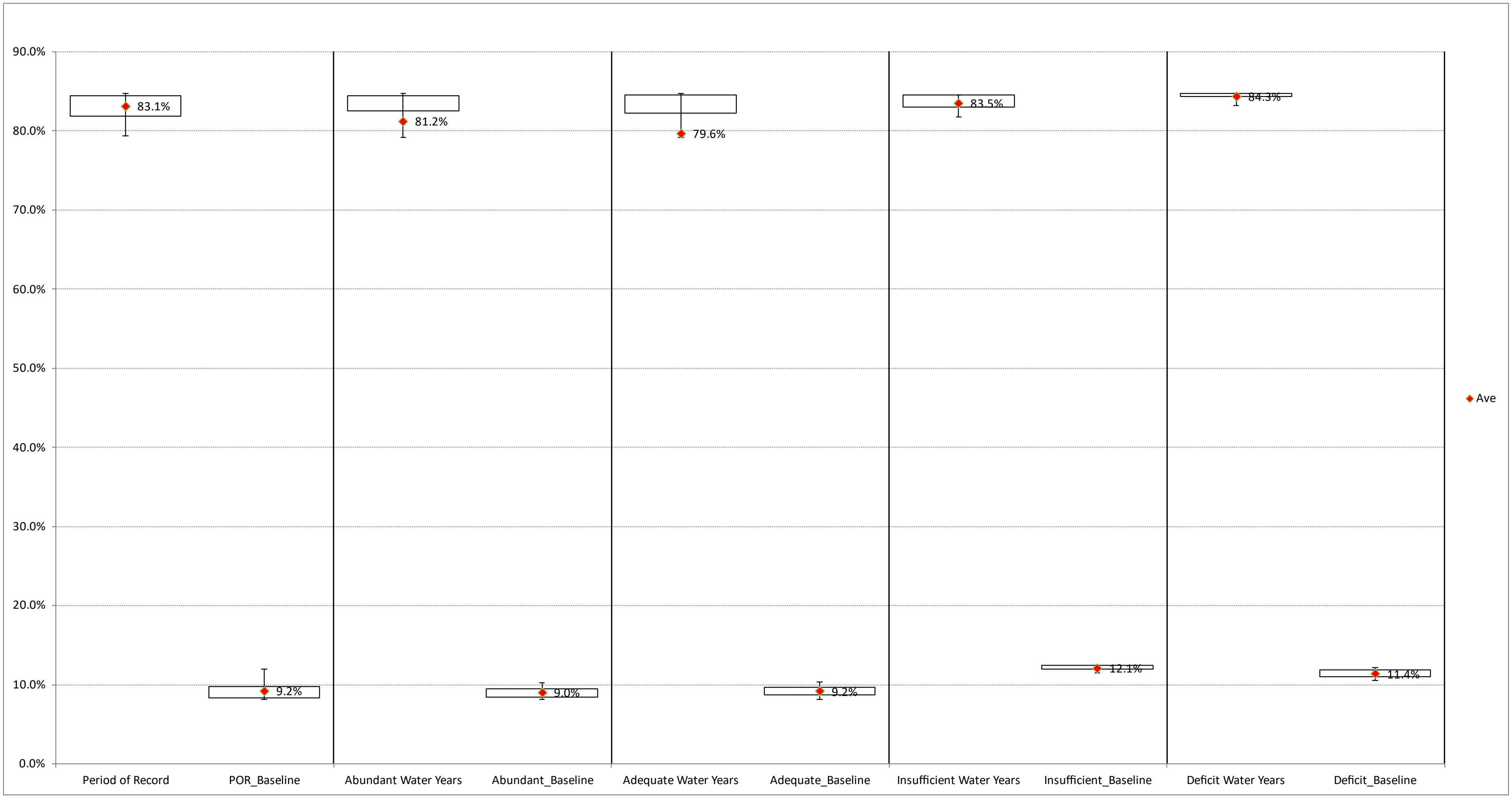

Figure 2-95. Cougar Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Cougar for juvenile spring Chinook fry under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

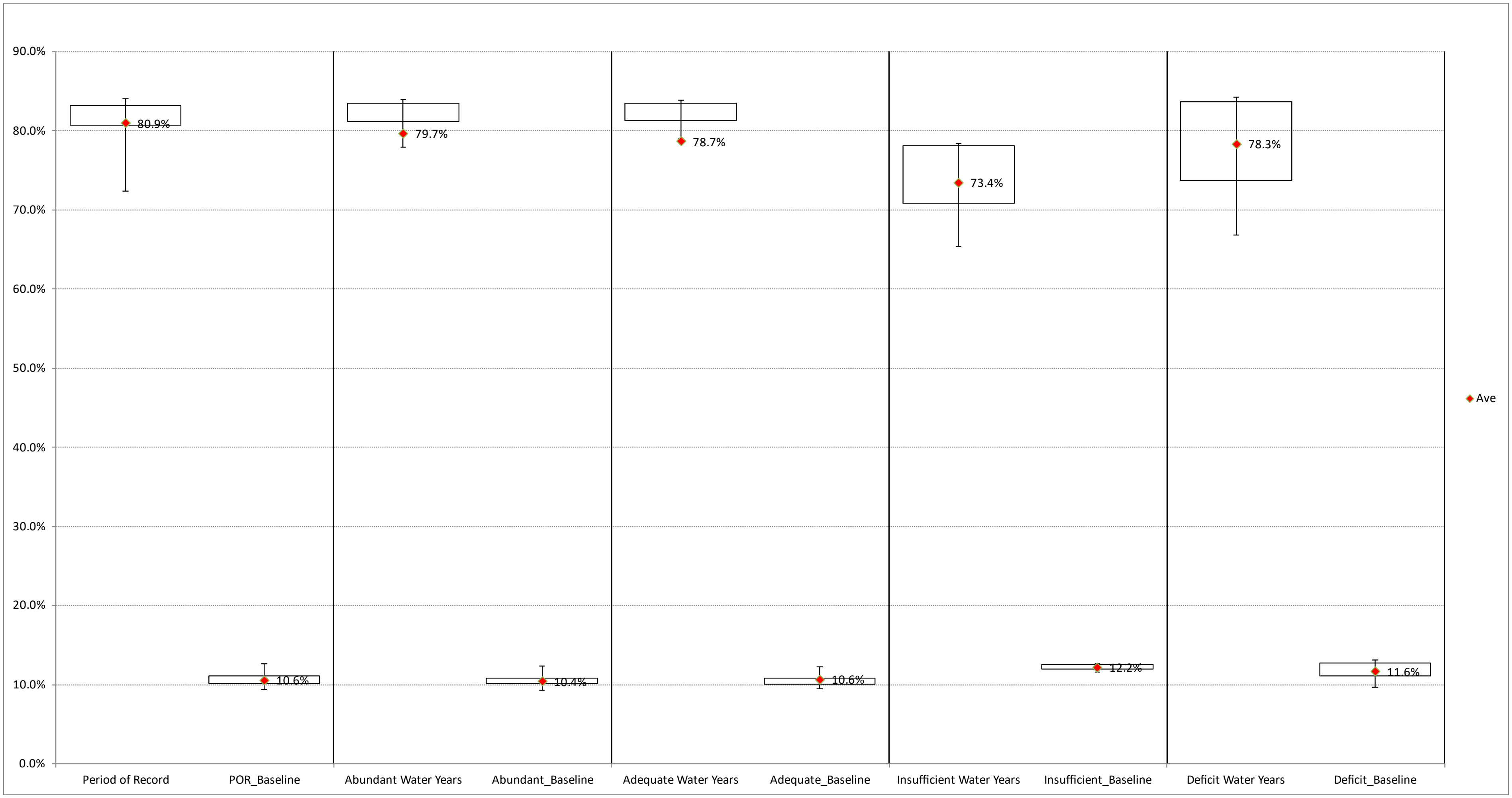

Figure 2-96. Cougar Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Cougar for juvenile spring Chinook sub-yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

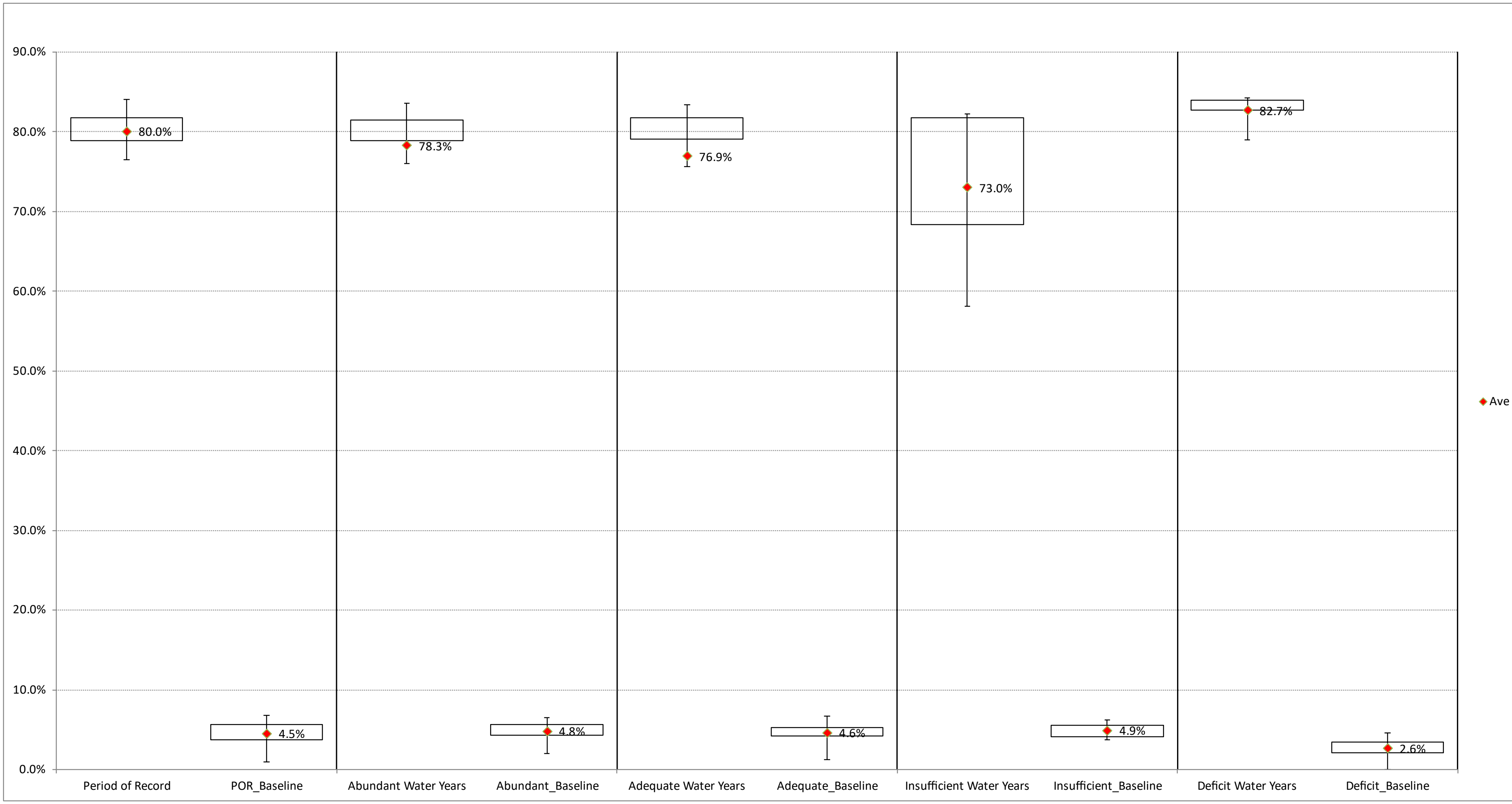

Figure 2-97. Cougar Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Cougar for juvenile spring Chinook yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.7.5 Middle Fork – Lookout Point

Figure 2-98. Lookout Point Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook fry under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

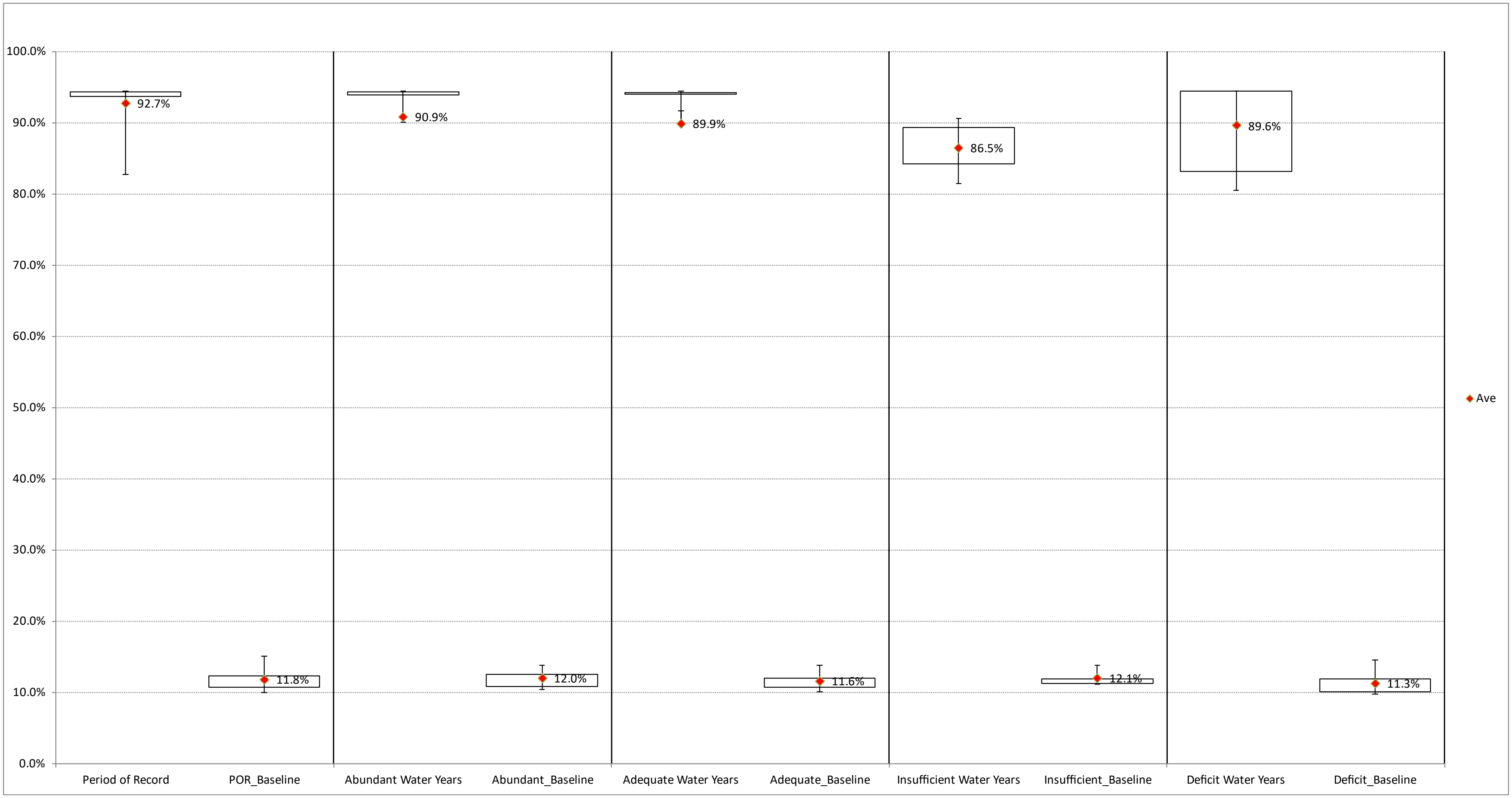

Figure 2-99. Lookout Point Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook sub-yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

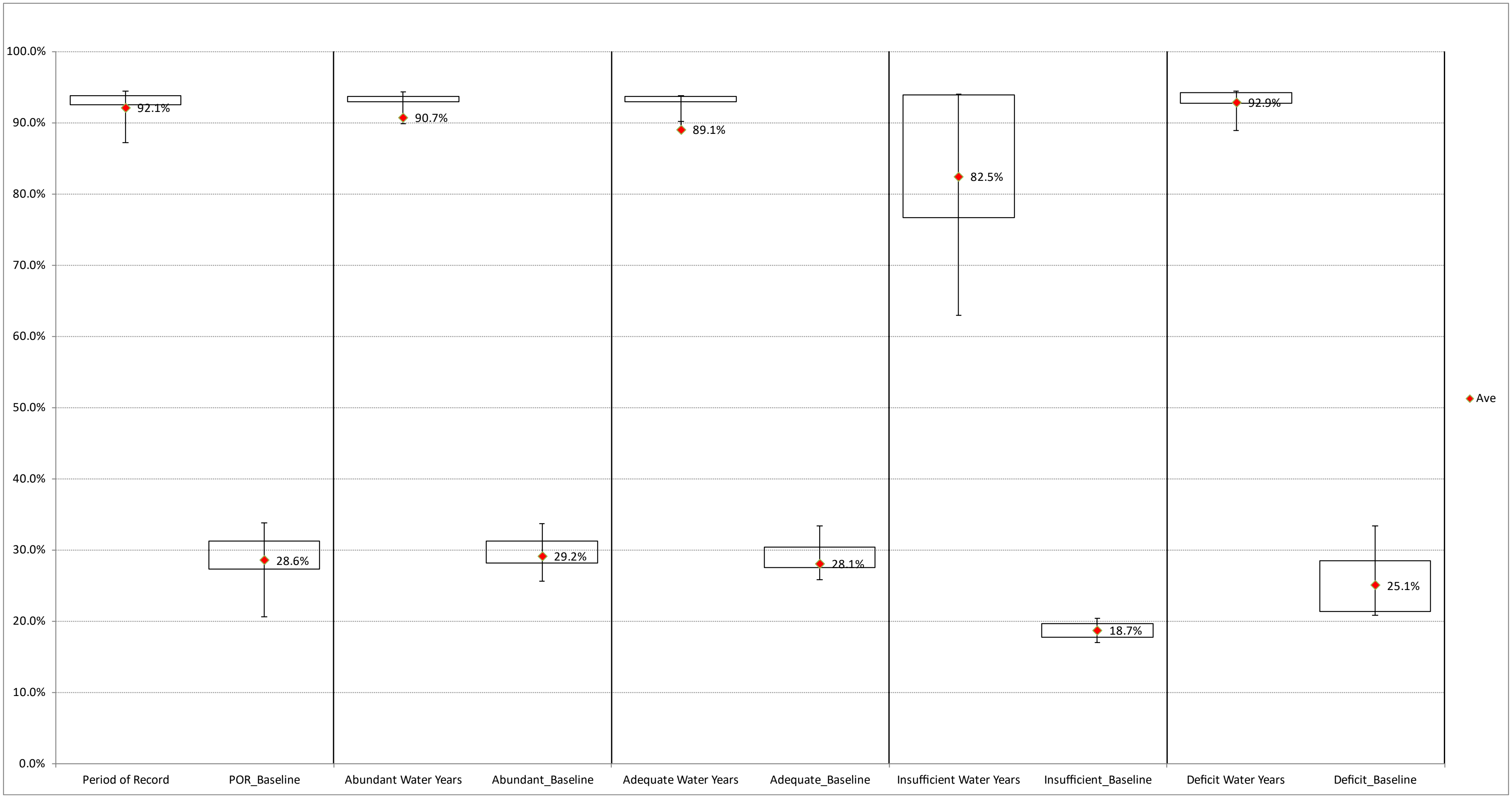

Figure 2-100. Lookout Point Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 4.
Downstream dam passage survival at Lookout Point for juvenile spring Chinook yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.

2.7.6 Middle Fork – Hills Creek

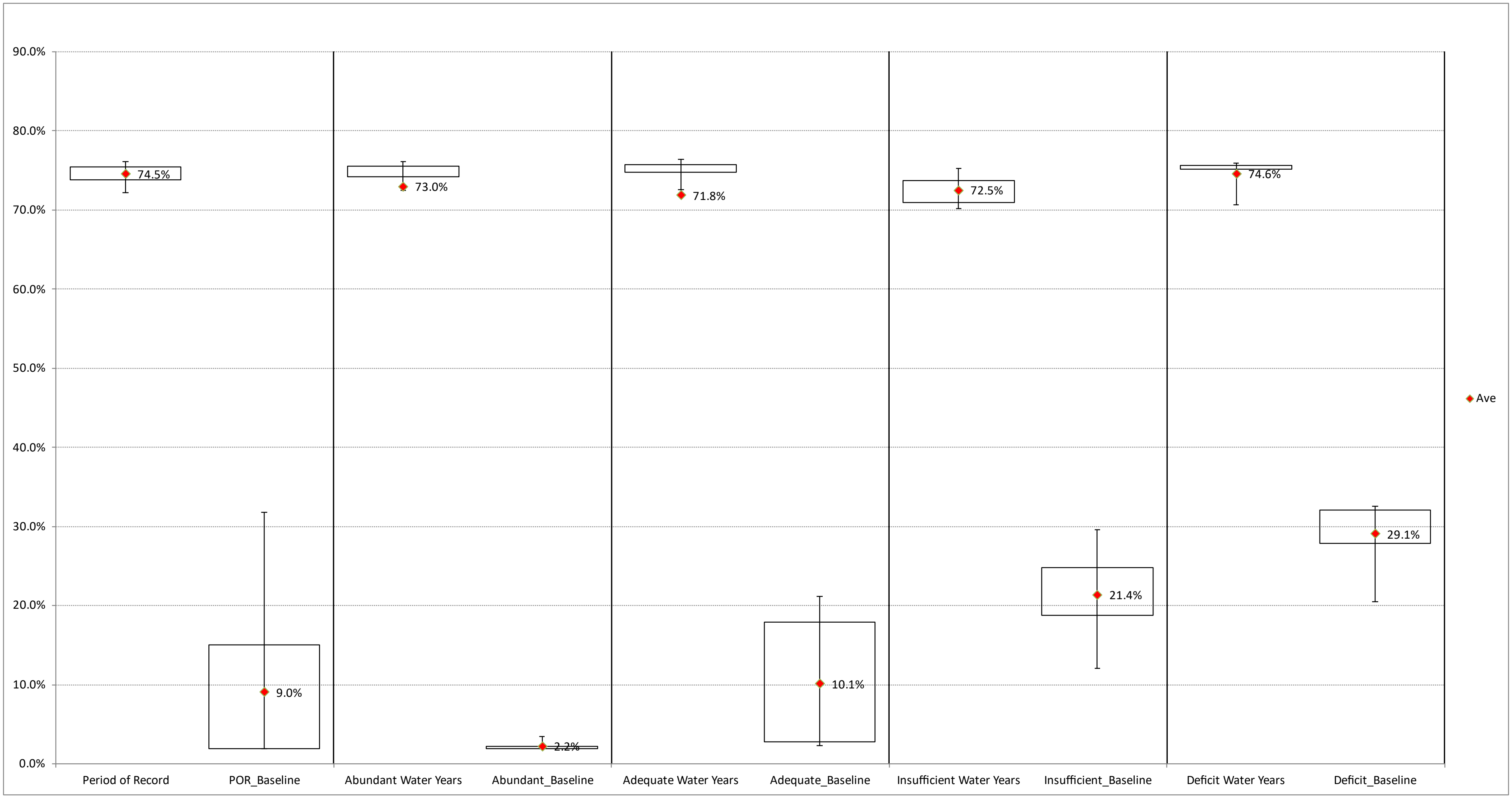

Figure 2-101. Hills Creek Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook fry under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

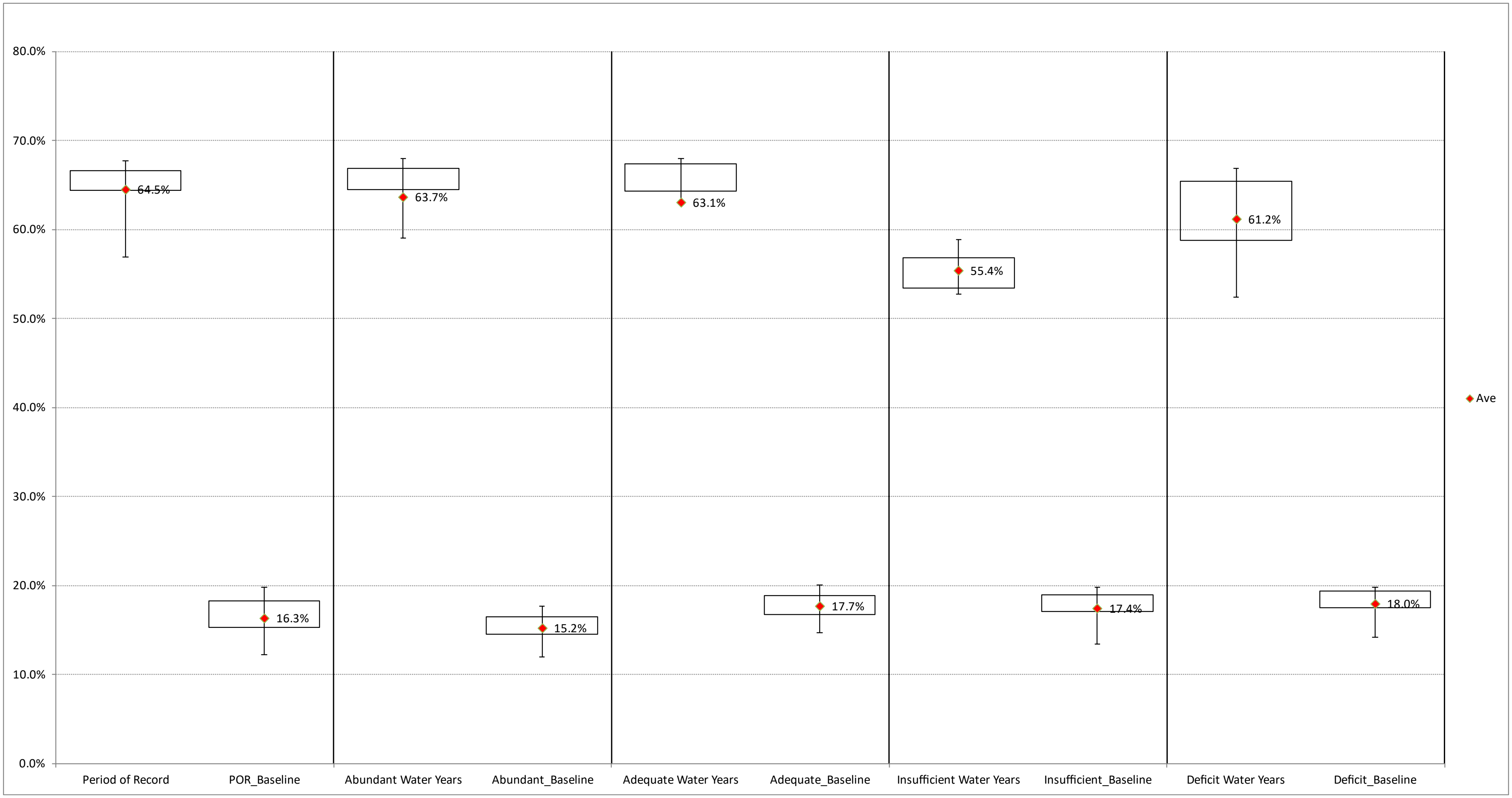

Figure 2-102. Hills Creek Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook sub-yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

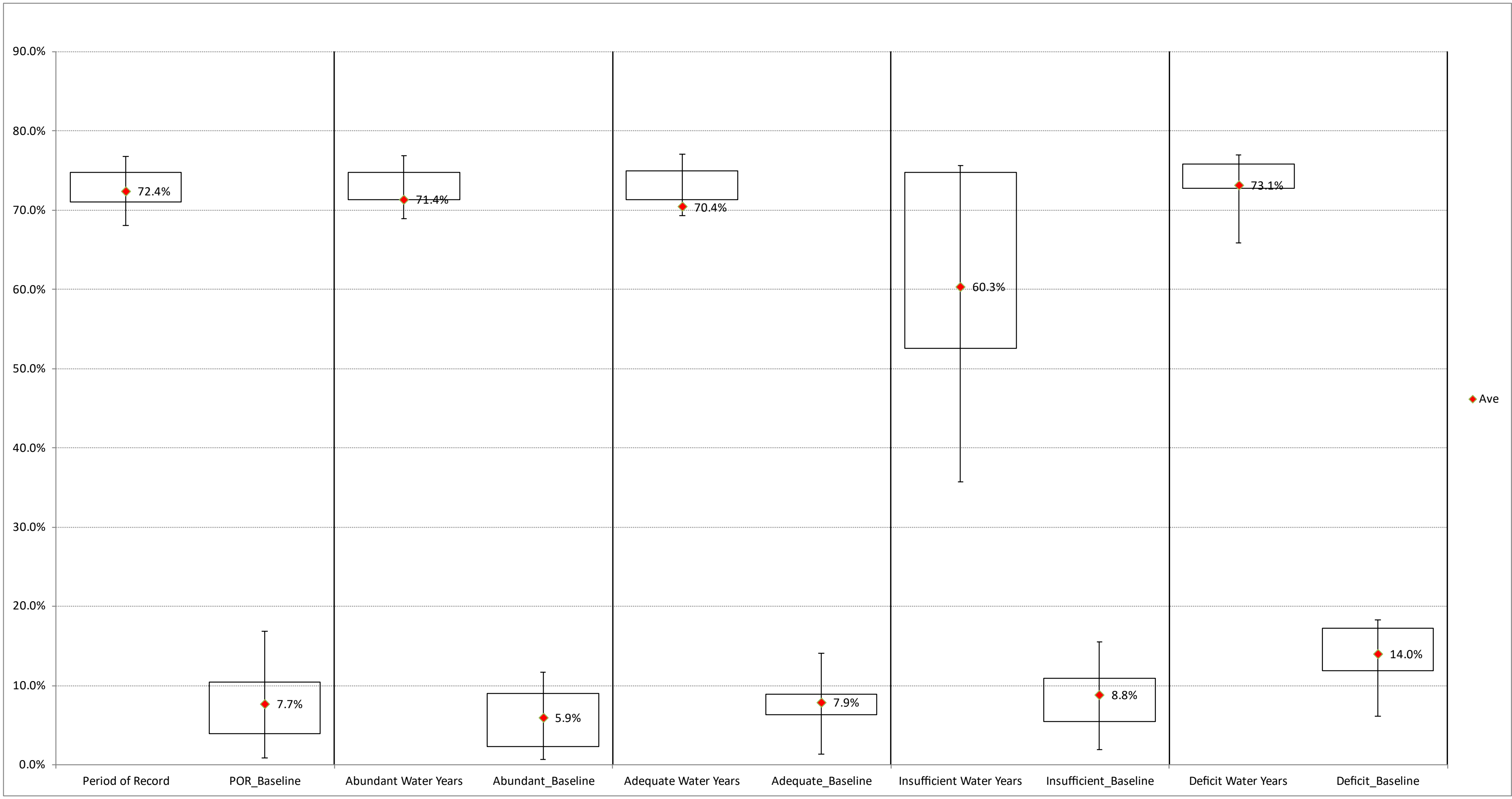

Figure 2-103. Hills Creek Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.8 STEELHEAD NO ACTION ALTERNATIVE (NAA OR BASELINE)

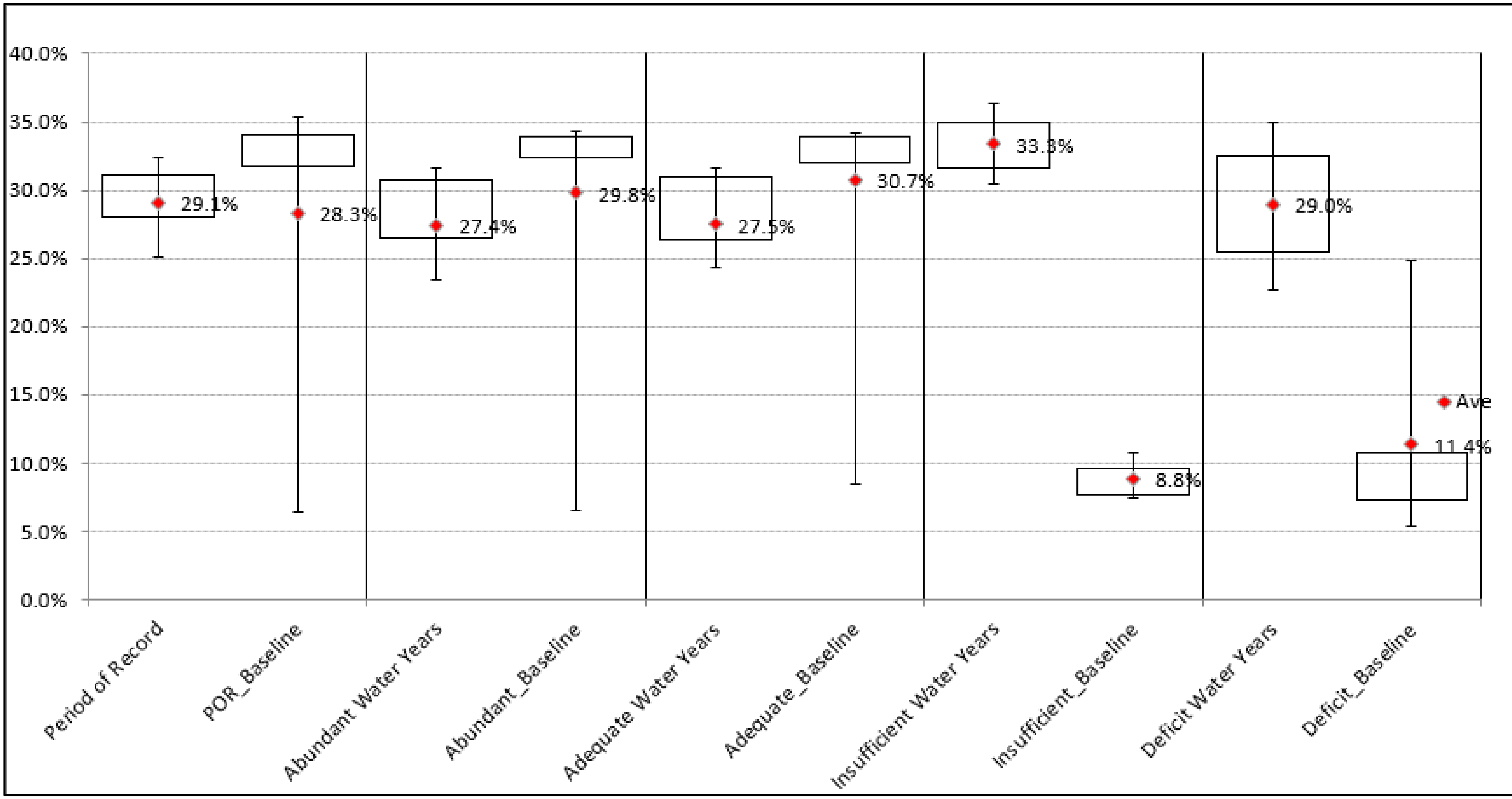

Figure 2-104. Detroit Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under the NAA. *Downstream dam passage survival at Detroit for juvenile winter steelhead sub-yearlings under the NAA. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

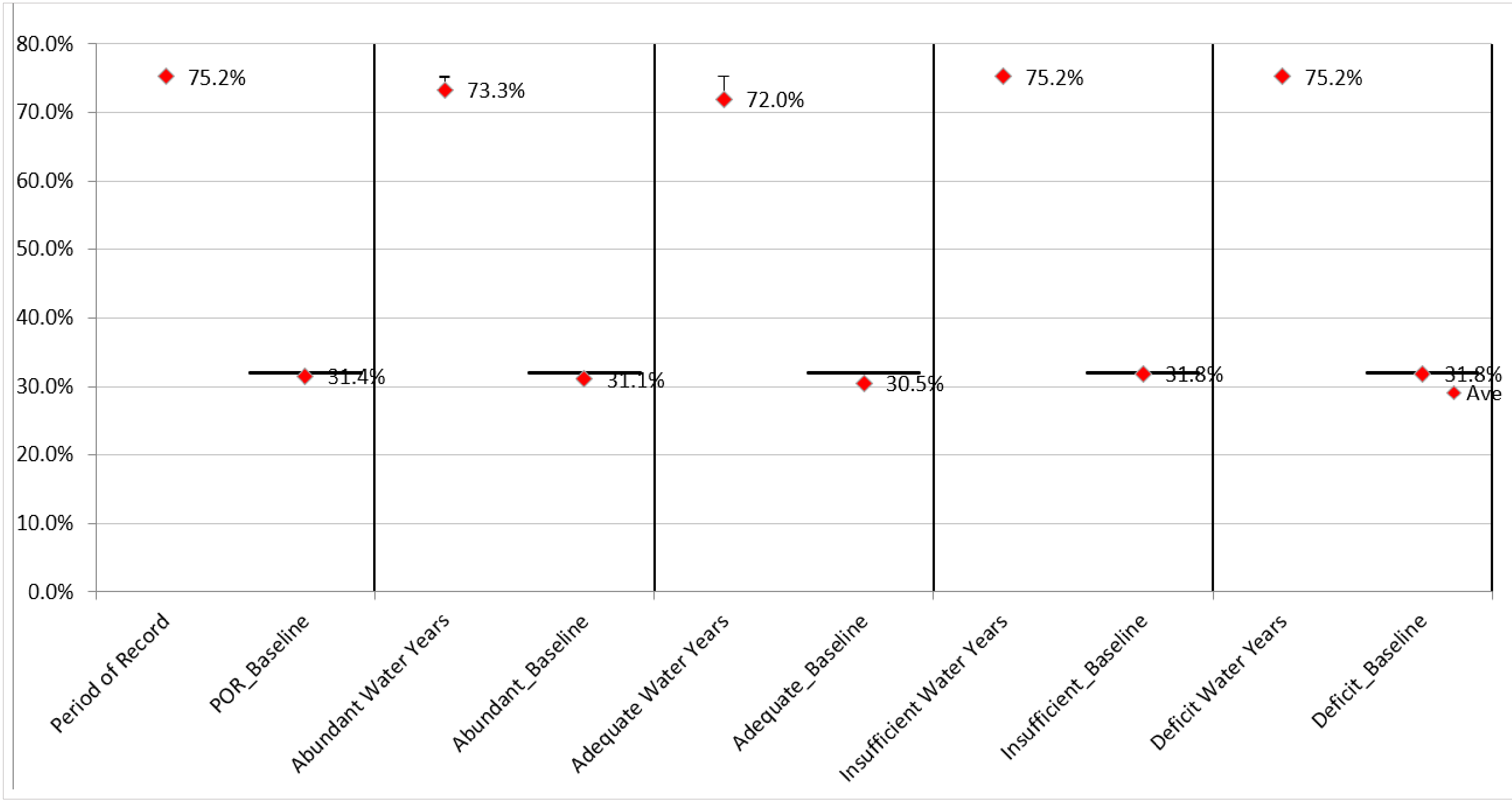

Figure 2-105. Detroit Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under the NAA. *The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

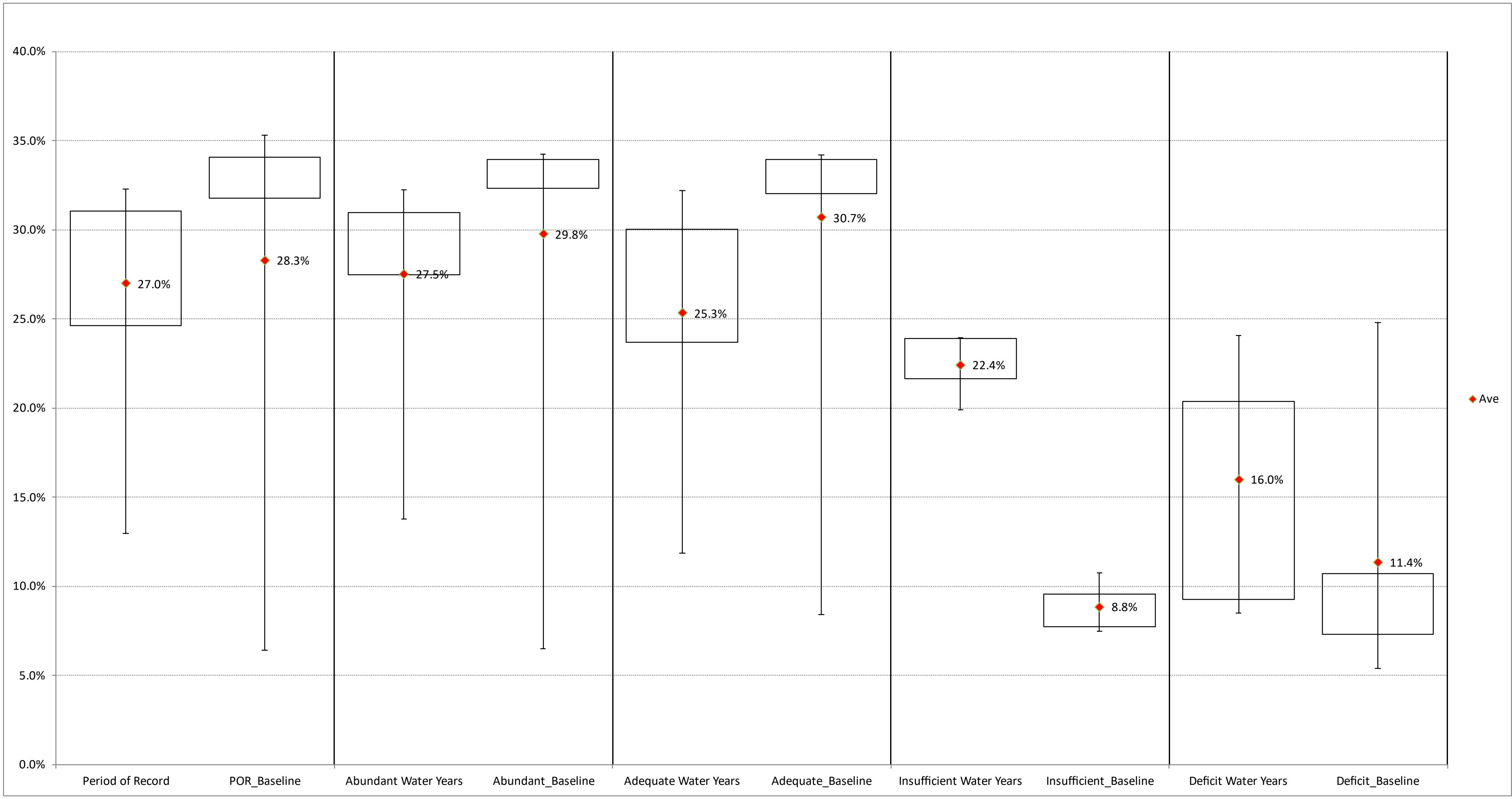

Figure 2-106. Detroit For 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival At Under the NAA.
Downstream dam passage survival at Detroit for juvenile winter steelhead 2 year olds under the NAA. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.

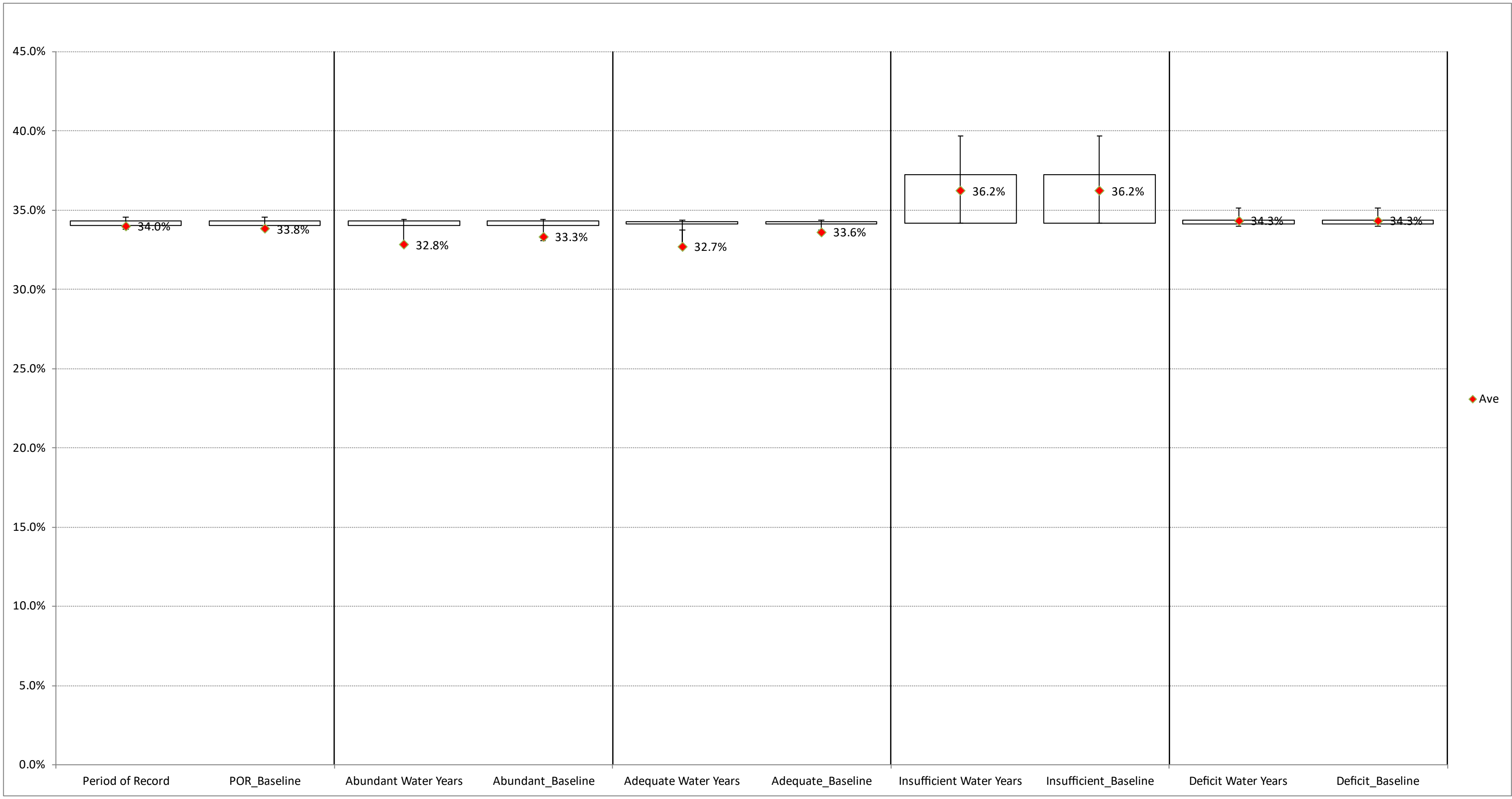

Figure 2-107. Foster Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under the NAA. *Downstream dam passage survival at Foster for juvenile winter steelhead sub-yearlings under the NAA. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

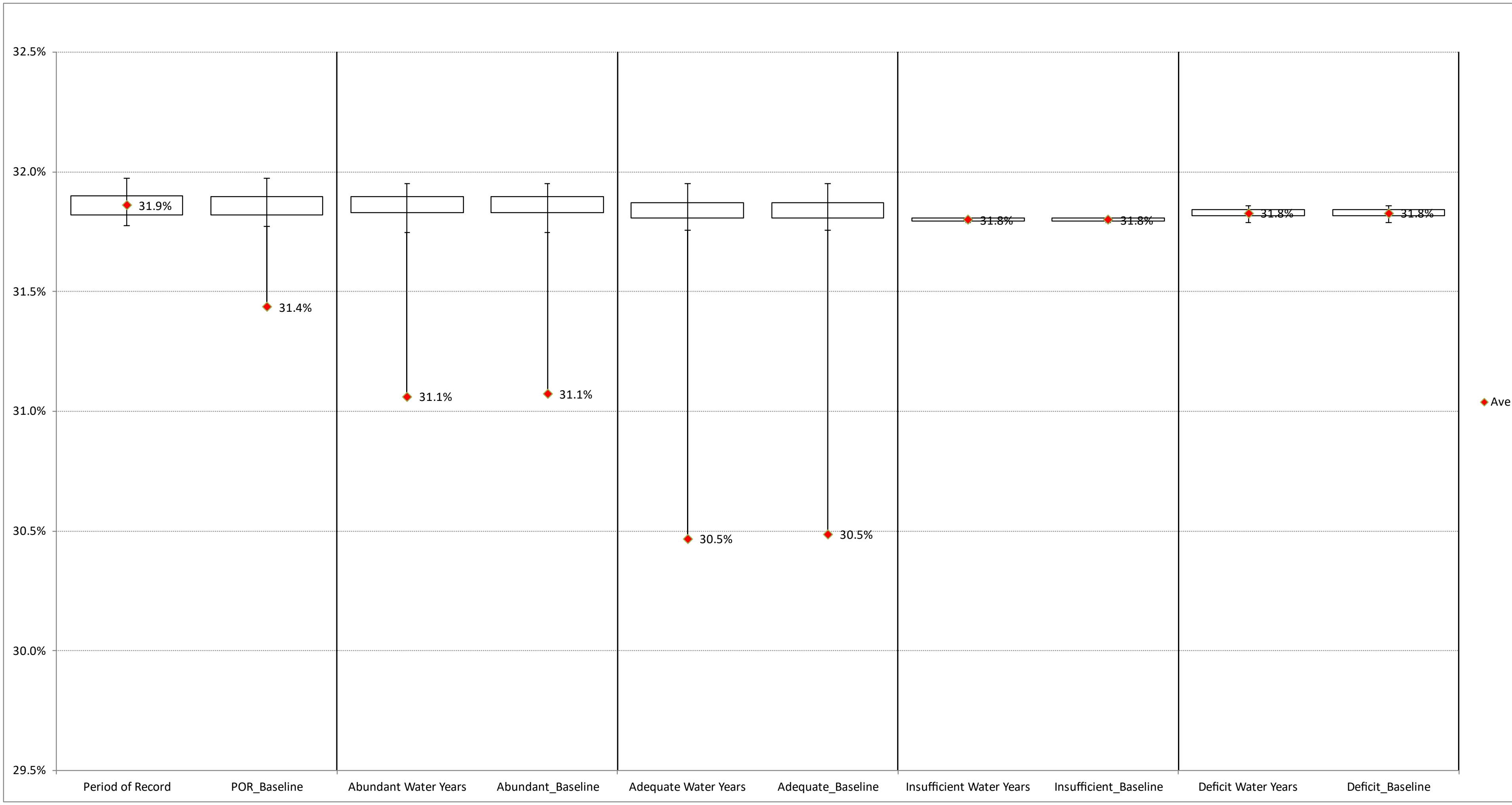

Figure 2-108. Foster Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under the NAA. *Downstream dam passage survival at Foster for juvenile winter steelhead yearlings under the NAA. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

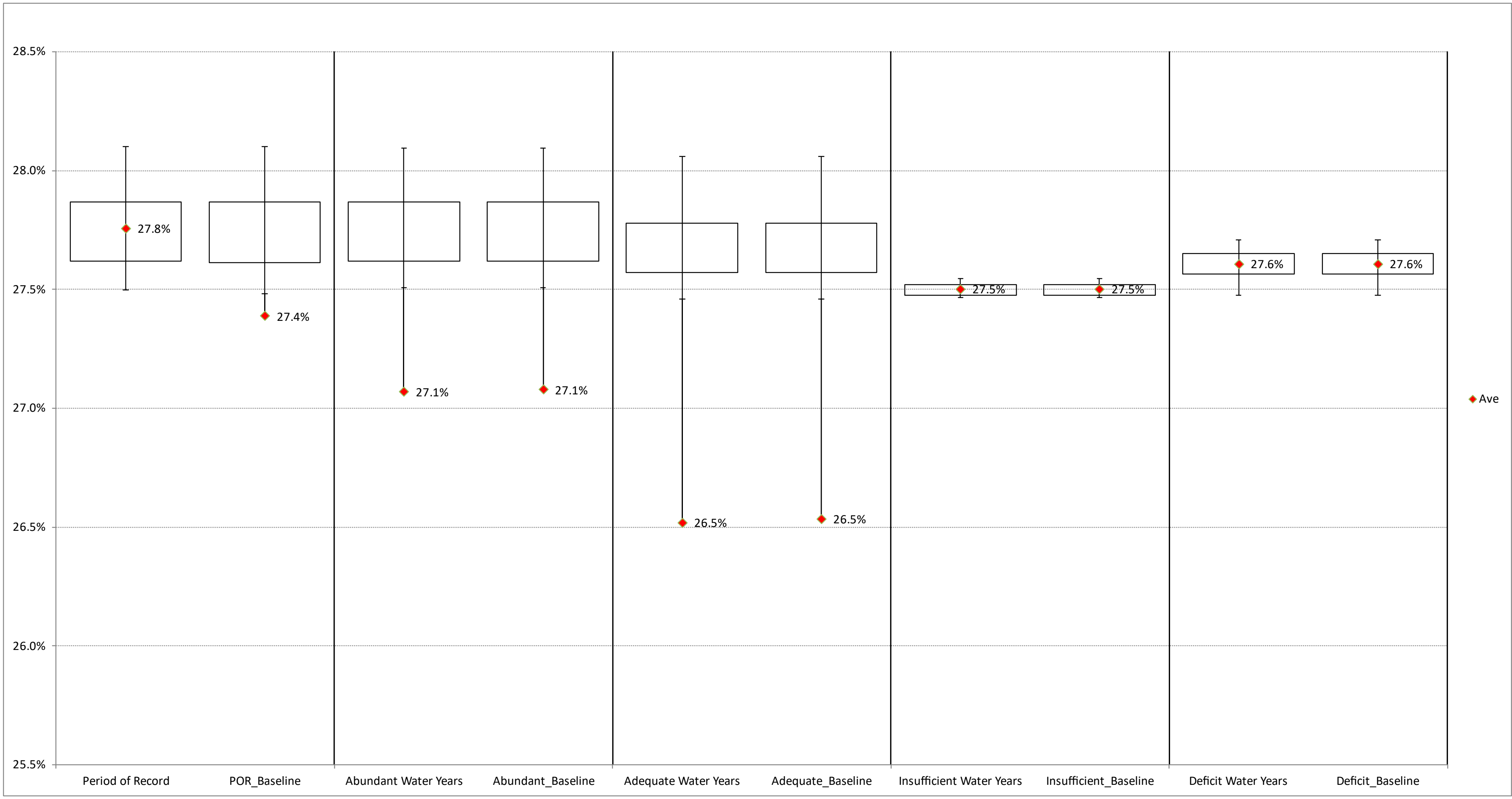

Figure 2-109. Foster 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival Under the NAA. *Downstream dam passage survival at Foster for juvenile winter steelhead 2 year olds under the NAA. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.9 STEELHEAD ALTERNATIVE 1

2.9.1 South Santiam – Foster

Figure 2-110. Foster Juvenile Winter Steelhead Sub-Yearlings Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Foster for juvenile winter steelhead sub-yearlings under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

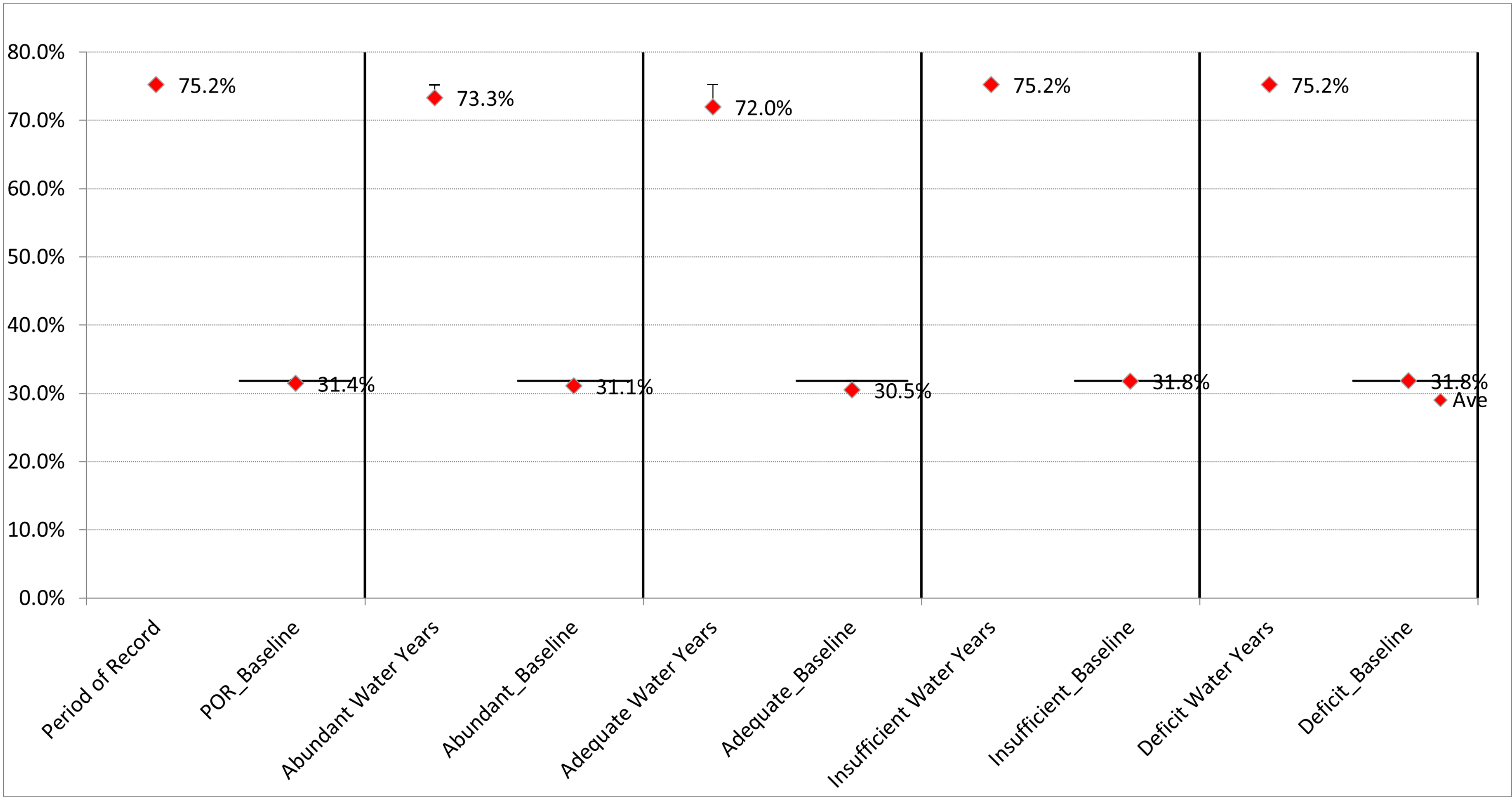

Figure 2-111. Foster Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Foster for juvenile winter steelhead yearlings under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

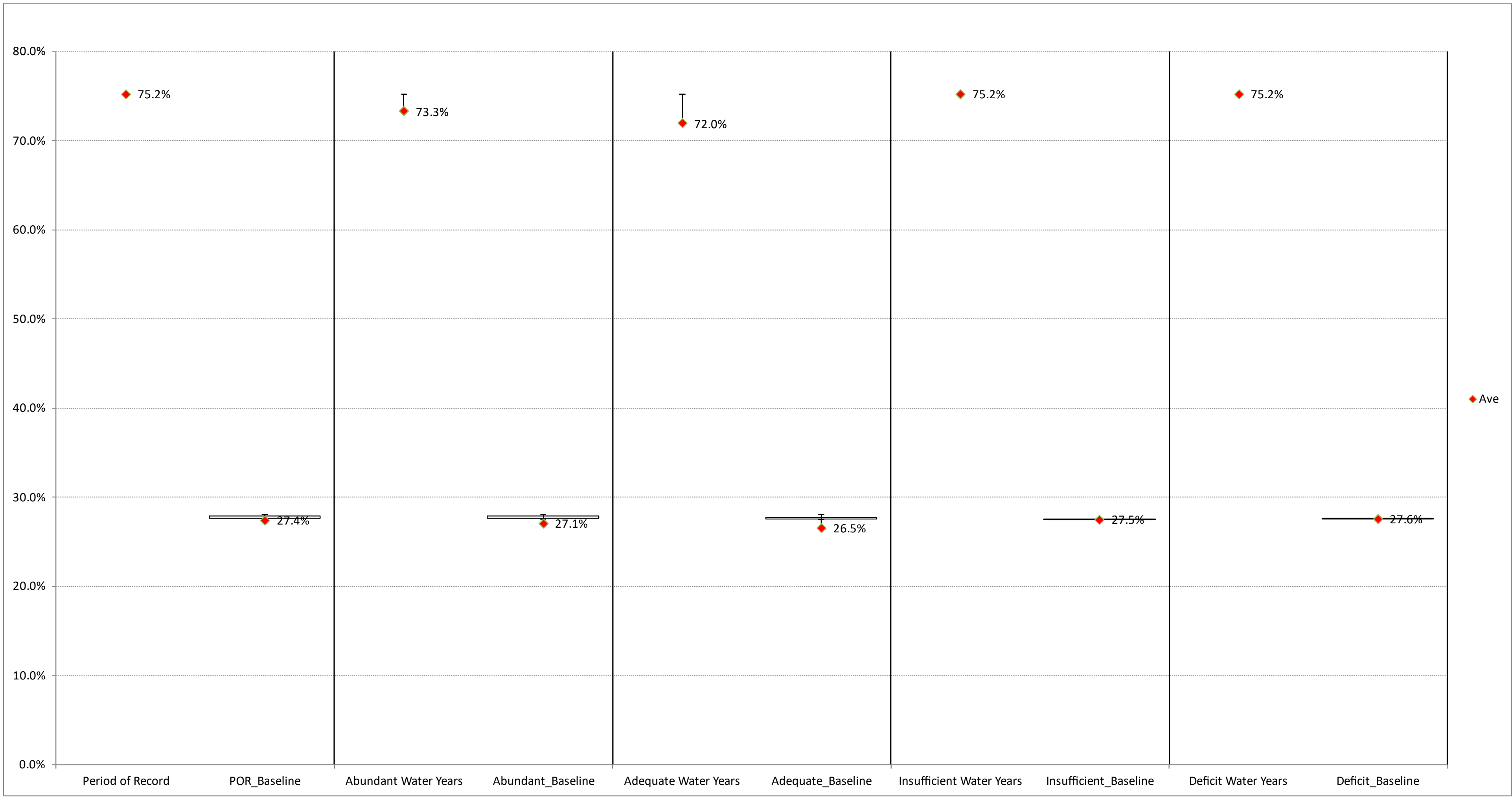

Figure 2-112. Foster 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Foster for juvenile winter steelhead 2 year olds under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.9.2 South Santiam – Green Peter

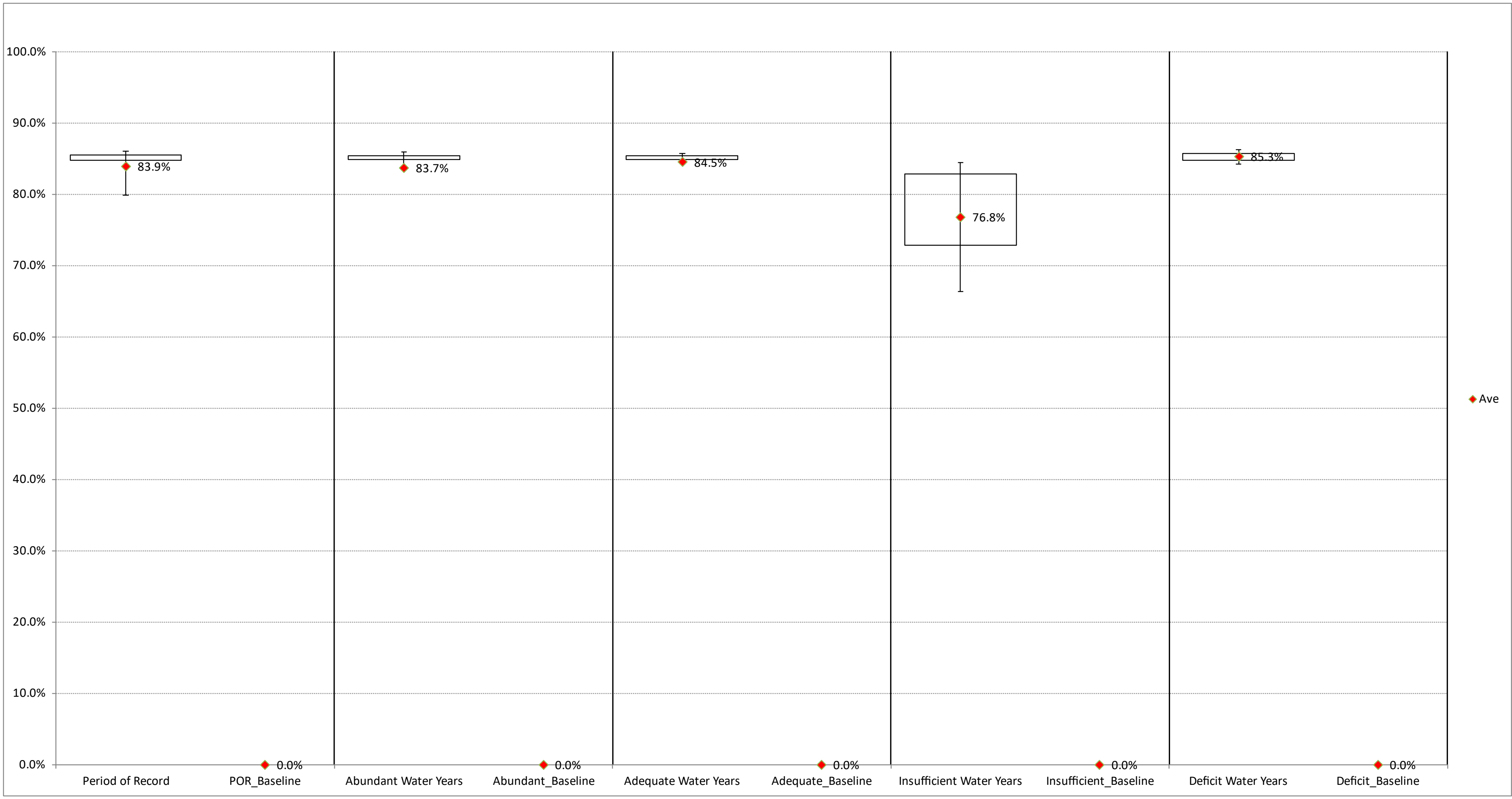

Figure 2-113. Green Peter Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Green Peter for juvenile winter steelhead sub-yearlings under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

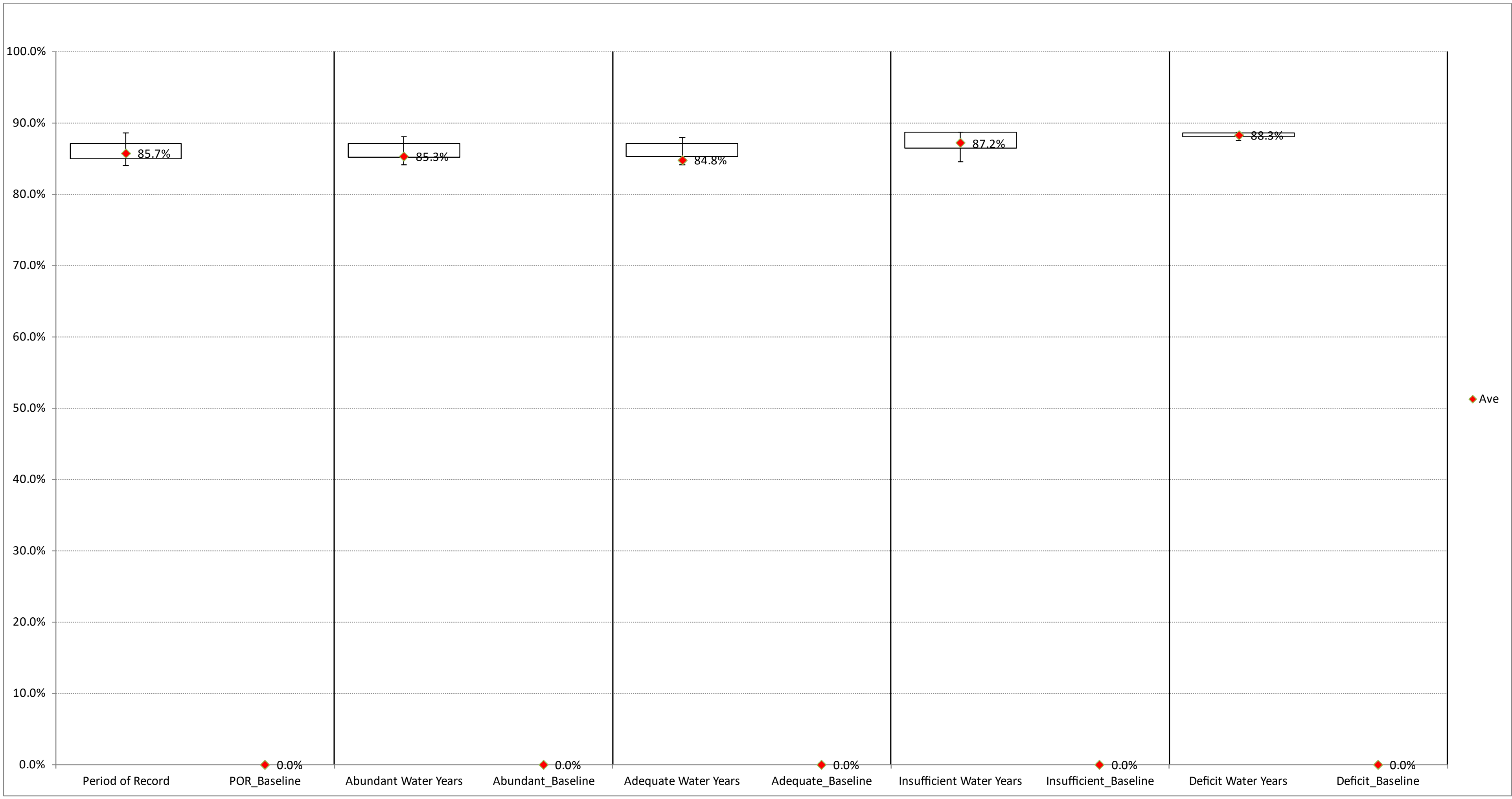

Figure 2-114. Green Peter Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Green Peter for juvenile winter steelhead yearlings under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

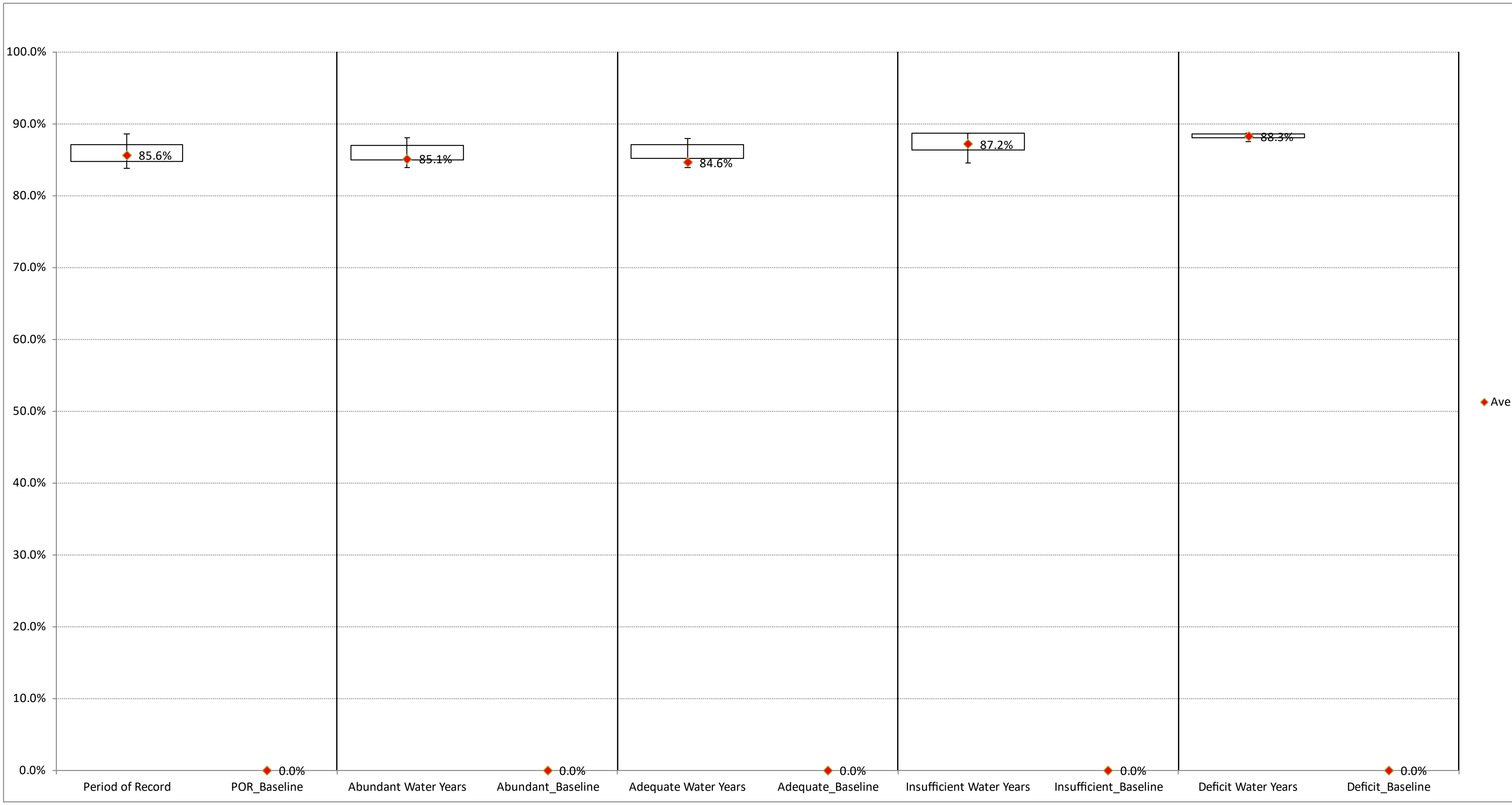

Figure 2-115. Green Peter 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Green Peter for juvenile winter steelhead 2 year olds under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.10 STEELHEAD ALTERNATIVE 2A AND ALTERNATIVE 2B

2.10.1 North Santiam - Detroit

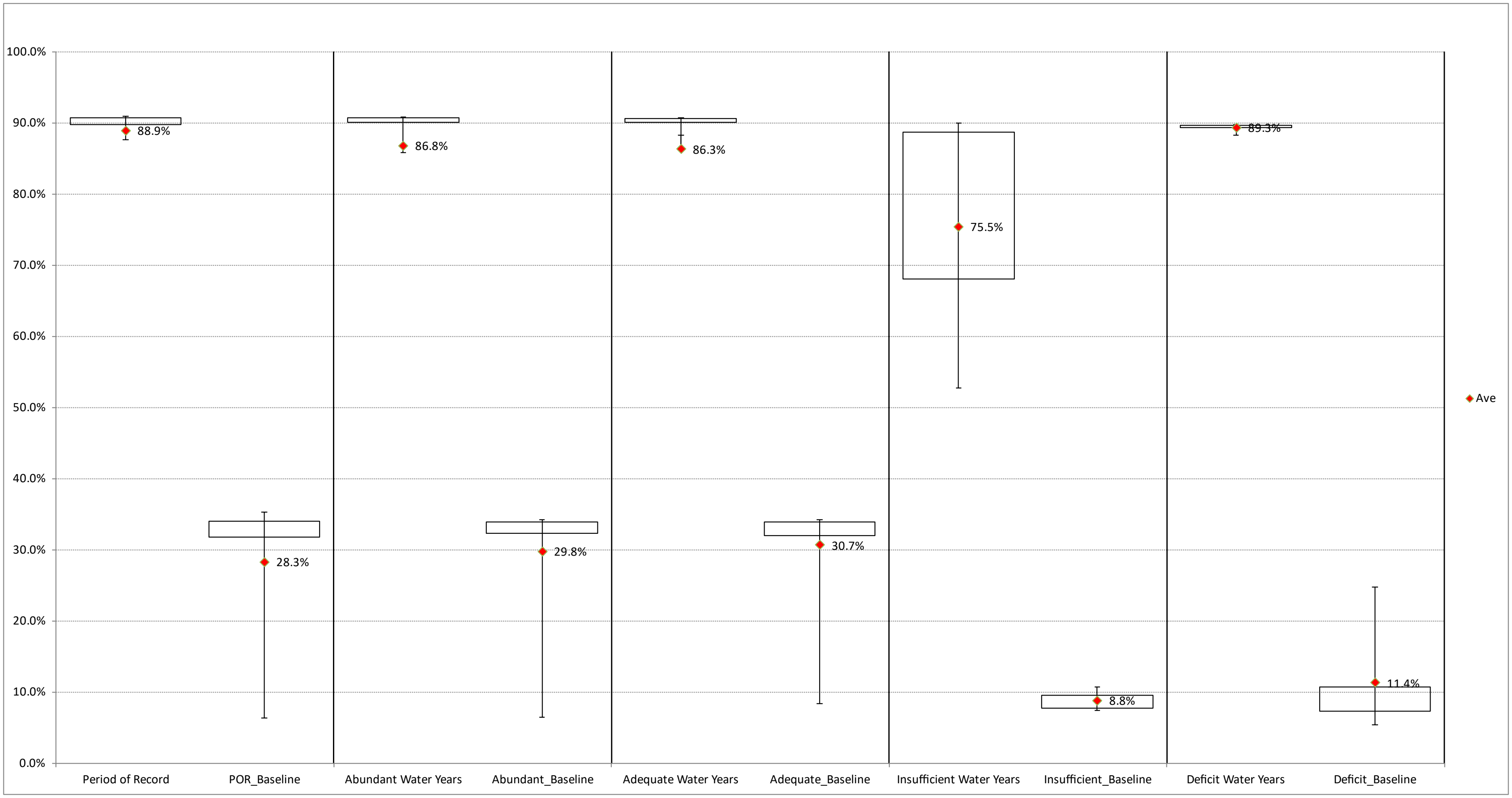

Figure 2-116. Detroit Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under Alternative 2a and 2b. *Downstream dam passage survival at Detroit for juvenile winter steelhead sub-yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

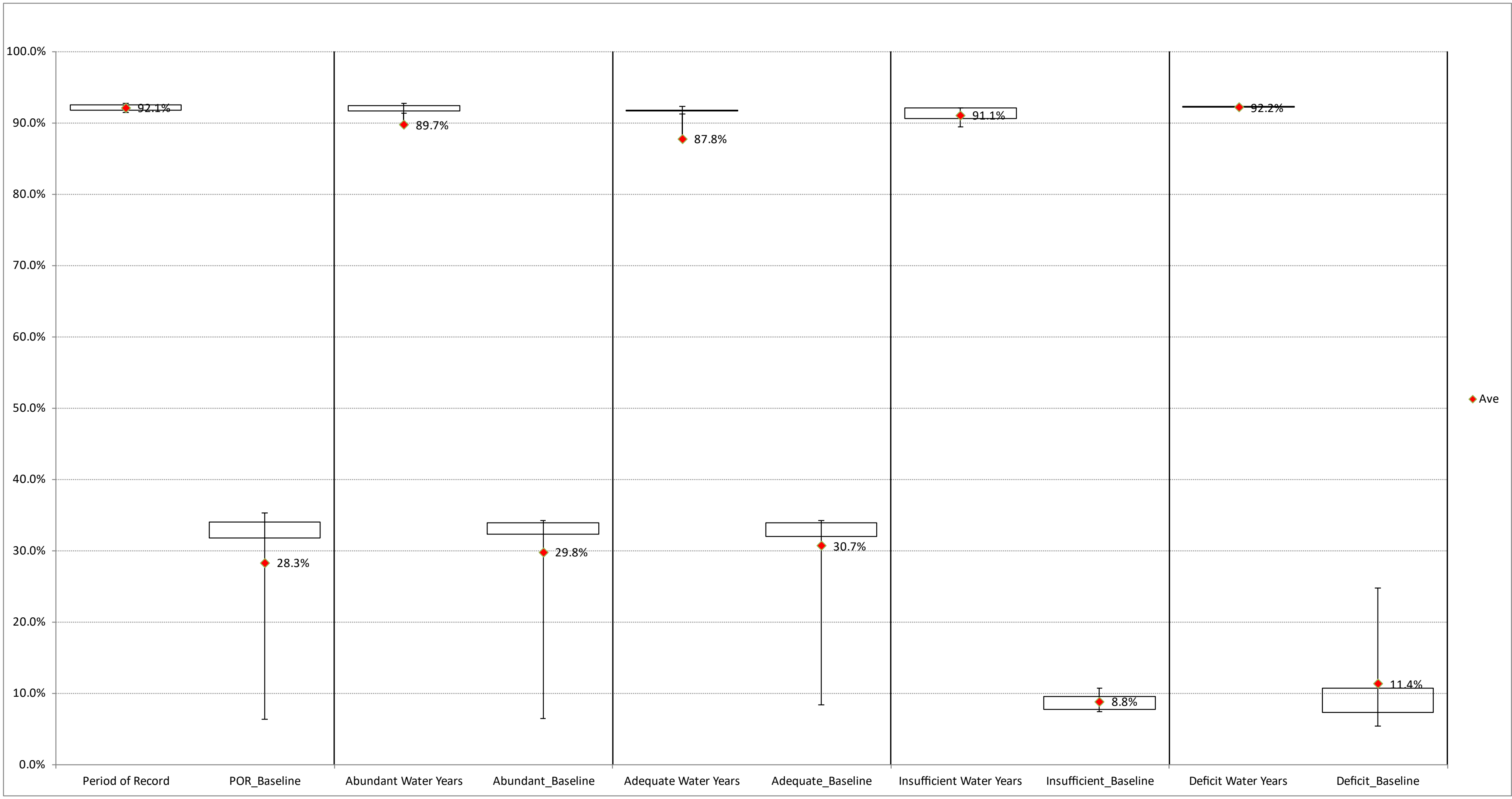

Figure 2-117. Detroit Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 2a and 2b. *Downstream dam passage survival at Detroit for juvenile winter steelhead yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

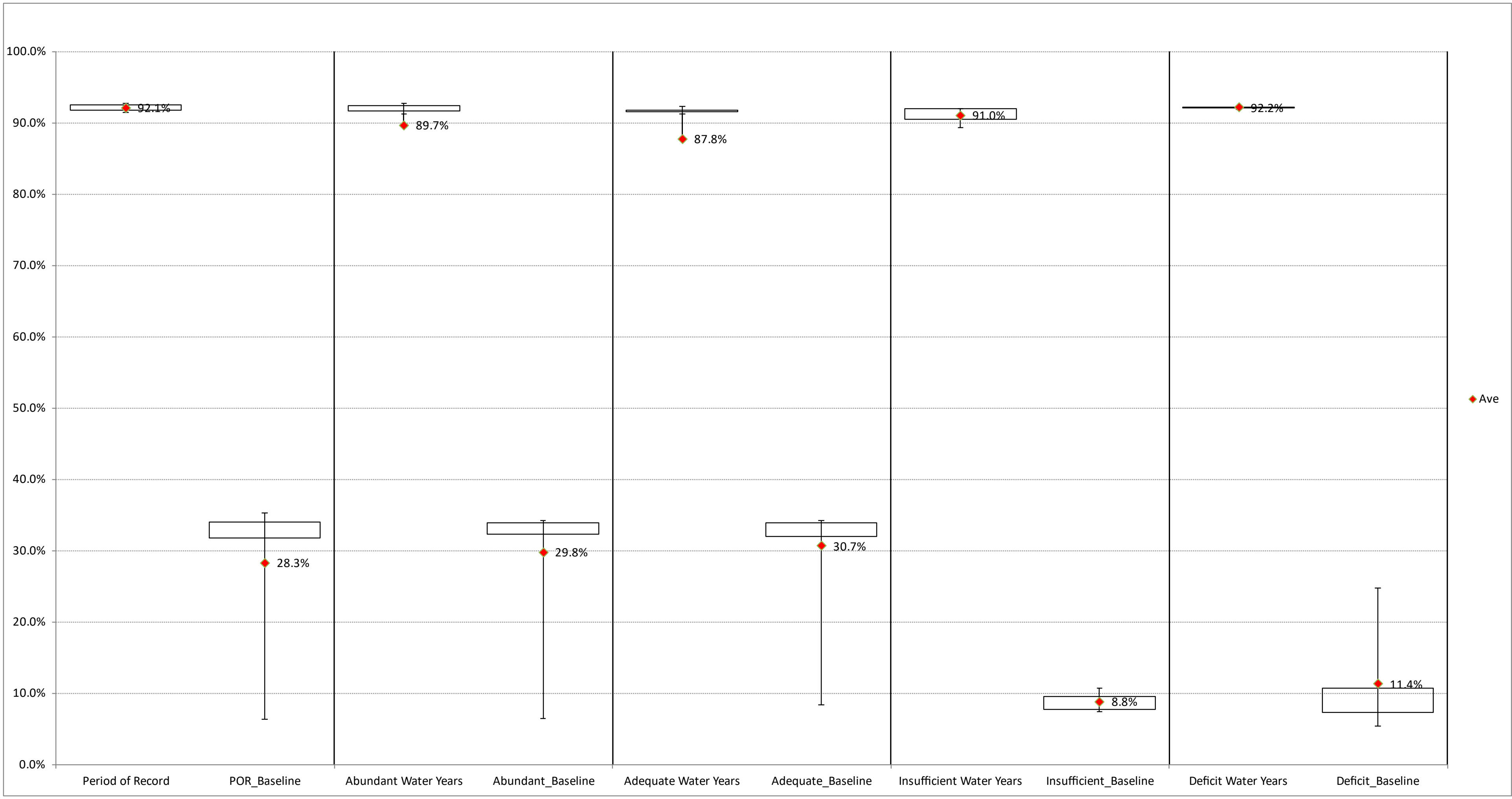

Figure 2-118. Detroit 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival Under Alternative 2a and 2b. *Downstream dam passage survival at Detroit for juvenile winter steelhead 2 year olds under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.10.2 South Santiam – Foster

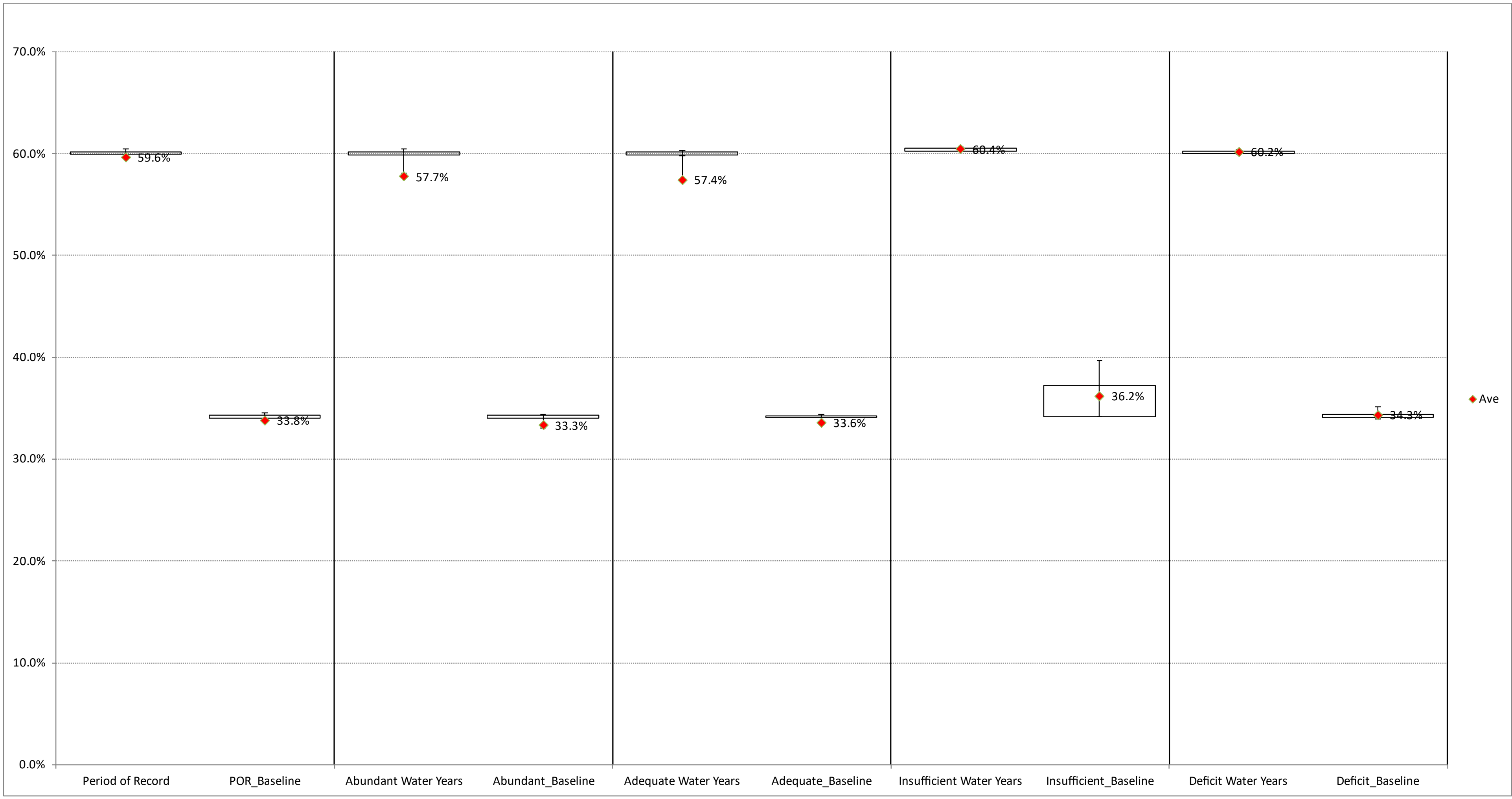

Figure 2-119. Foster Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under Alternative 2a and 2b. *Downstream dam passage survival at Foster for juvenile winter steelhead sub-yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

Figure 2-120. Foster Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 2a and 2b. *Downstream dam passage survival at Foster for juvenile winter steelhead yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

Figure 2-121. Foster 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival Under Alternative 2a and 2b. *Downstream dam passage survival at Foster for juvenile winter steelhead 2 year olds under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.10.3 South Santiam – Green Peter

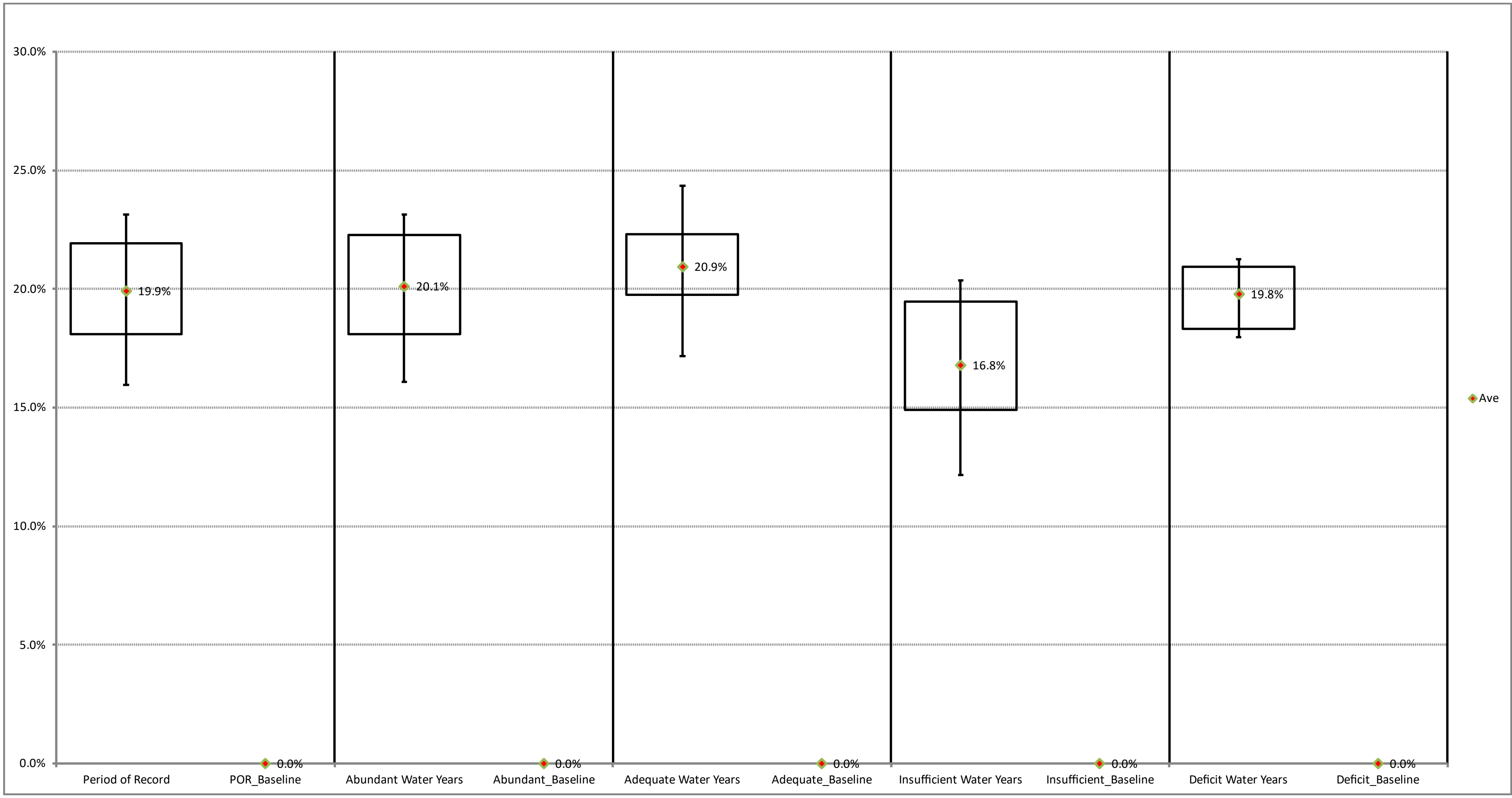

Figure 2-122. Green Peter Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under Alternative 2a and 2b. *Downstream dam passage survival at Green Peter for juvenile winter steelhead sub-yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

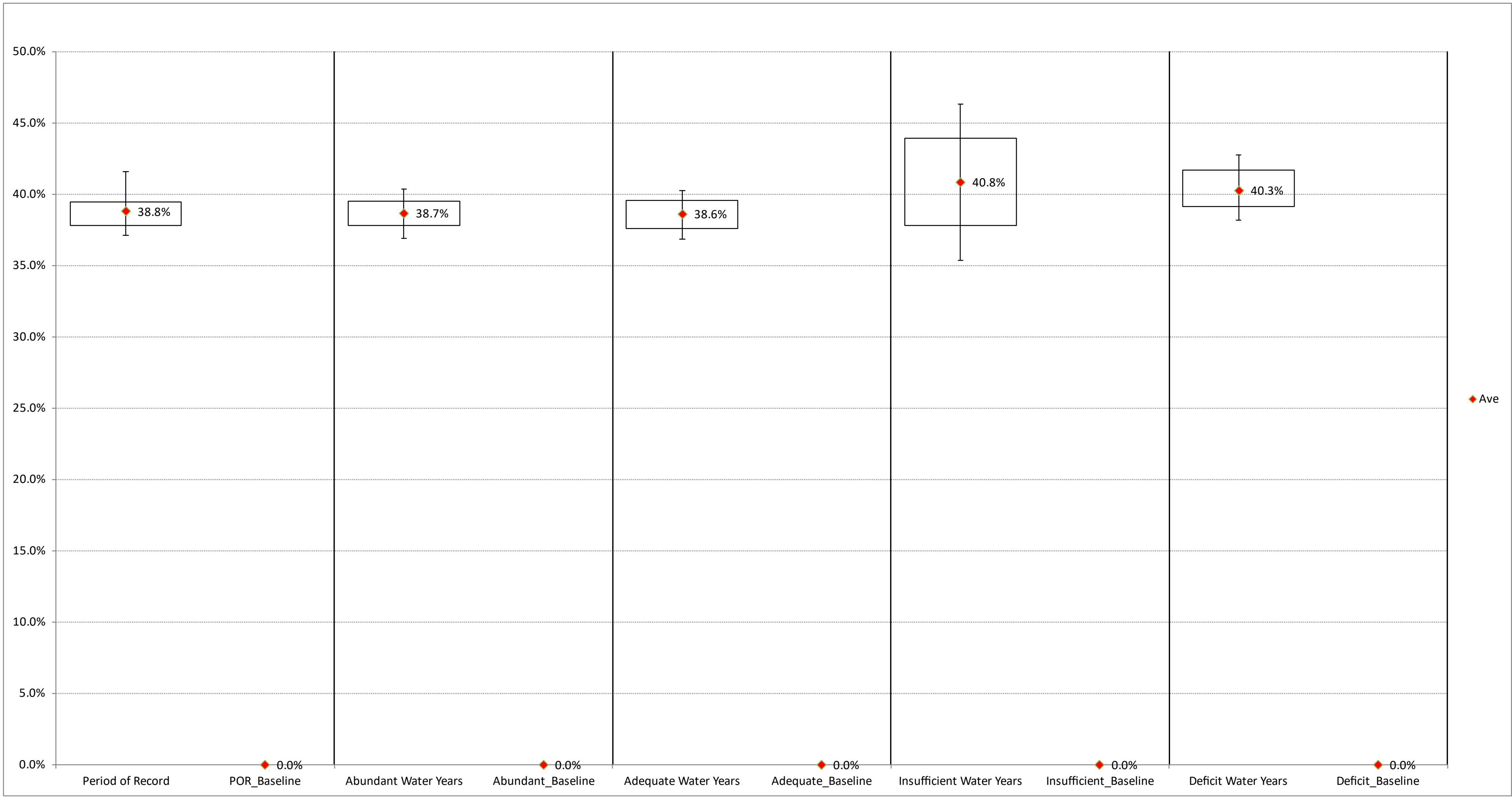

Figure 2-123. Green Peter Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 2a and 2b. *Downstream dam passage survival at Green Peter for juvenile winter steelhead yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

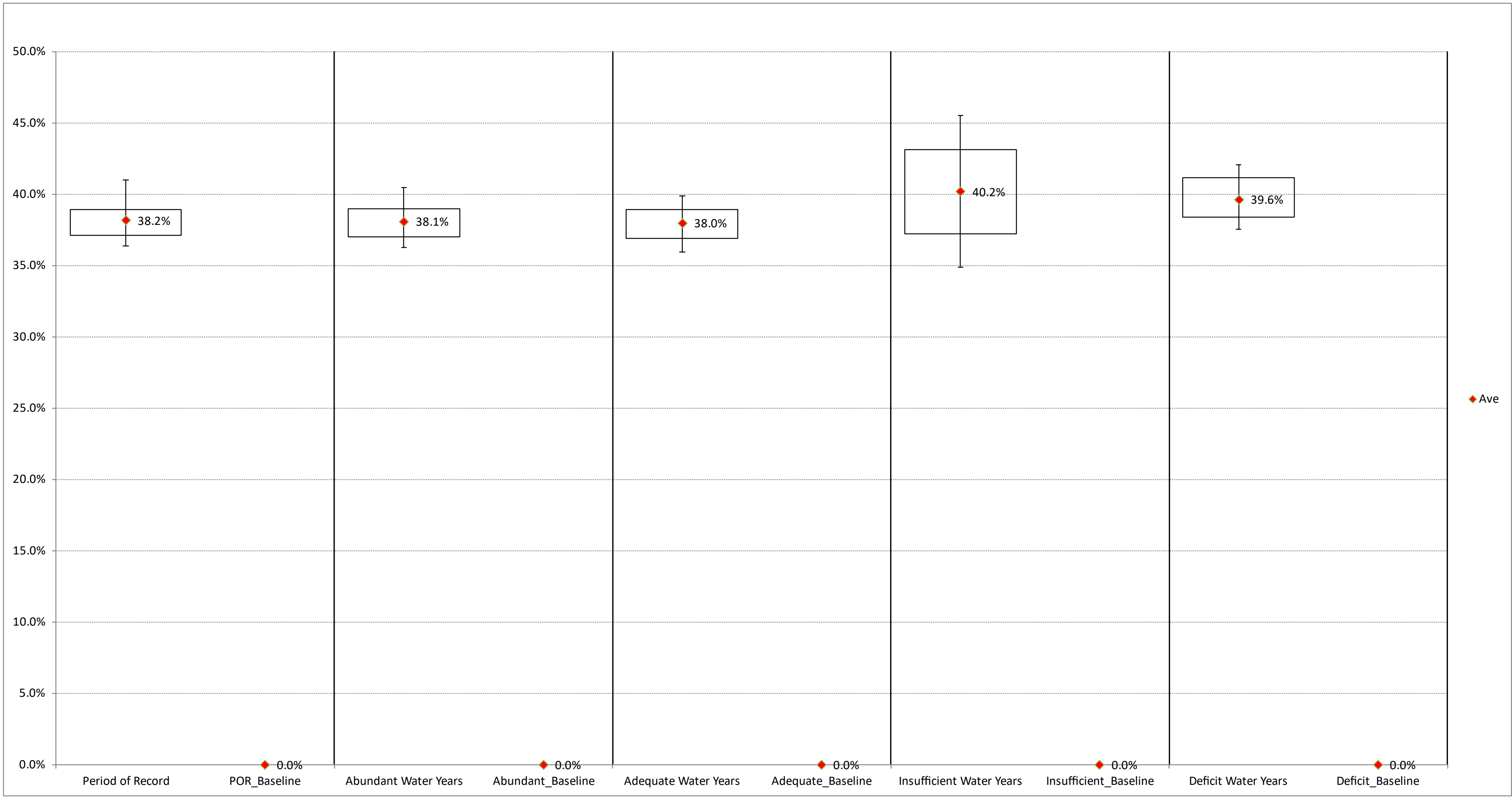

Figure 2-124. Green Peter 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival Under Alternative 2a and 2b. *Downstream dam passage survival at Detroit for juvenile winter steelhead 2 year olds under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.11 STEELHEAD ALTERNATIVE 3A

2.11.1 North Santiam – Detroit

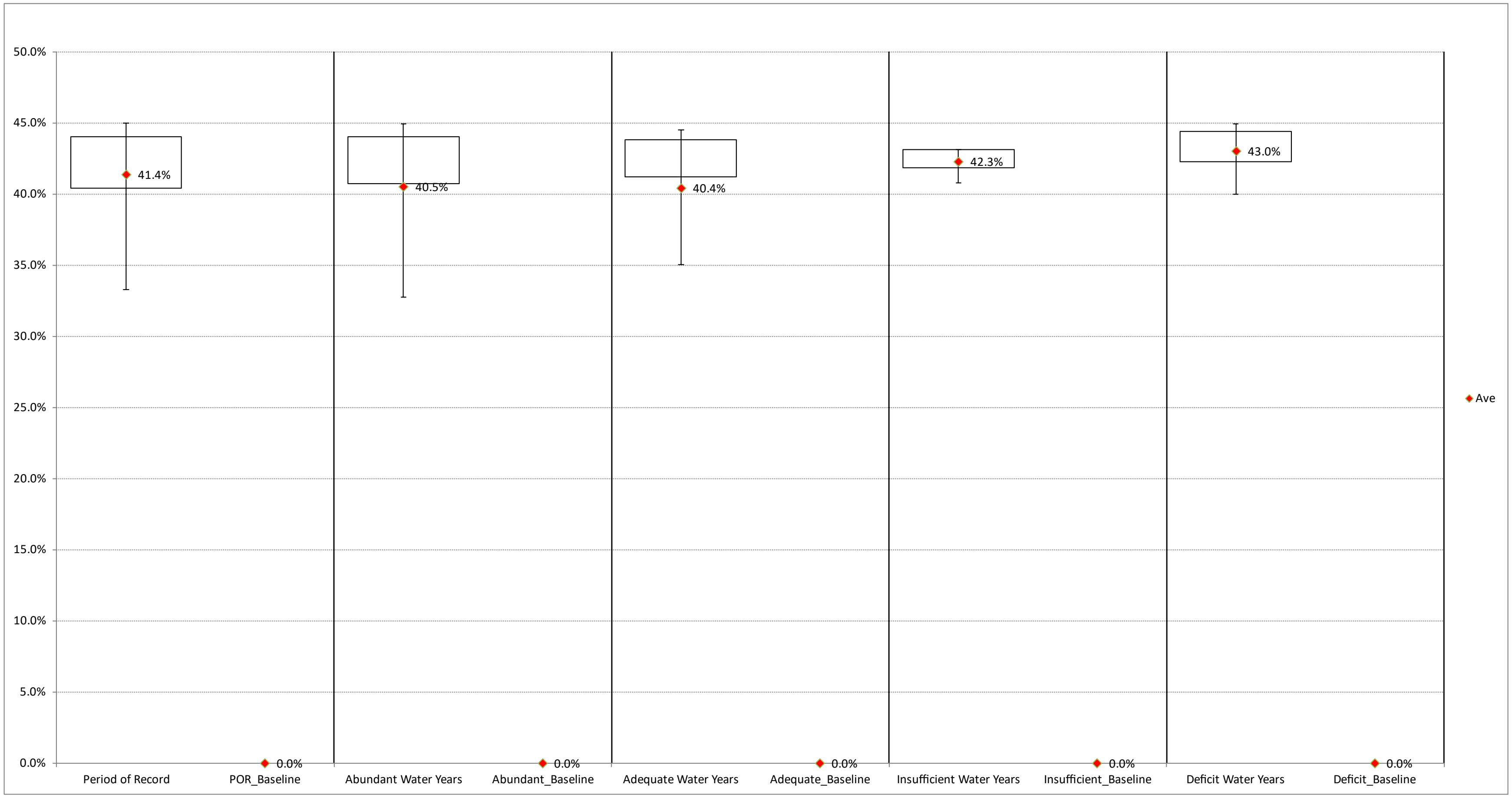

Figure 2-125. Detroit Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Detroit for juvenile winter steelhead sub-yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel*

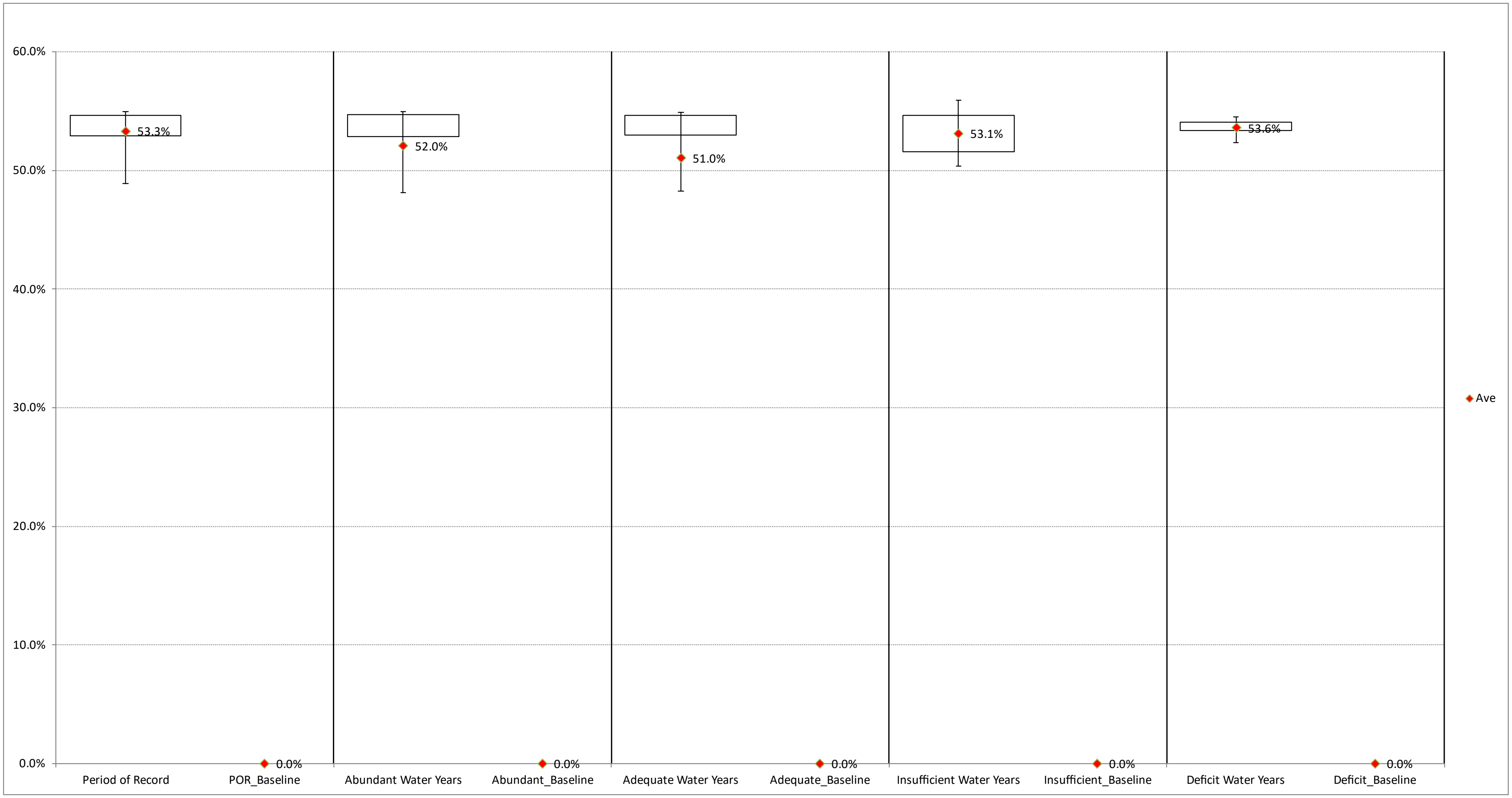

Figure 2-126. Detroit Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Detroit for juvenile winter steelhead yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

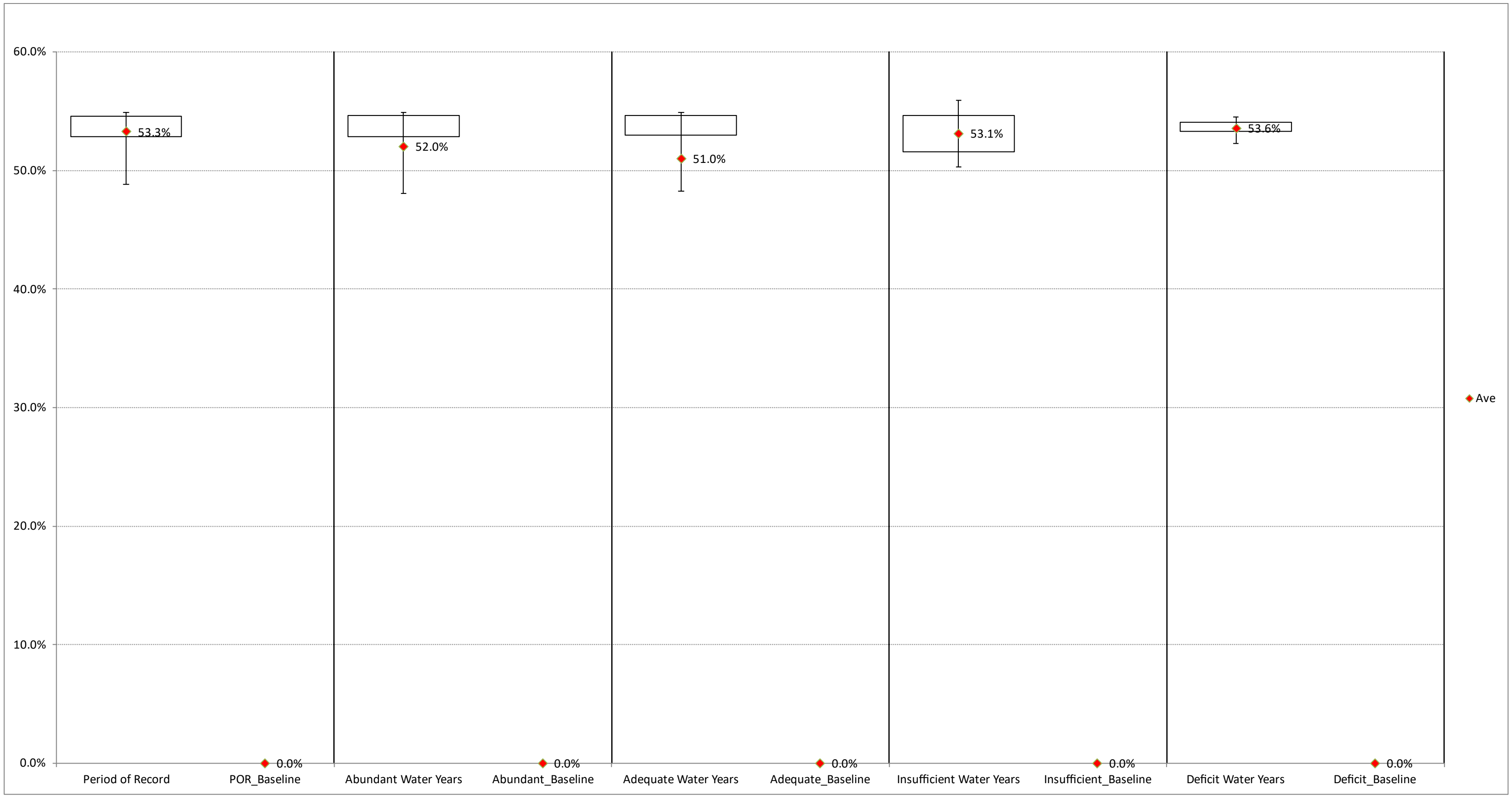

Figure 2-127. Detroit 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival Under Alternative 3a.
Downstream dam passage survival at Detroit for juvenile winter steelhead 2 year olds under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.

2.11.2 South Santiam – Foster

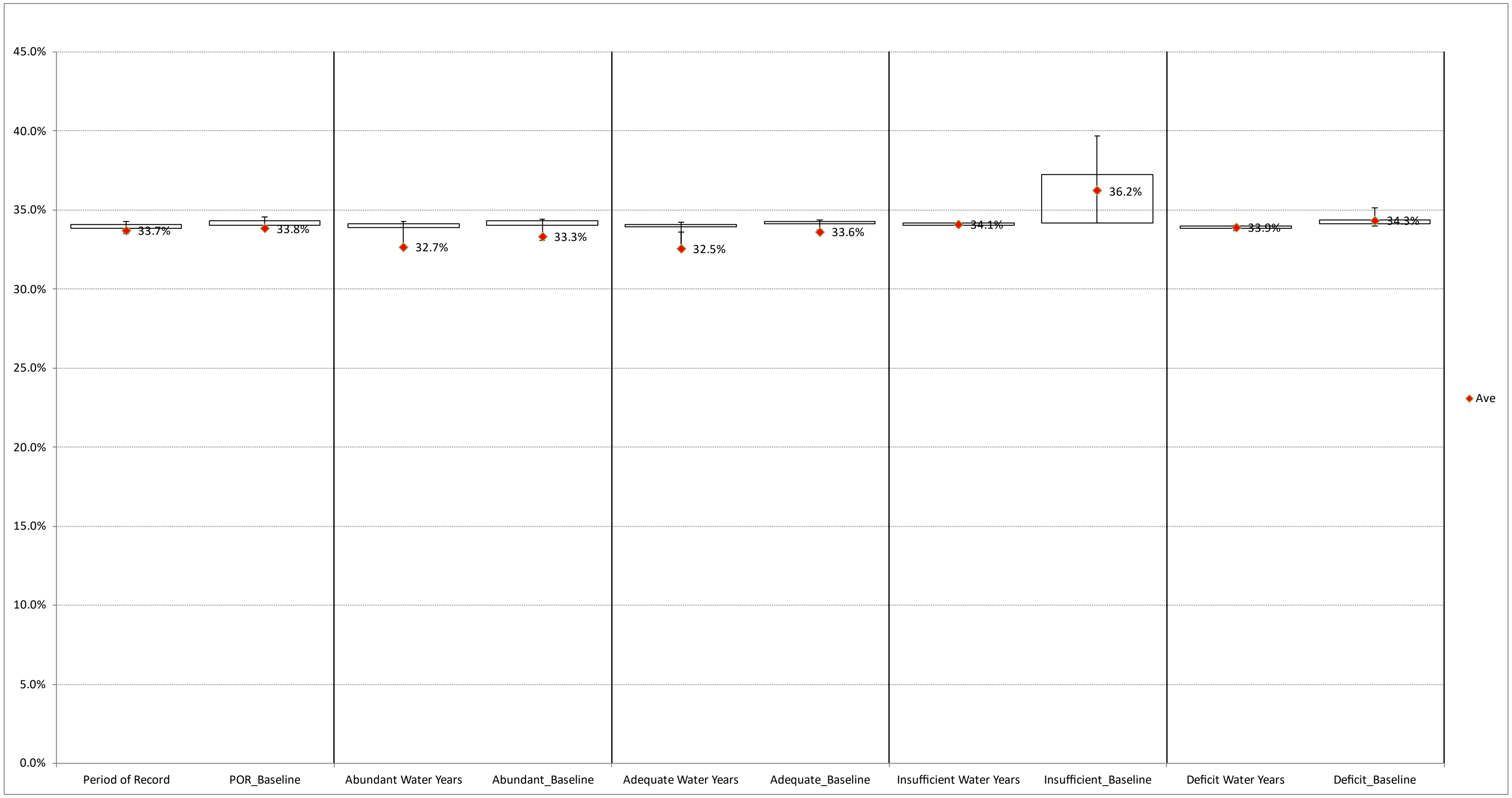

Figure 2-128. Foster Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Foster for juvenile winter steelhead sub-yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

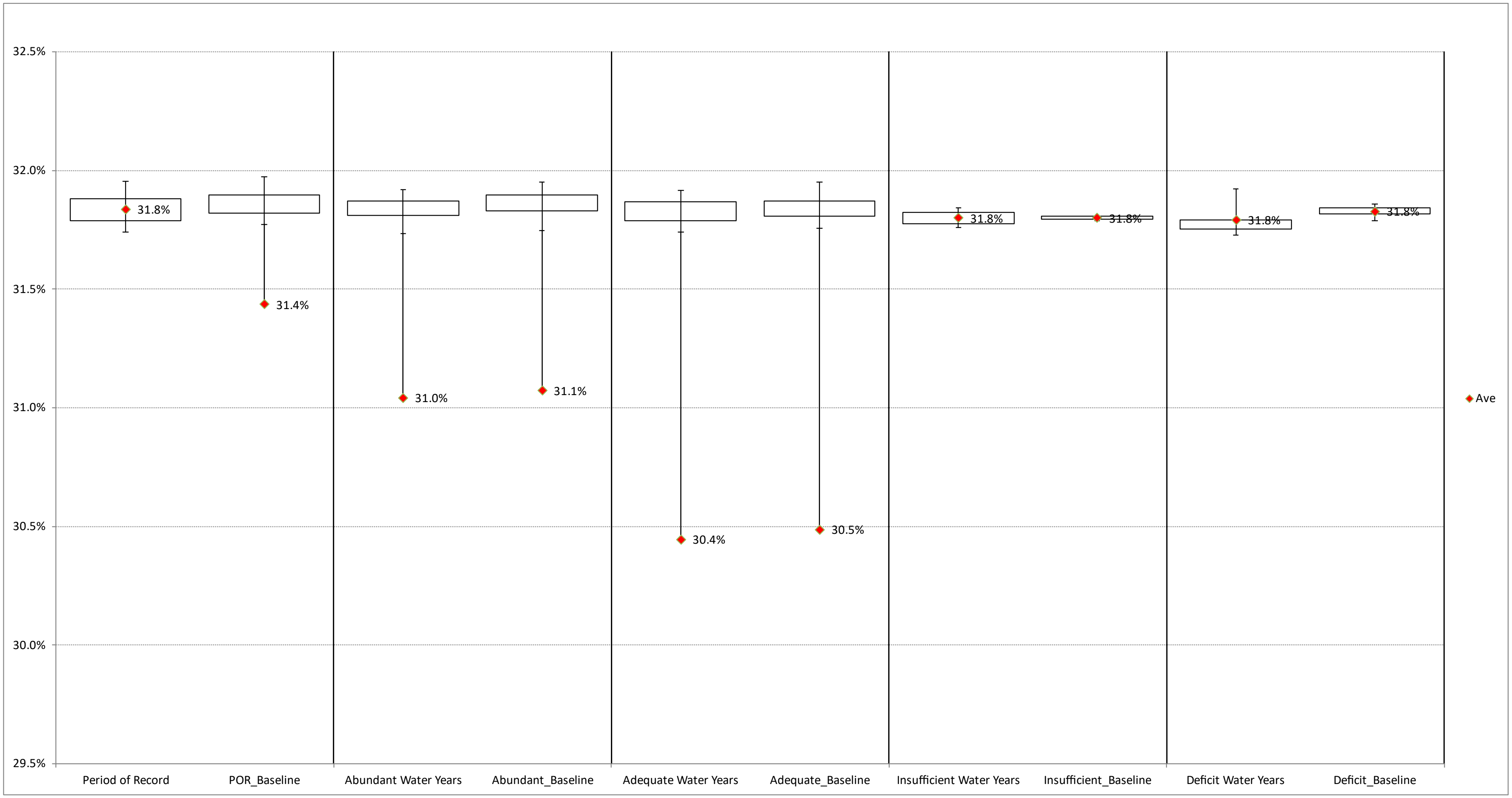

Figure 2-129. Foster Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Foster for juvenile winter steelhead yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

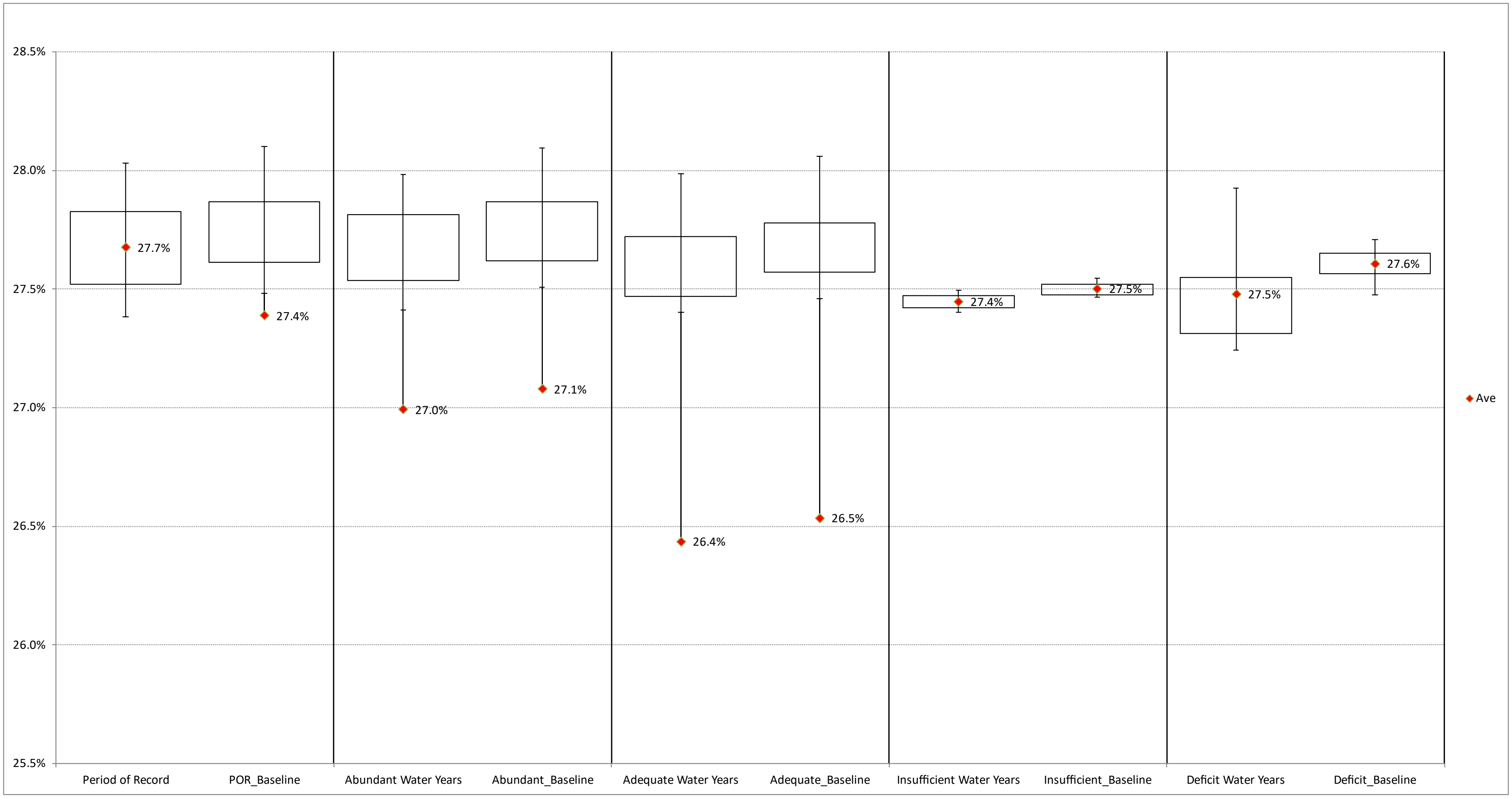

Figure 2-130. Foster Juvenile Winter Steelhead 2 Year Old Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Foster for juvenile winter steelhead 2 year olds under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.11.3 South Santiam – Green Peter

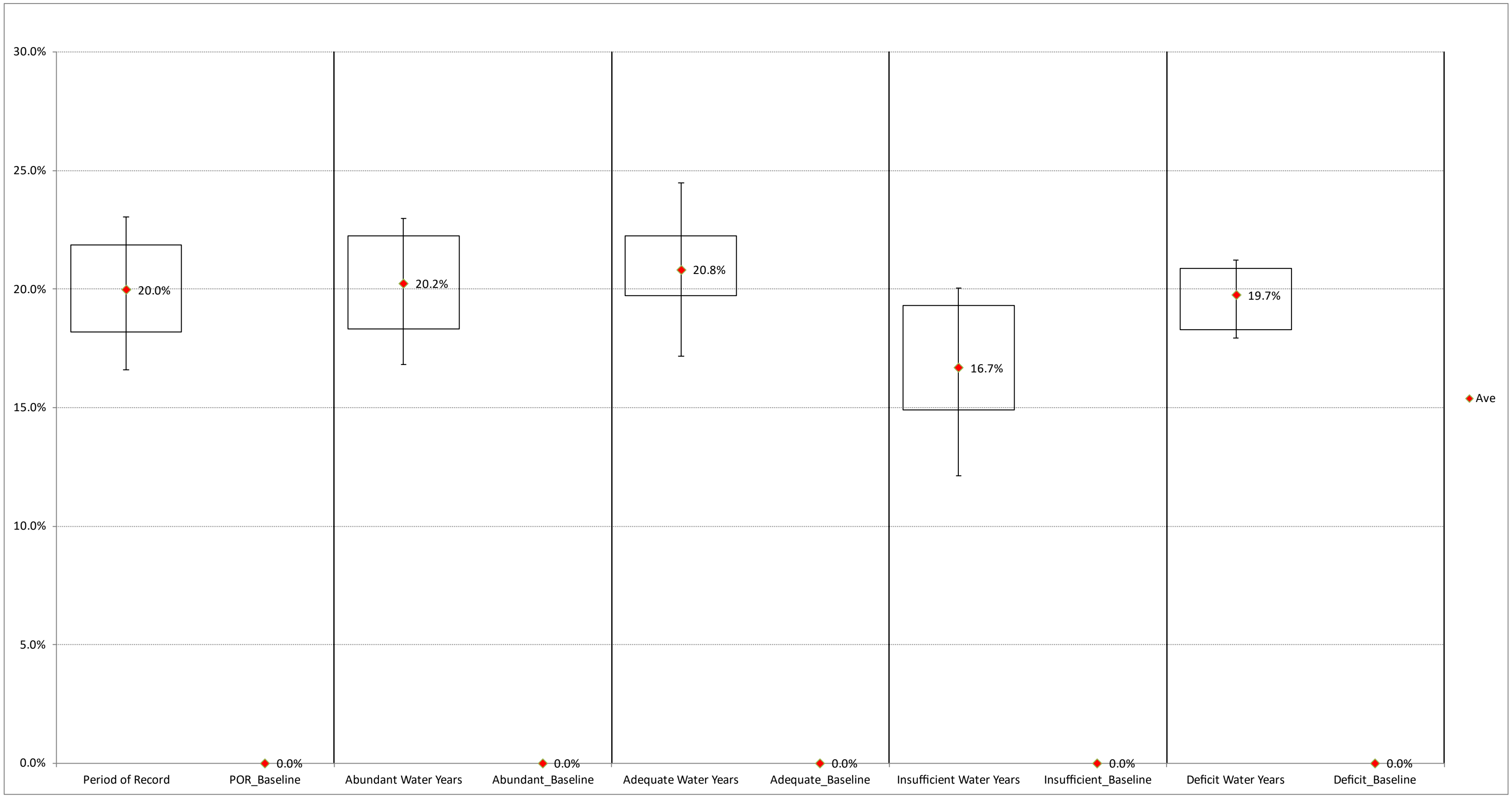

Figure 2-131. Green Peter Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Green Peter for juvenile winter steelhead sub-yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

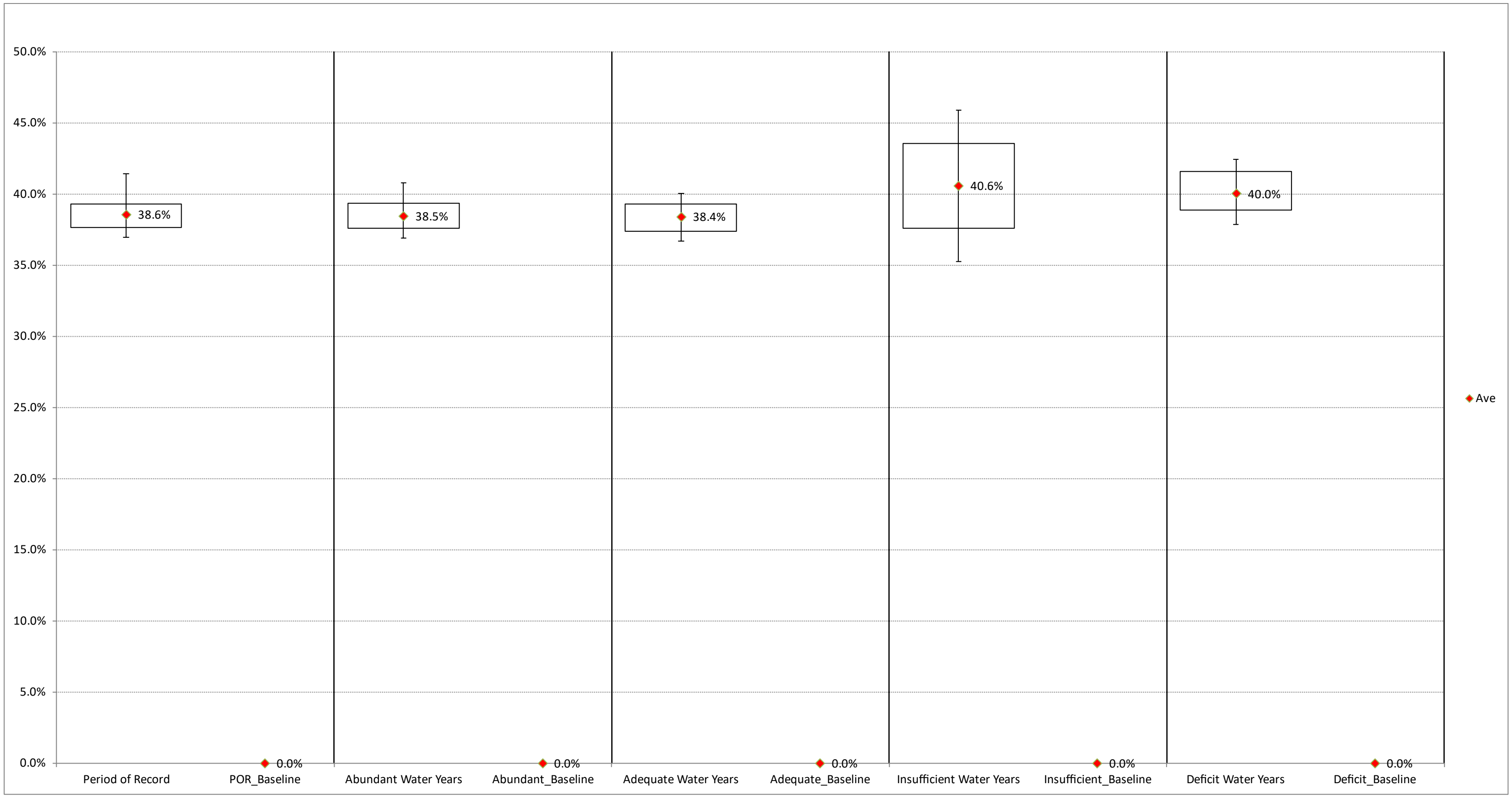

Figure 2-132. Green Peter Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Green Peter for juvenile winter steelhead yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

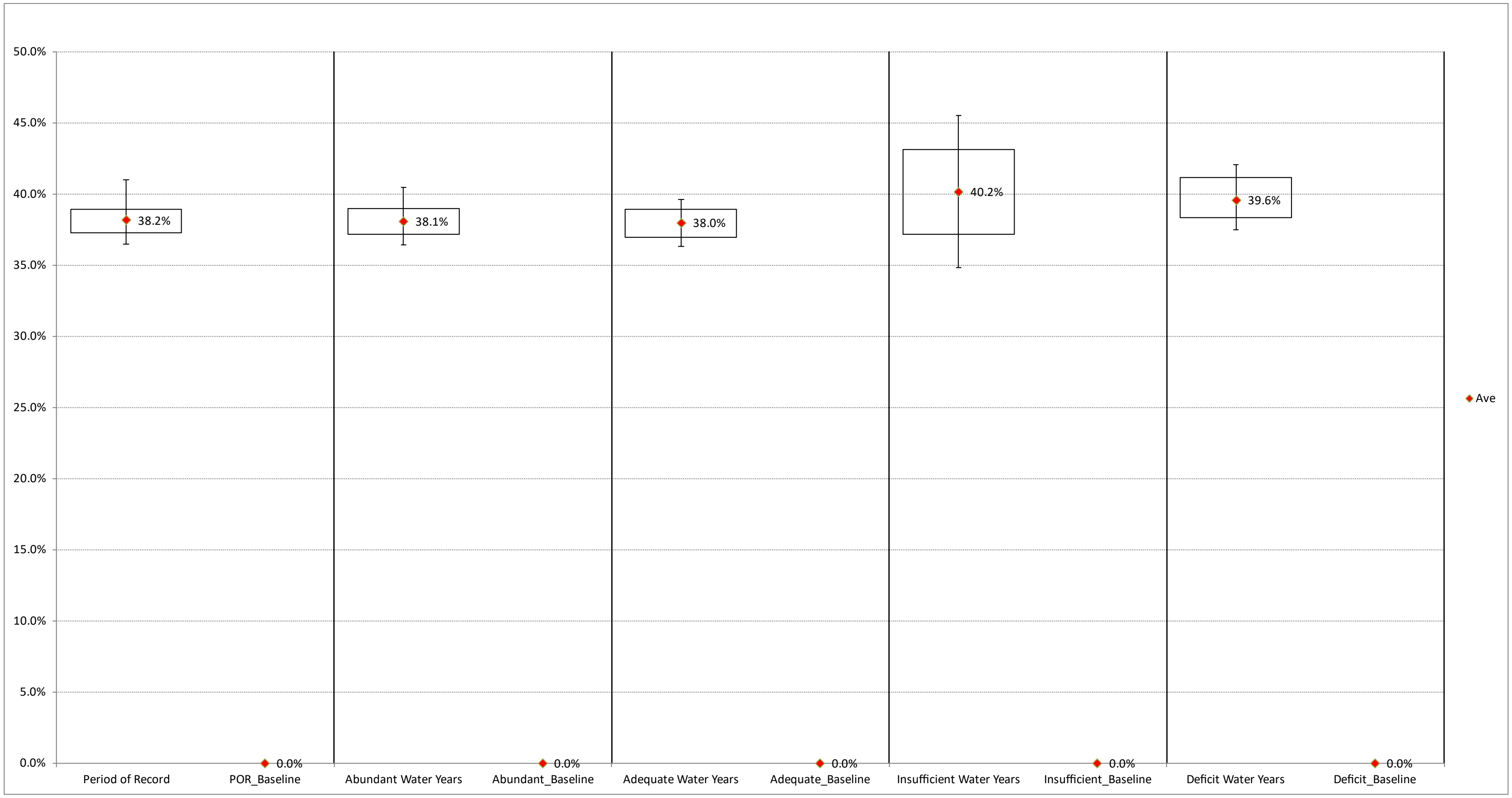

Figure 2-133. Green Peter 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Green Peter for juvenile winter steelhead 2 year olds under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.12 STEELHEAD ALTERNATIVE 3B

2.12.1 North Santiam – Detroit

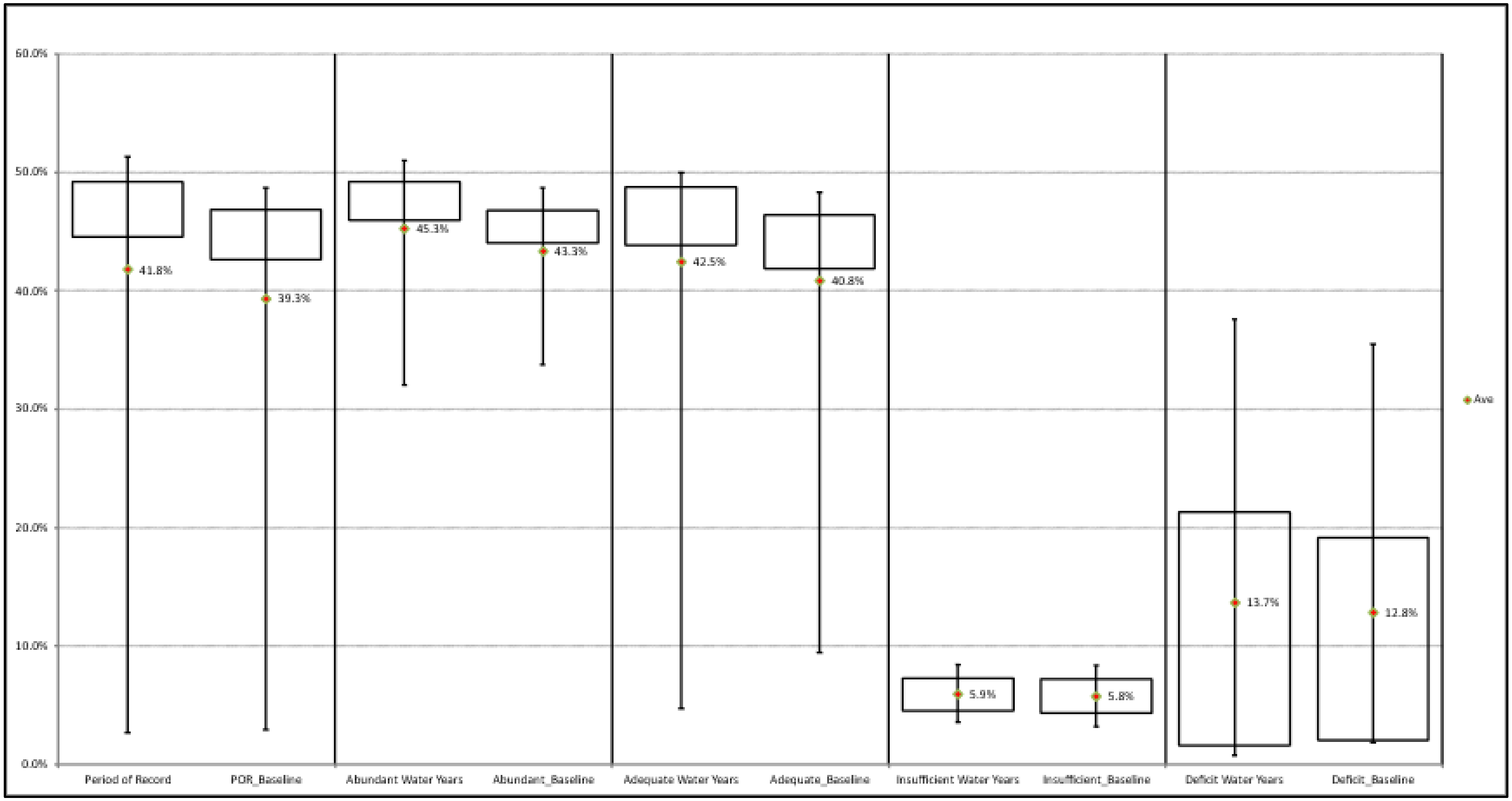

Figure 2-134. Detroit Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Detroit for juvenile winter steelhead sub-yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

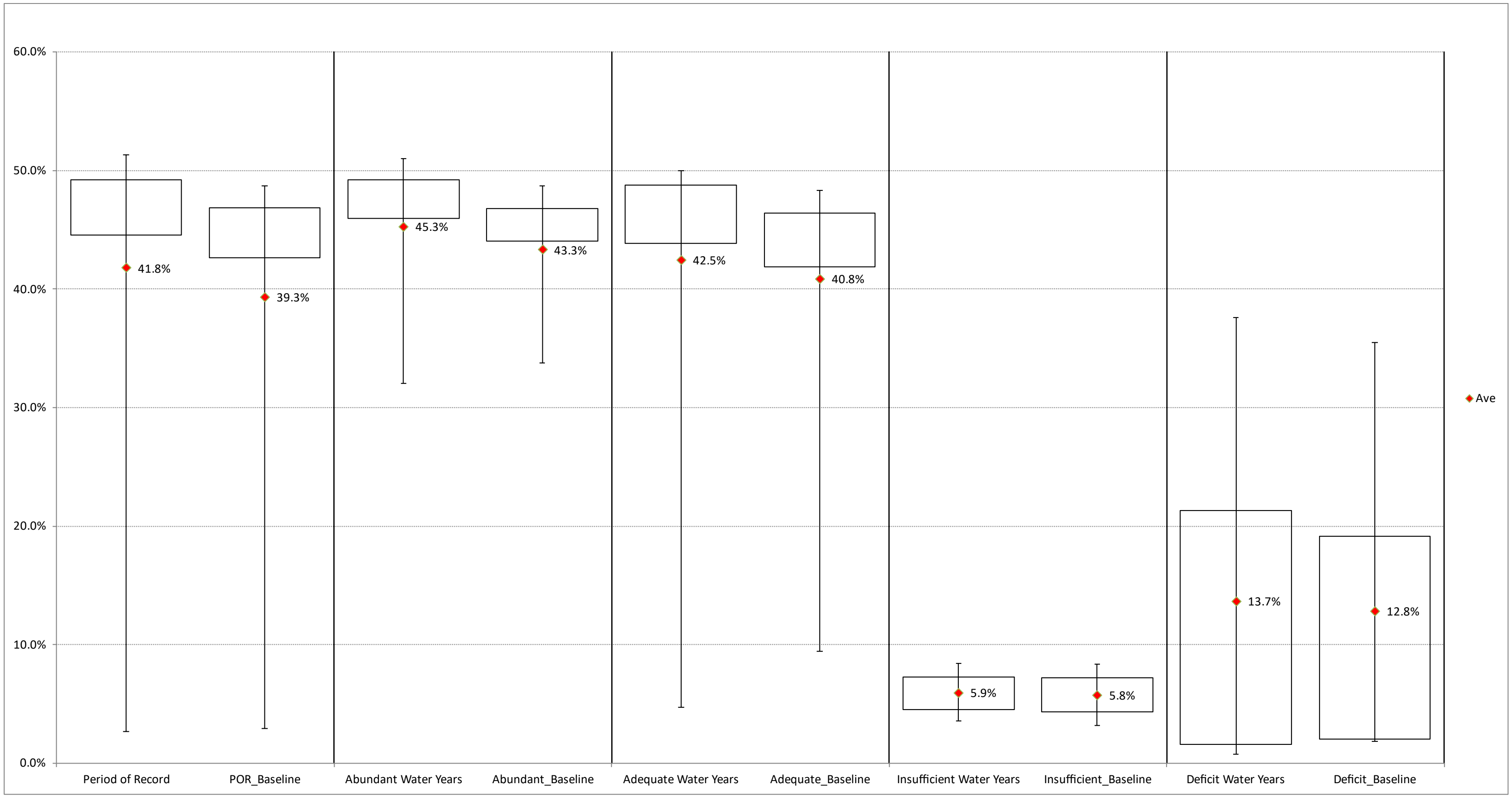

Figure 2-135. Detroit Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Detroit for juvenile winter steelhead yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

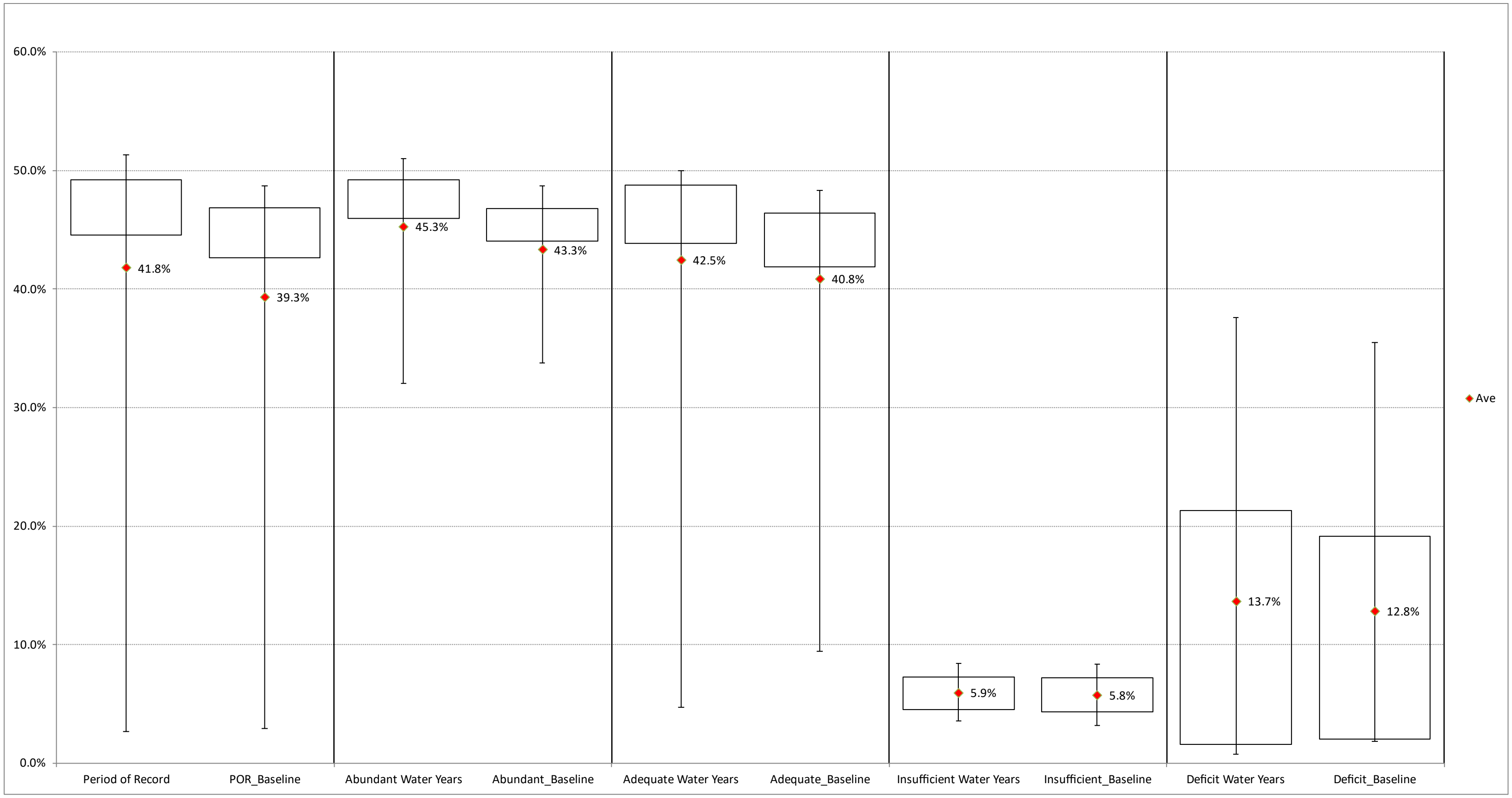

Figure 2-136. Detroit 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival Under Alternative 3b.
Downstream dam passage survival at Detroit for juvenile winter steelhead 2 year olds under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.

2.12.2 South Santiam – Foster

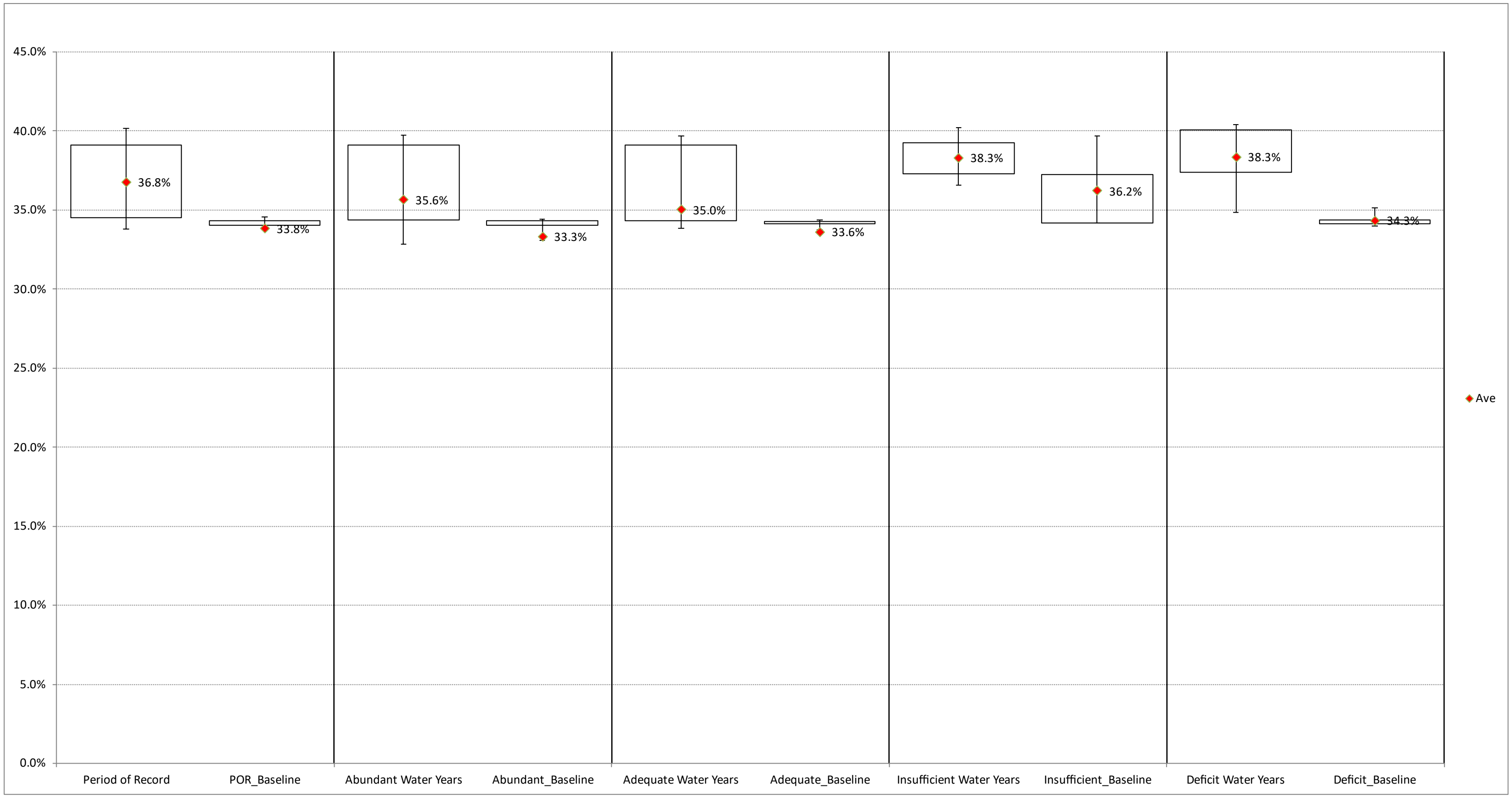

Figure 2-137. Foster Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Foster for juvenile winter steelhead sub-yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

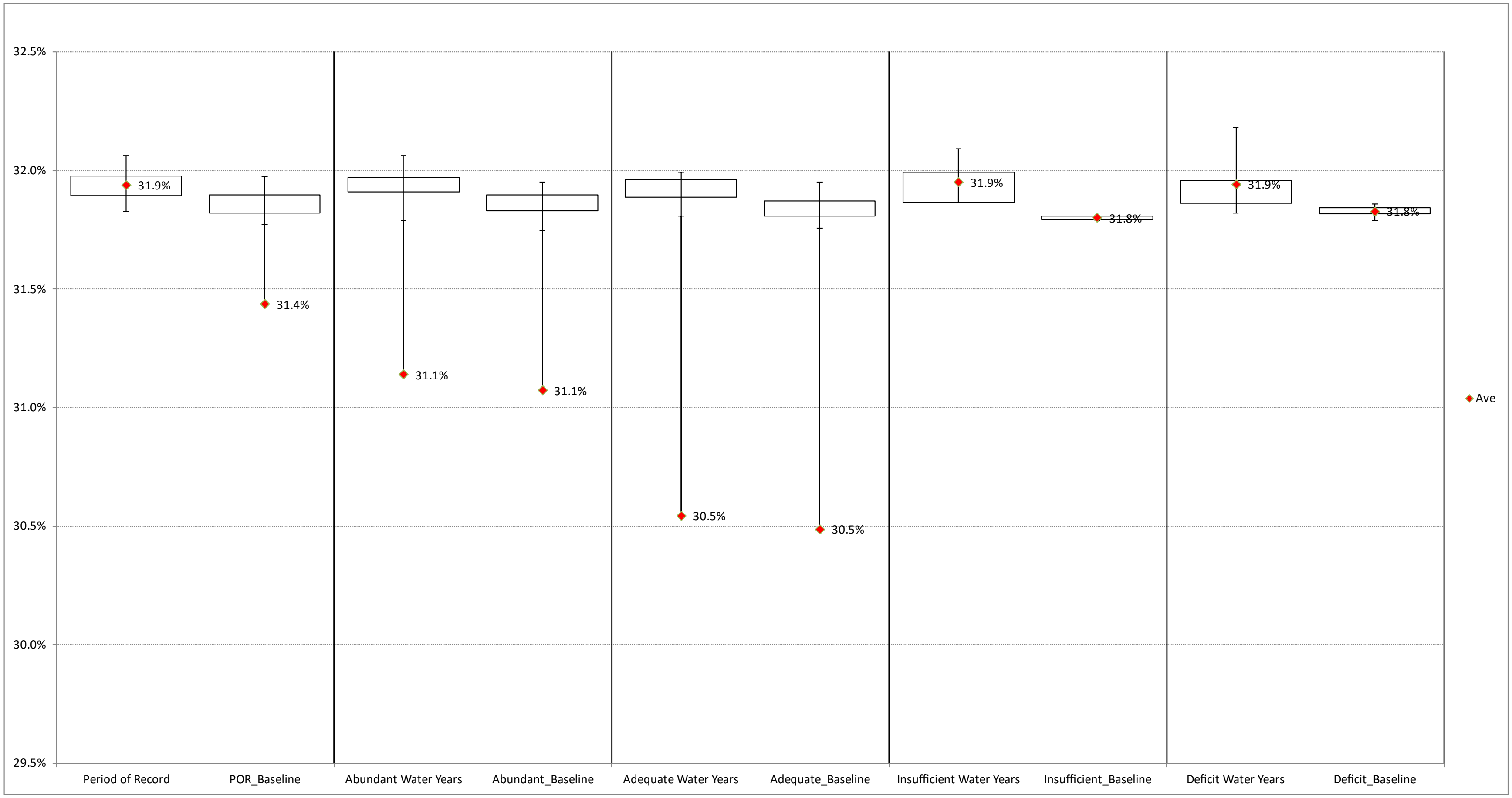

Figure 2-138. Foster Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Foster for juvenile winter steelhead yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

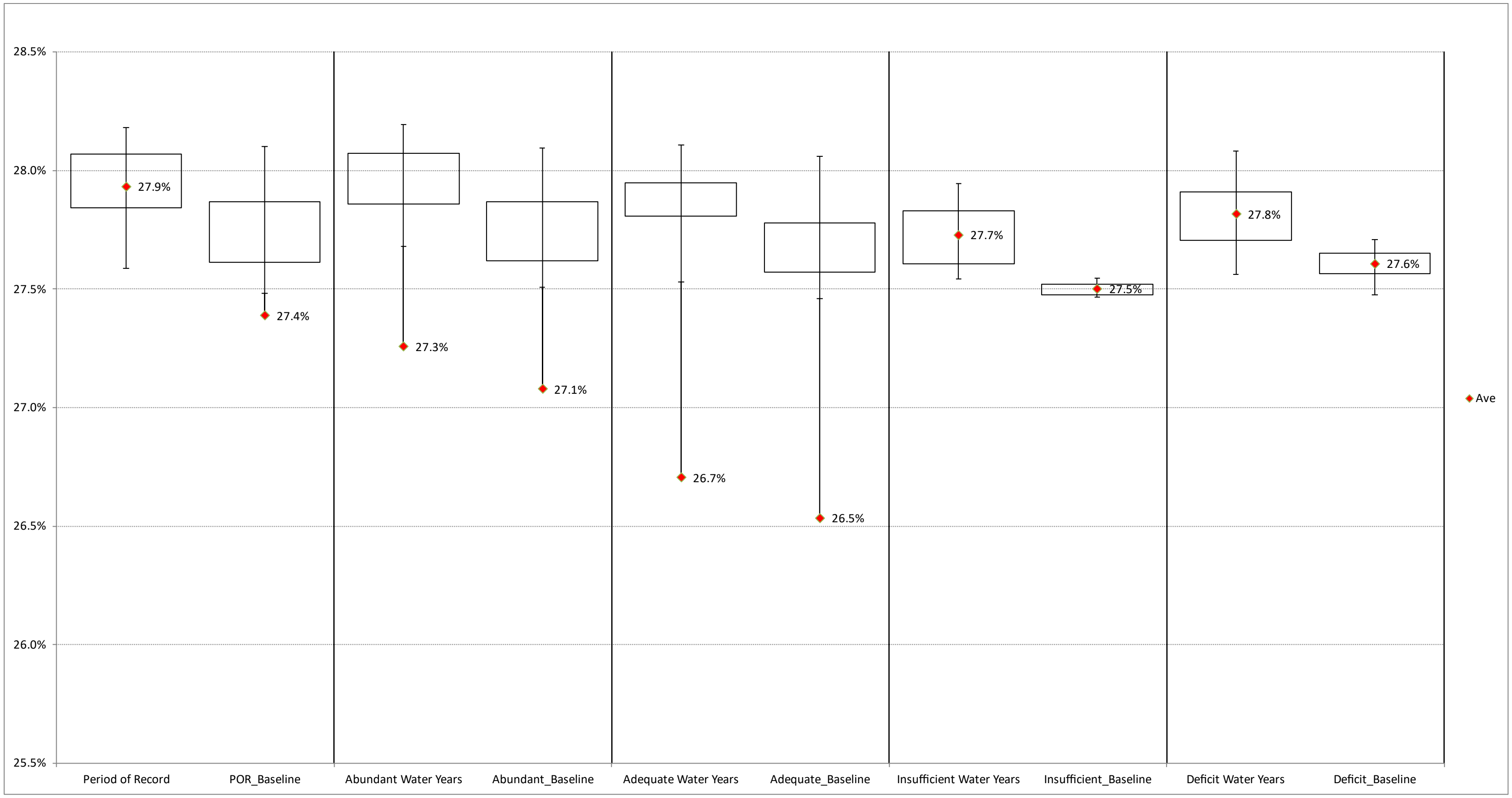

Figure 2-139. Foster 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Foster for juvenile winter steelhead 2 year olds under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.12.3 South Santiam – Green Peter

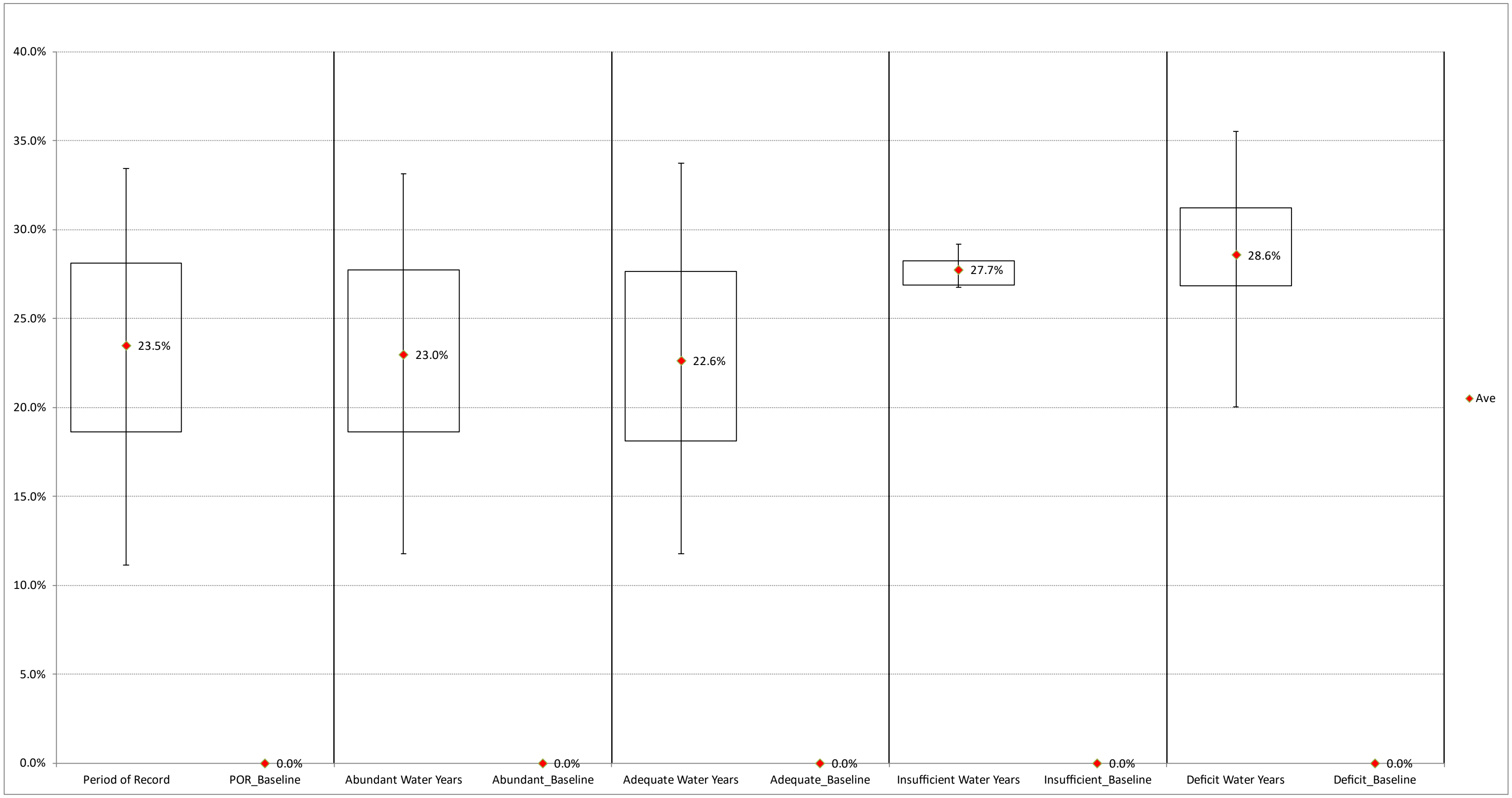

Figure 2-140. Green Peter Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Green Peter for juvenile winter steelhead sub-yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

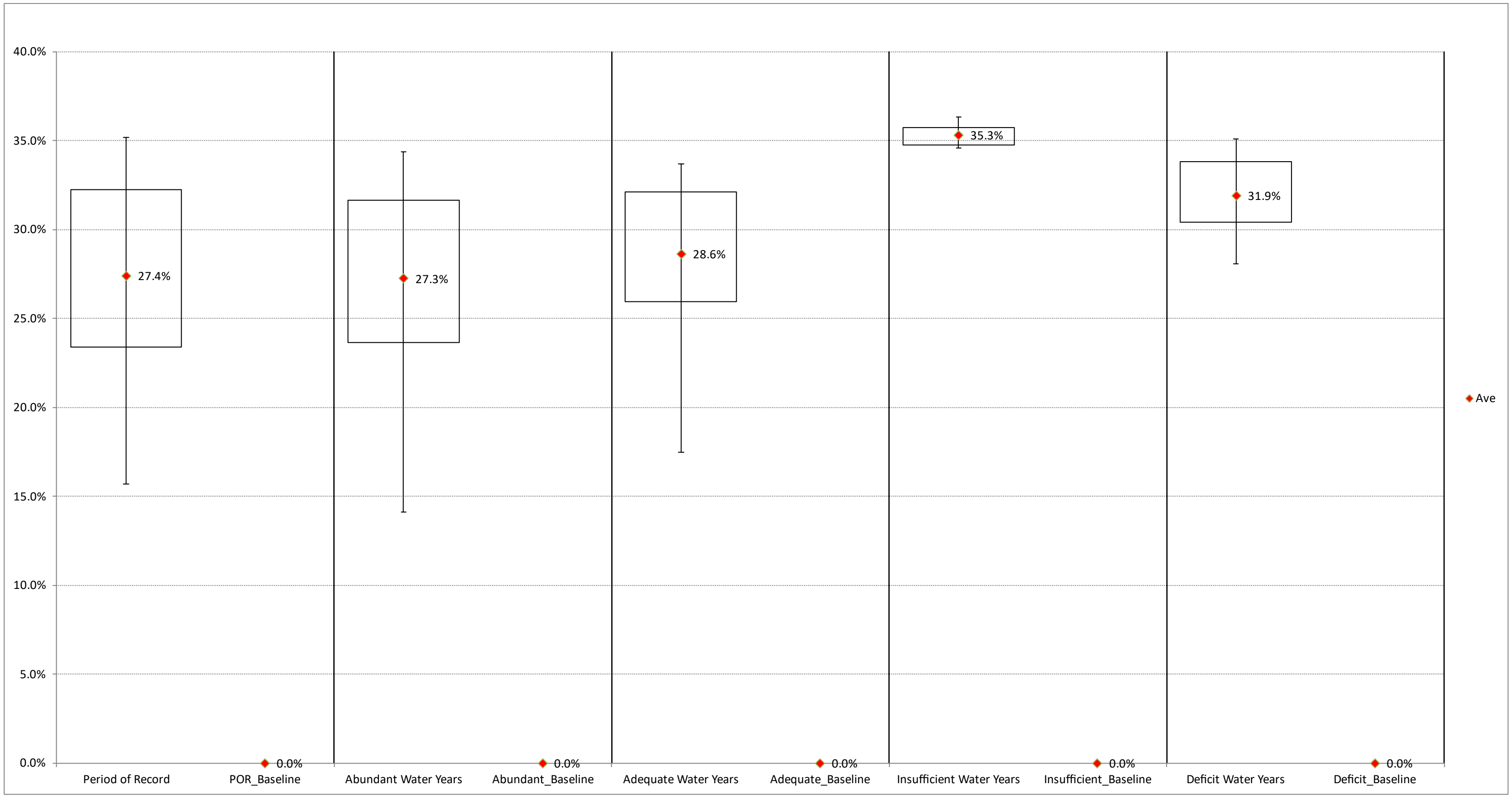

Figure 2-141. Green Peter Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Green Peter for juvenile winter steelhead yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

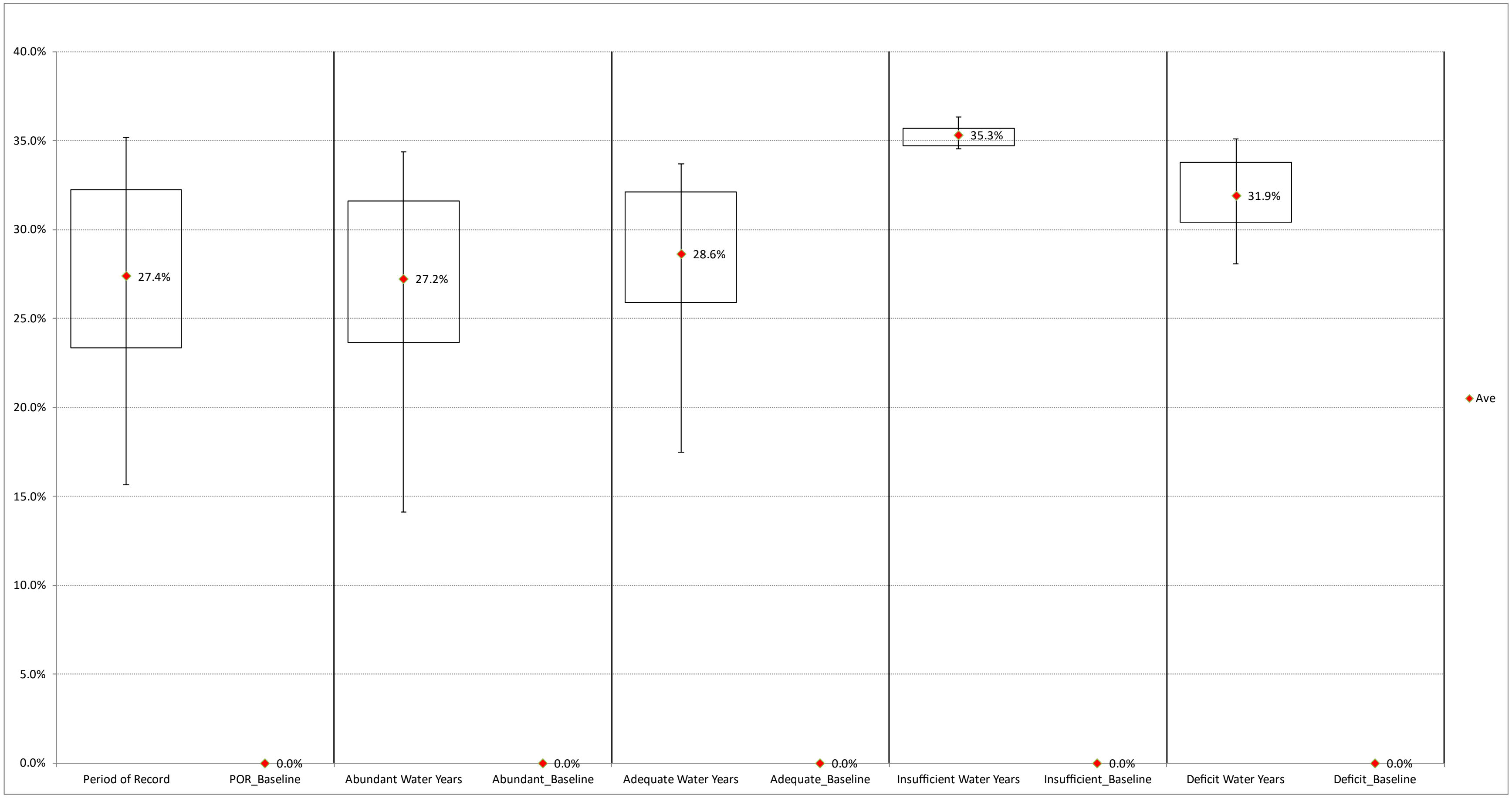

Figure 2-142. Green Peter 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival Under Alternative 3b.
Downstream dam passage survival at Green Peter for juvenile winter steelhead 2 year olds under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.

2.13 STEELHEAD ALTERNATIVE 4

2.13.1 North Santiam – Detroit

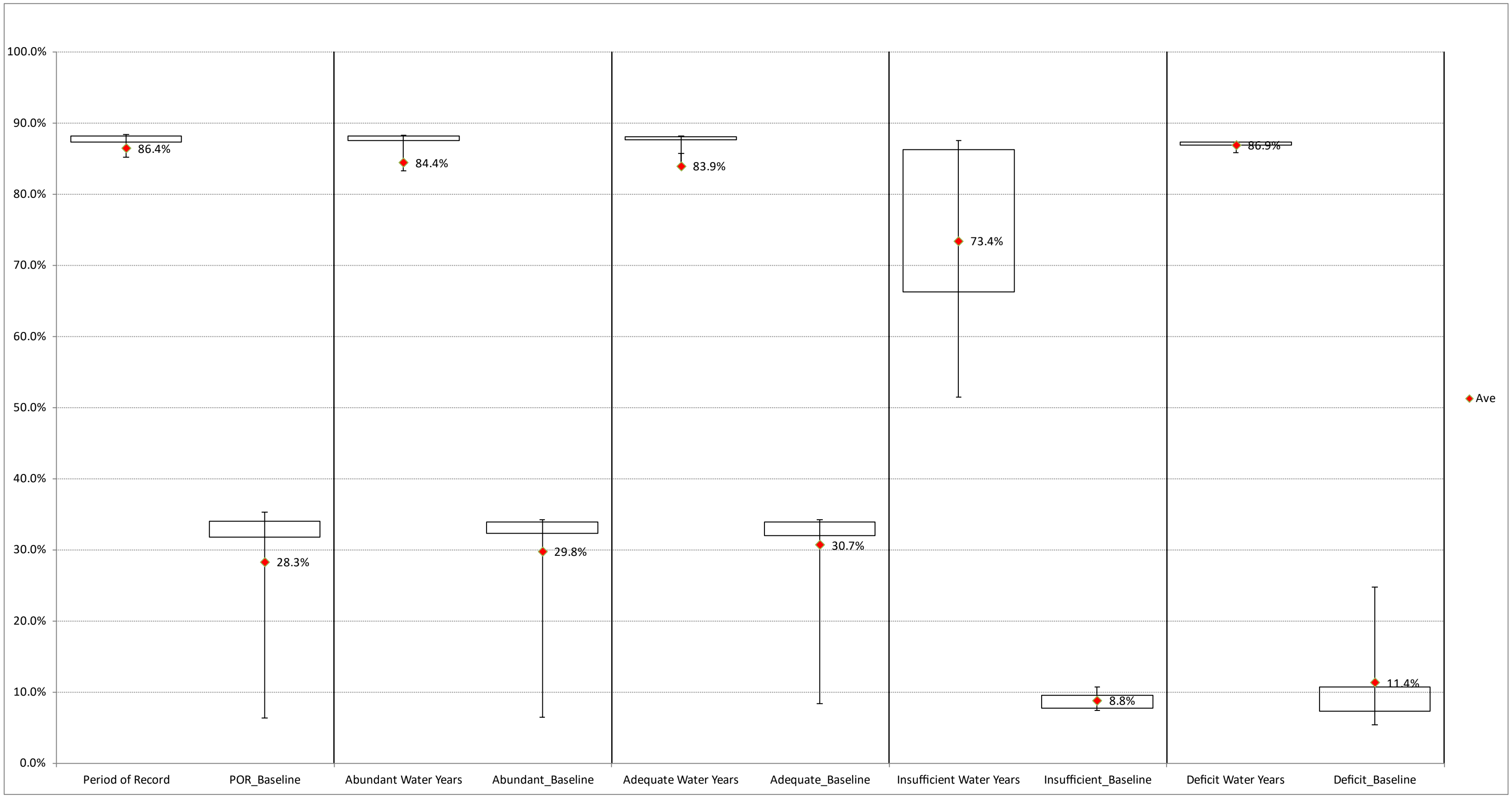

Figure 2-143. Detroit Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Detroit for juvenile winter steelhead sub-yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

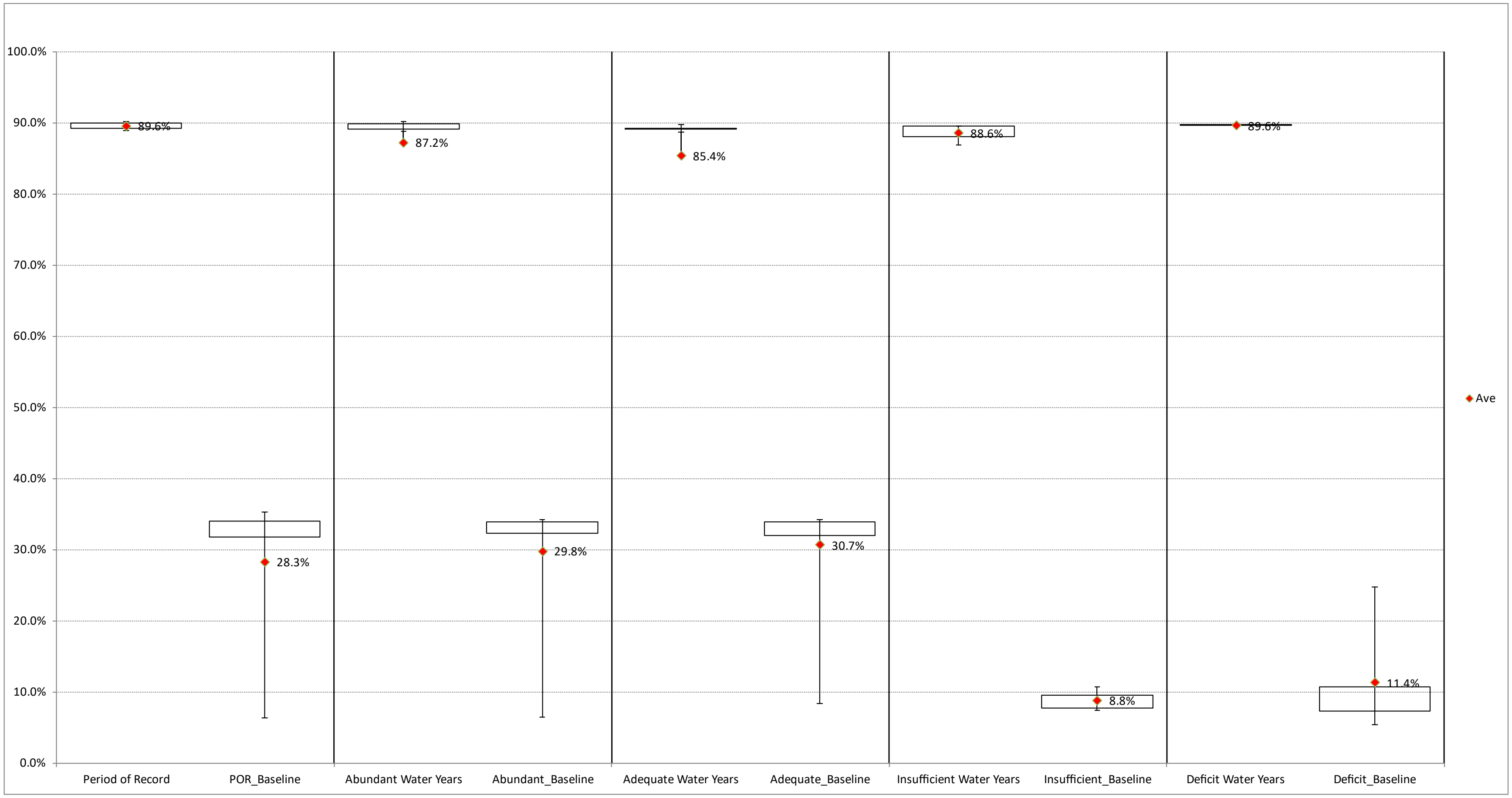

Figure 2-144. Detroit Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Detroit for juvenile winter steelhead yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

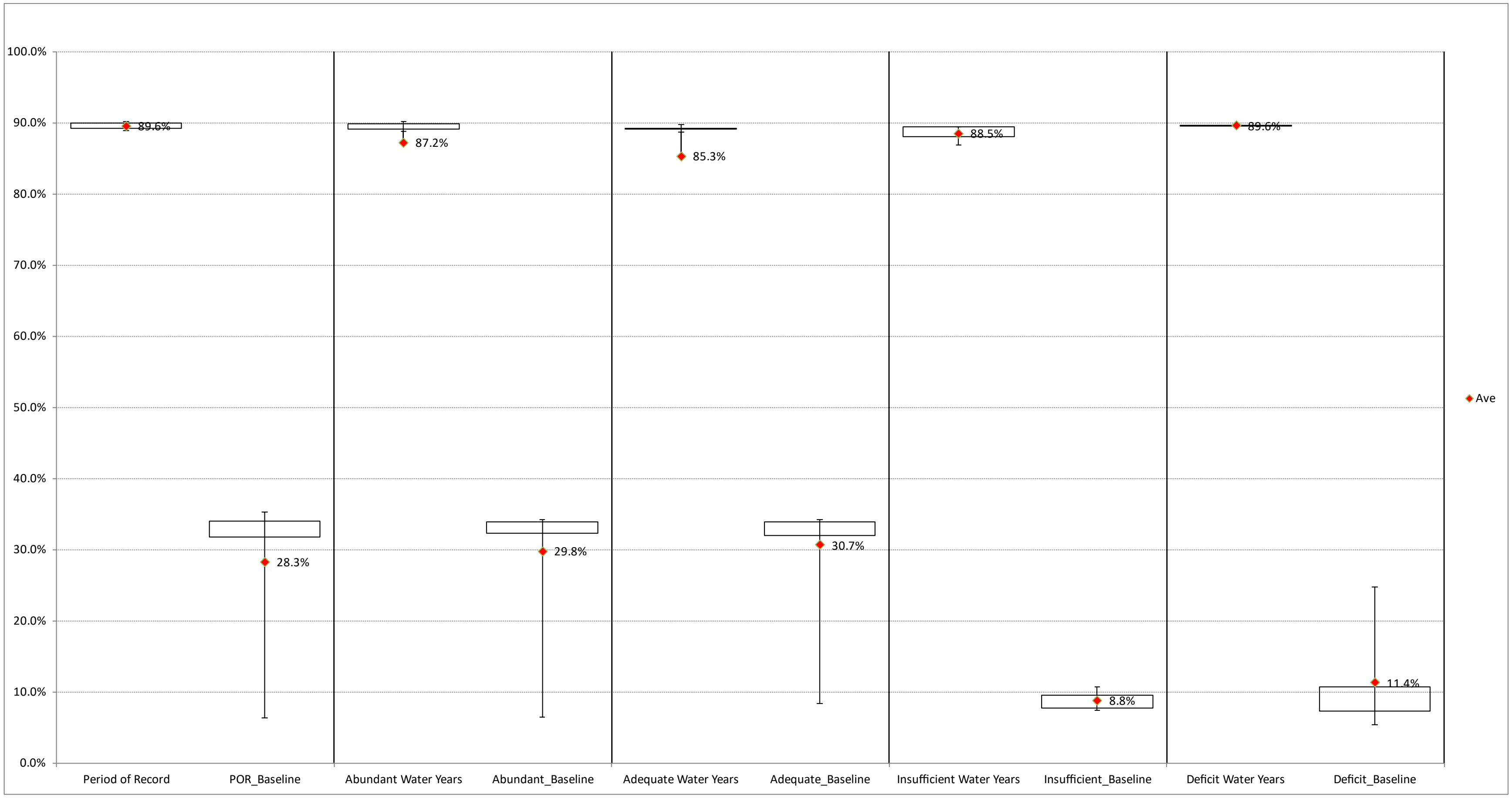

Figure 2-145. Detroit Juvenile Winter Steelhead 2-Year-Old Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Detroit for juvenile winter steelhead 2 year olds under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.13.2 South Santiam – Foster

Figure 2-146. Foster Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under Alternative 4.
Downstream dam passage survival at Foster for juvenile winter steelhead sub-yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.

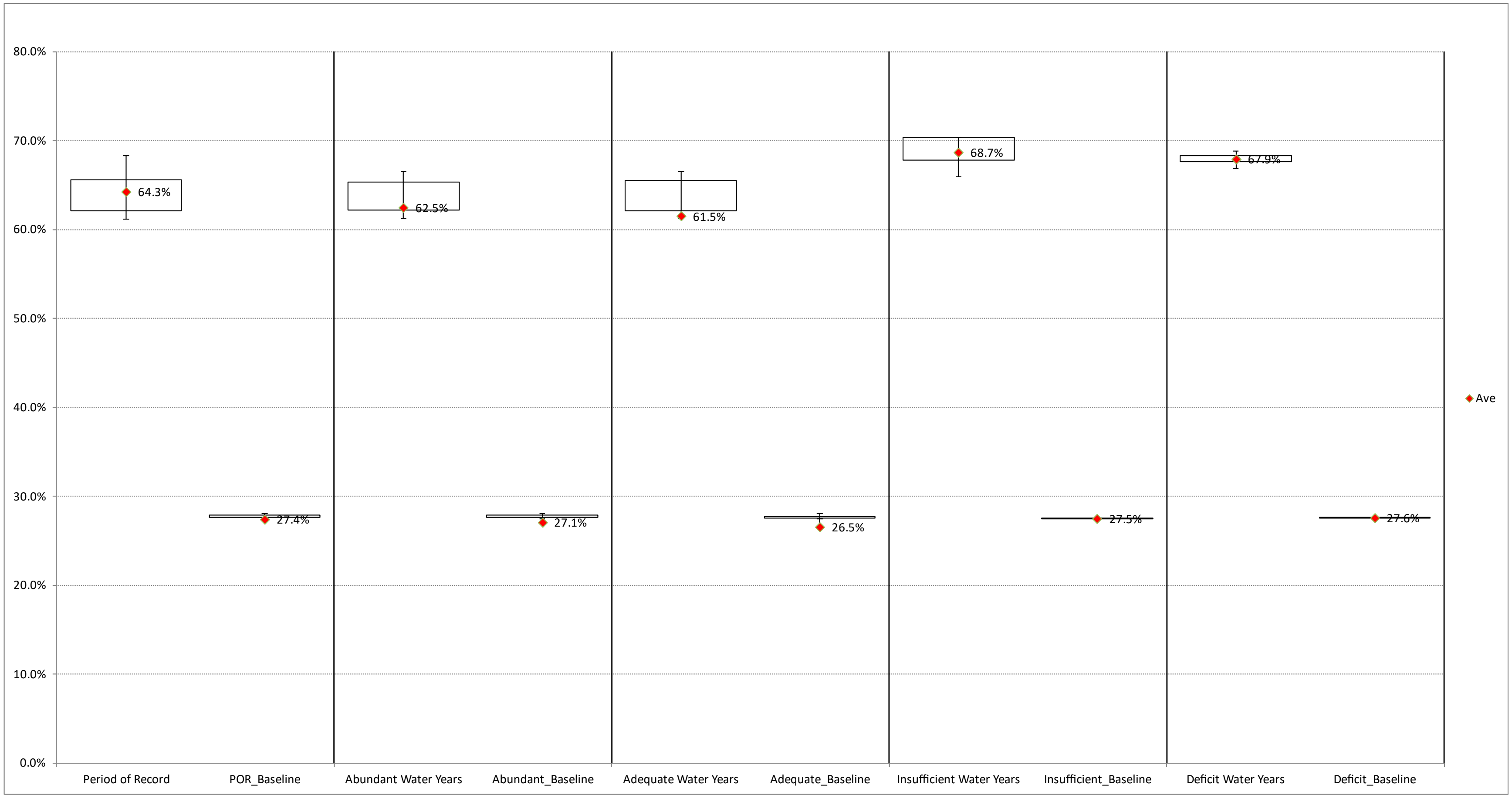

Figure 2-147. Foster Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Foster for juvenile winter steelhead yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

Figure 2-148. Foster for 2-year-old juvenile winter steelhead Downstream dam passage survival under Alternative 4. *Downstream dam passage survival at Foster for juvenile winter steelhead 2 year olds under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

CHAPTER 3 - BULL TROUT EFFECTS ANALYSIS

3.1 ASSESSMENT METHODS

Among WVS dams, bull trout (*Salvelinus confluentus*) populations currently exist above Cougar and Hills Creek dams, and are at the time of this assessment were being considered by the USFWS and other stakeholders for reintroduction above Detroit Dam. For purposes of this assessment, it was assumed bull trout reintroduction has occurred above Detroit Dam.

Historical habitat loss and fragmentation, interaction with nonnative species, harvest, and fish passage issues are widely regarded as the most significant primary threat factors affecting bull trout (USFWS 2008). A final recovery plan was published on September 30, 2015 with an ultimate goal to manage threats and ensure sufficient distribution and abundance to improve the status of bull trout throughout their extant range. The Oregon Bull Trout Recovery Strategy prepared by USFWS and others lists the following statewide limiting factors, and those specifically identified for bull trout in the Upper Willamette:

Statewide Limiting Factors	Upper Willamette Threats
Temperature Flow Barriers Human development	Altered flow and geomorphic processes Entrainment and fish passage Illegal harvest Prey base Hybridization and competition Predation

Currently local bull trout populations above WVS dams primarily exhibit an adfluvial life history, relying on reservoirs for rearing and forage. Habitat connectivity is a key objective identified for recovery of the species, providing bull trout access to additional habitat in order to reduce risks associated with a constrained distribution, and allowing for mixing of spawners among local populations supporting genetic health. Studies document there is a high rate of return back upstream to the base of WVS dams for bull trout successfully passing downstream (Zymonas et al. 2021). Most of those returning are sub-adults or mature adults, based on their size. There is also evidence of high fidelity by bull trout in the McKenzie (DeHaan and Diggs 2009; Bohling 2019; Zymonas et al. 2021). In the Deschutes River, where cool water temperatures are maintained by significant ground water inputs, return rates of bull trout passing downstream of Round Butte Dam have been high (unpublished data emailed from Chris Allen and Peter Lickwar, USFWS to Rich Piaskowski, USACE, 2.17.22).

Although there may be benefits of providing access for bull trout below WVS Dams, there are also risks for bull trout moving downstream in a watershed. These include injury or mortality from passage at dams, and the risk of mortality from factors downstream of dams (e.g. poor habitat and forage conditions, injury or mortality from predators and angling, lack of spawning habitat). There are no reports of spawning populations established volitionally from bull trout moving below WVS dams. With the exception of below Cougar Dam, there are no areas for successful spawning to occur below WVS dams due to ambient water temperature limitations, and these are predicted to be negatively impacted by climate change. In addition to climate change, habitat quality for bull trout below dams can be expected to further degrade over time due to fire, competition with warmwater and exotic fishes, land use and development, among other factors. If downstream passage rates are greater than upstream passage rates, then the existing populations could decline unless recruitment from individuals remaining upstream of the dam is adequate to sustain the population. In the North Santiam and Middle Fork it was assumed individuals must be able to successfully return upstream and spawn, otherwise their loss results in lower population abundance and productivity in the sub-basin.

Population persistence in the short term depends on habitat, and in the longer term on life history diversity and genetic integrity of local populations (e.g., McElhany et al. 2000). This assessment first estimated the amount of habitat above and below Detroit, Cougar, and Hills Creek Dams. Second, fish passage conditions and exposure risk to predation and local fisheries were assessed. Finally, information on habitat and risks from predation and fisheries were used to qualitatively assess population abundance, productivity, distribution and diversity under each WVS EIS alternative compared to the NAA. The results of the population attribute assessment were then used to classify the NEPA effect categories for each alternative at the sub-basin scale.

3.1.1 Habitat Assessment

Schaller et al. (2014) surveyed biologists with knowledge of bull trout to identify and weight variables affecting aquatic habitat conditions for bull trout. Scores were defined for assessing each of the variables for different life stage needs of bull trout, and then applied with the weighting factors to assess habitat conditions in river reaches of interest. The highest weighted variables identified by Schaller et al. (2014) were surface flow, water temperature and passage impediments (see Table 3.17 in Schaller et al. 2014), indicating these were considered the most important variables by the biologists surveyed. Other viable weightings were much smaller, indicating they would have much less of an influence when comparing effects among alternatives in an assessment. This assessment therefore assessed habitat based on indices of surface flow and water temperature.

Habitat conditions were assessed for streams above and below WVS dams in the North Santiam, McKenzie and Middle Fork sub-basins using reaches delineated consistent with those recently applied by ICF (2022) when modeling habitat conditions under each WVS EIS alternative using the Ecosystem Diagnostic and Treatment (EDT) model. This allowed for the application of information on habitat conditions for variables of interest already summarized by ICF to be used. Using hydrology and temperature scores from the EDT model results from each WVS EIS alternative, a score was develop for each reach of interest:

*Bull trout habitat score = [(above principal dam hydrology score + temperature score) * reach length]*

This approach allows changes and hydrology and water temperatures as effected by WVS dams in each WVS EIS alternative to be accounted for. Habitat scores were then summarized as percentages of the total above and below each dam.

Reservoir habitat availability was assessed by calculating the percent differences in monthly pool volume for each alternative as compared to volume available under the NAA. Pool volumes used were based on RES-SIM modeling for the NAA and each alternative.

Stream and reservoir habitat information was then used in the subsequent sections (fish passage and risk exposure; population attributes) to qualitative assess effects at the local population scale under each WVS EIS alternative.

3.1.2 Fish Passage and Risk exposure

For downstream passage rates at Cougar Dam under the NAA, information on bull trout upstream returns and juvenile Chinook passage survival were used to approximate downstream passage rates for bull trout at Cougar Dam. Most bull trout pass downstream in the fall, when regulating outlet is operating. When the RO is available and operating at moderate flows, juvenile Chinook salmon survival is expected to be 65-75%. It was therefore assumed a downstream passage concrete survival from the low end of the range estimated for juvenile Chinook of 65% (i.e. a mortality rate of 35%), allowing for the potential for some bull trout to pass into the turbine penstocks or when RO operations are not favorable (lower gate opening; higher hydraulic head). Using the number of bull trout trapped below Cougar Dam in 2011 to 2022, and downstream mortality assumptions, we estimated an average downstream annual passage rate of 23% (range 0% to 48%) (Table [Downstream passage rate and annual population mortality]). When applying this passage rate to a current annual spawner abundance estimate of 101 (63 redds * 1.6 adults/redd), an annual adult mortality was estimated at 8% (range 0% to 17%) by multiplying the percent estimated to pass downstream by the estimated downstream passage mortality (i.e. 23% * 35% = 8%). It was assumed the downstream passage and mortality rates estimated for Cougar Dam were the same at Hills Creek Dam.

Table 3.1.2-1. Downstream passage rate and annual population mortality assumptions for bull trout attempting to pass below Cougar Dam, assuming a route specific mortality of 35% and spawner abundance of 101.

Category	Number passing upstream	Estimated number passing downstream (# passing upstream / 35% mortality rate)	Percent of annual spawner abundance passing downstream	Mortality as a percent of the annual spawner abundance
Maximum	17	49	48%	17%
Mean	8	23	23%	8%
Median	6.5	19	18%	6%
Minimum	0	0	0%	0%

A downstream passage survival rate of 60% was applied for downstream passage survival at Detroit Dam for the NAA using information on juvenile Chinook downstream passage survival through turbines at this dam (Beeman and Adams 2015). Assuming similar passage rates and spawning abundance as used for Cougar Dam, the percentage of the annual spawner abundance expressed as downstream passage mortality was approximated as 9%.
Under each alternative, the relative change in downstream passage rates were qualitatively assessed according to the type of passage conditions included at each dam. Qualitative assumptions were documented in the assessment tables in the results section below.

For upstream passage, permanent adult fish collection facilities designed for salmonids currently exist Minto Dam below Detroit and Big Cliff dams in the North Santiam Sub-basin, and below Cougar Dam in the McKenzie Sub-basin. Upstream passage conditions were assumed to be the same under each WVS EIS alternative as compared to the NAA at these locations. For Hills Creek Dam, currently temporary trapping occurs in the dam tailrace. This approach was assumed to continue under the alternatives as a partially effective upstream passage approach, except where a new adult fish facility was included in the WVS EIS alternative providing a fully effective upstream passage condition.

Both predation and harvest are included as primary threats to recovery of bull trout in the Upper Willamette. Changes in risk of exposure to piscivorous fish was qualitatively assessed considering the present of piscivorous species above and below WVS dams in the North Santiam, McKenzie and Middle Fork. Other studies have documented negative effects of these factors on bull trout (e.g., Beauchamp and Van Tassell 2001; Birkeland et al. 2005; Hixon et al. 2014; Jackson et al. 2001). Significant population of piscivorous fishes known to prey on salmonids occur in WVS reservoirs (e.g., Monzyk et al. 2011). Lookout Point has the most piscivorous fish species, and in-reservoir survival of juvenile salmonids there has been estimated at < 20% between April and Oct (Kock et al. 2018). With the exception of Cougar Reservoir, it was assumed piscivorous fish populations in reservoirs up and downstream of sub-basins with bull trout would not significantly change under any of the WVS EIS alternatives as it relates to risks for bull trout. For Cougar Dam, it was assumed a significant reduction in piscivorous fish would occur where alternatives include a deep reservoir drawdown to near the diversion tunnel based on similar findings at Fall Creek Reservoir (Murphy et al. 2019). Most bull trout observed passing below WVS dams are adults are larger sub-adults, and therefore predation risk was not considered as it relates to be bull trout moving below dams.

Changes in risk of exposure to fisheries was qualitatively assessed considering the type and fishing pressure occurring downstream of WVS dams in the North Santiam, McKenzie and Middle Fork. Qualitative assumptions were documented in the assessment tables in the results section below. Local sport fisheries increase the risk of stress, injury, and mortality. Evidence of injury from hook and line capture of bull trout has been reported for bull trout in Hills Creek and South Fork McKenzie (Reis et al. 2012; Zymonas et al. 2020; Zymonas et al. 2021). A large trout fishery occurs in Detroit Reservoir as well, as evidenced by the levels of hatchery trout stocked there annually. Fishing in Lookout Point Reservoir also occurs, where the use of baits and other techniques that bull trout are susceptible too are allowed. However, information on the level of fishing effort that occurs in Lookout Point Reservoir was not available. It was assumed current fisheries regulations and level of fishing effort (pressure) would continue under each alternative.

3.1.3 Population Attributes and Effects Determinations

Information on habitat and risk factors were then used to assess expected change in demographic properties of each local population in order to characterize population performance under the alternatives compared to the NAA. The attributes assessed included population size (abundance), population growth rate (productivity), distribution and diversity consistent with definitions included in McElhany et al. (2000). Qualitative assumptions used when characterizing the expected changes in each population attribute were documented in the assessment tables in the results section below.

Determination of effects (from none/negligible to major positive or negative effects) were classified based on the population attribute assessment. McElhany et al. (2003) summarized that “Abundance and productivity measures demonstrate the ability of a population to persist, whereas diversity and spatial structure provide confidence that the population can sustain population persistence in the face of future environmental variation”, and accordingly weighted the importance of abundance and productivity higher when assessing population viability. For consistency, if a negative change in abundance and productivity were assessed for bull trout, then the overall effect determination was based on the change assessed for those attributes. With the exception of when abundance and productivity was assessed a negative effect, all attributes were considered by applying a qualitative effects category reflecting the mid-level of the categories applied for each attribute based on the effects scale criteria included in Table [Definitions of effects levels applied…].

Table. Definitions of effects levels applied for assessing the effects of each WVS EIS alternative on bull trout.

Effect Scale	Criteria
None/negligible	No/negligible change from NAA in population attributes (approx. <5%) resulting from alternative when considering accessible habitat and fish passage conditions.
Minor	Minor change from NAA in population attributes (approx. 5-10%) resulting from alternative when considering accessible habitat and fish passage conditions.
Moderate	Moderate change from NAA in population attributes (approx. 10-25%) resulting from alternative when considering accessible habitat and fish passage conditions.
Major	Major change from NAA in population attributes (approx. >25%) resulting from alternative when considering accessible habitat and fish passage conditions.

3.2 ASSESSMENT RESULTS

3.2.1 Habitat

Stream Habitat Above and Below Dams

Resulting habitat scores for stream reaches above and below Hills Creek (HCR), Cougar (CGR) and Detroit (DET) reservoirs are presented in Table [Habitat Scores calculated from EDT hydrology and temperature scores]. Monthly percent pool volume differences are presented in Tables [Percent difference in average reservoir pool volume…] for Hills Creek and Detroit reservoirs. Similar information was not available for Cougar Reservoir when this assessment was completed, however the data for these other reservoirs was used when assessing how Cougar Reservoir volumes would change under each alternative. This information was then used to assessment fish passage and population attributes.

Table 3.2.1-1. Habitat scores calculated from EDT hydrology and temperature scores (ICF 2022) for river reaches above and below the Detroit and Big Cliff dam complex, Cougar Dam (CGR), and Hills Creek Dam (HCR). EDT rankings, in general, occur on a scale of 0 to 4 with 0 being the best and 4 being the worst.

NAA 2015	Intra-annual low flow	Temperature	Channel Length	Habitat Score
NAA 2015				
Above HCR	0.8	0.8	16.6	26.8
Below HCR	0.8	0.7	24.5	35.8
Above CGR	0.8	0.9	27.0	47.3
Below CGR	0.8	0.9	33.2	57.0
Above Detroit	0.8	0.8	50.3	83.1
Below Detroit	0.8	0.8	47.9	79.2
Alt1 2015				
Above HCR	0.8	0.8	16.6	26.7
Below HCR	0.8	0.7	24.5	36.2
Above CGR	0.8	0.9	27.0	47.4
Below CGR	0.8	0.9	33.2	57.1
Above Detroit	0.8	0.8	50.3	82.6
Below Detroit	0.8	0.8	47.9	76.2
Alt2a 2015				
Above HCR	0.9	0.8	16.6	27.0
Below HCR	0.8	0.7	24.5	37.6
Above CGR	0.9	0.9	27.0	48.6
Below CGR	0.9	0.9	33.2	58.9
Above Detroit	0.9	0.8	50.3	85.0
Below Detroit	0.9	0.8	47.9	78.1
Alt2b 2015				
Above HCR	0.9	0.8	16.6	27.0
Below HCR	0.8	0.7	24.5	37.6
Above CGR	0.9	0.9	27.0	48.6
Below CGR	0.9	0.9	33.2	59.0
Above Detroit	0.9	0.8	50.3	84.9
Below Detroit	0.9	0.7	47.9	77.0
Alt 3a 2015				

NAA 2015	Intra-annual low flow	Temperature	Channel Length	Habitat Score
Above HCR	0.8	0.7	16.6	24.8
Below HCR	0.8	0.7	24.5	36.0
Above CGR	0.8	0.9	27.0	47.8
Below CGR	0.8	0.9	33.2	57.8
Above Detroit	0.9	0.8	50.3	85.6
Below Detroit	0.9	0.7	47.9	75.9
Alt3b 2015				
Above HCR	0.8	0.8	16.6	26.9
Below HCR	0.8	0.7	24.5	36.6
Above CGR	0.8	0.9	27.0	48.3
Below CGR	0.9	0.9	33.2	58.4
Above Detroit	0.8	0.8	50.3	83.0
Below Detroit	0.8	0.8	47.9	75.7
Alt4 2015				
Above HCR	0.8	0.8	16.6	26.7
Below HCR	0.8	0.7	24.5	35.9
Above CGR	0.8	0.9	27.0	47.4
Below CGR	0.8	0.9	33.2	57.1
Above Detroit	0.8	0.8	50.3	83.4
Below Detroit	0.8	0.7	47.9	75.6

Table. Percent of stream habitat for river reaches above and below the Detroit and Big Cliff dam complex, Cougar Dam, and Hills Creek Dam, under the no action alternative for dry year conditions (2015), based on habitat scores calculated from EDT hydrology and temperature scores (ICF 2022).

Reach	Percent of Total
Middle Fork Sub-basin	
Above Hills Creek Dam	42%
Below Hills Creek Dam*	58%
McKenzie Sub-basin	
Above Cougar Dam	45%
Below Cougar Dam	55%
North Santiam Sub-basin	
Above Detroit Dam	52%
Below Big Cliff Dam	48%

*(including N. Fork Middle Fork)

Reservoir Habitat

Table. Percent difference in average reservoir pool volume at Detroit Reservoir for each WVS EIS Alternative compared to the NAA by month.

Average Pool Volume - Percent Difference from NAA						
	Alt 1	**Alt 2a**	**Alt 2b**	**Alt 3a**	**Alt 3b**	**Alt 4**
Jan	1%	0%	0%	-16%	-16%	1%
Feb	0%	0%	0%	-22%	-5%	0%
Mar	1%	1%	1%	-65%	-3%	1%
Apr	5%	5%	5%	-82%	3%	5%
May	5%	4%	4%	-86%	3%	4%
Jun	4%	3%	3%	-85%	2%	3%
Jul	6%	1%	1%	-82%	-2%	1%
Aug	6%	-2%	-2%	-82%	-7%	-2%
Sep	9%	-2%	-2%	-81%	-14%	-2%
Oct	6%	3%	3%	-76%	-34%	3%
Nov	2%	1%	1%	-69%	-66%	1%
Dec	0%	-1%	-1%	-51%	-51%	-1%

Table. Percent difference in average reservoir pool volume in Hills Creek Reservoir for each WVS EIS Alternative compared to the NAA by month.

Average Pool Volume - Percent Difference from NAA						
	Alt 1	**Alt 2a**	**Alt 2b**	**Alt 3a**	**Alt 3b**	**Alt 4**
Jan	0%	-2%	-2%	-3%	-3%	-2%
Feb	0%	-1%	-2%	4%	-17%	-1%
Mar	0%	-1%	-1%	3%	-37%	-1%
Apr	5%	4%	4%	5%	-45%	4%
May	13%	12%	11%	13%	-48%	12%
Jun	18%	12%	12%	13%	-46%	12%
Jul	12%	7%	6%	-1%	-41%	7%
Aug	4%	7%	3%	-15%	-36%	8%
Sep	0%	7%	1%	-27%	-30%	7%
Oct	1%	2%	-4%	-26%	-23%	2%
Nov	-2%	-7%	-7%	-19%	-18%	-6%
Dec	-1%	-6%	-5%	-8%	-6%	-5%

3.2.2 Fish Passage and Risk Exposure

North Santiam

Table. Assessment of bull trout passage and key habitat attributes under the No Action Alternative (NAA) and assessed change the attributes under the Action Alternatives compared to the NAA in the North Santiam Sub-basin.

Attribute	Description of NAA
Emigration rate below Detroit Dam	Most emigration assumed in autumn, similar to other local populations. Reservoir draw down in autumn decreases depth to turbine? penstocks improving attraction and passage opportunity. Adult downstream passage rate assumed to be similar or lower than estimated for CGR Dam (~8%) due to size or reservoir and forebay. Juvenile and sub-adult downstream passage rate assumed low because many observed to rear within or above other WVS reservoirs.
Survival rate passing Detroit Dam	Reservoir draw down in autumn decrease depth to penstocks, also decreasing hydraulic head. However survival rate will likely be low (< 50%) similar to data on yearling size Chinook passing DET turbines.
Access to other local spawning populations	With bull trout reintroduced above DET Dam, there would not be other local spawning populations within the North Santiam Sub-basin, or in adjacent sub-basins in the Willamette Basin, resulting in a very low potential for spawning to occur with other local populations. Existing dam conditions and operations results in a low downstream passage efficiency and passage survival. Those returning will be transported upstream via truck and haul from the Minto Adult Fish Facility.
Upstream passage at Detroit Dam	A permanent upstream migrant trap and haul facilities exist at the Minto Adult Fish Facility, operated early spring to late autumn, providing for safe and effective upstream fish passage for Big Cliff and Detoit dams.
Rearing and foraging opportunity	Juveniles rear upstream of DET reservoir. Most sub-adults and adults forage in DET reservoir between spawning events. Some sub-adults and adults move below DET dam. Suitable habitat exists downstream of BCL?Dam and in the Sub-basin at large.

Attribute	Change from NAA	Alternatives 1, 2A, 2B, 4, and 5
Emigration rate below Detroit Dam	Moderate improvement	A floating screen structure (FSS) will provide for improved attraction and collection of downstream migrants at DET dam. There is uncertainty in how many bull trout will use the structure however a surface route available during spring to autumn expected to increase downstream migrant rate from DET Reservoir compared to the NAA.
Survival rate passing Detroit Dam	Major improvement	A floating screen structure (FSS) will provide for a safe surface passage route downstream of DET dam. Bull trout entering will be collected and transported below the dam with a high survival rate. It is uncertain how many bull trout

		will use the structure, but assumed annual downstream passage rates will increased compared to the NAA.
Access to other local spawning populations	Negligible improvement	Operation of the FSS will increase downstream passage efficiency and downstream passage survival, increasing the number of bull trout below DET and BCL dams and therefore the potential for individuals to migrate and spawn with other populations. However the distance to other spawning populations requires significant migration into the Clackamas, McKenzie or Middle Fork sub-basins. Those returning will be transported upstream via truck and haul from the Minto Adult Fish Facility.
Upstream passage at Detroit Dam	No change	Same as NAA
Rearing and foraging opportunity	Moderate improvement	Operation of the FSS will increase downstream passage efficiency and downstream passage survival, increasing the number of bull trout below DET and BLC dams accessing additional habitat. Those returning will be transported upstream via truck and haul from the Minto Adult Fish Facility.

Attribute	Change from NAA	Alternative 3A and 3B
Emigration rate below Detroit Dam	Moderate improvement	Seasonal deeper drawdowns to 25 ft over the top of the ROs will increase the attraction and passage rate of bull trout seeking to pass downstream of DET Dam because the depth to the top of the RO outlet is significantly decreased. A significant reservoir pool will remain and the majority of bull are expected to remain in the reservoir to rear and forage.
Survival rate passing Detroit Dam	Moderate improvement	Prioritized use of RO during seasonal drawdowns will provide a moderate improvement in passage survival rates by decreasing passage through turbine penstocks and increasing passage when hydraulic head is reduced over the ROs. Additional passage mortality will occur when fish also pass downstream through BCL dam.
Access to other local spawning populations	Negligible improvement	Seasonal reservoir drawdowns will result in a negligible increase in the number and survival of bull trout moving below DET and BCL dams. However the distance to other spawning populations requires significant migration into the Clackamas, McKenzie or Middle Fork sub-basins. Those returning will be transported upstream via truck and haul from the Minto Adult Fish Facility.
Upstream passage at Detroit Dam	No change	Same as NAA

Rearing and foraging opportunity	Negligible (3b) to minor 3a) improvement	Seasonal reservoir drawdowns will result in a negligible increase in the number and survival of bull trout moving below DET Dam. No change for rearing upstream of the reservoir. Negligible improvement to downstream passage conditions will resuilt in some increase in the number of fish rearing or foraging below DET Reservoir. Fish must then also pass downstream of Big Cliff Dam to access stream habitat.

McKenzie

Table. Assessment of bull trout passage and key habitat attributes under the No Action Alternative (NAA) and assessed change the attributes under the Action Alternatives compared to the NAA in the McKenzie Sub-basin.

Attribute	Description of NAA
Emigration rate below Cougar Dam	Most emigration in autumn. RO is located above penstock outlet. Reservoir draw down in autumn decrease depth to RO improving attraction and passage opportunity however few pass downstream annually. Adult downstream passage rate assumed to be ~8%. Juvenile and sub-adult downstream passage rate assumed low because many observed to rear within or above CGR Reservoir.
Survival rate passing Cougar Dam	Most emigration in autumn. RO is located above penstock outlet. Reservoir draw down in autumn decreases depth to RO decreasing risk of injury associated with hydraulic head. Survival higher through RO than turbines (approximate at ~65%)
Access to other local spawning populations	Other local spawning populations occur in the McKenzie Sub-basin. For the local population above CGR Dam, accessing the nearest spawning populations requires passage downstream of CGR Dam. Existing dam conditions and operations results in a low downstream passage efficiency and passage survival. Those returning will be transported upstream via truck and haul from the CGR Adult Fish Facility. Limited evidence of genetic exchange among these local populations.
Upstream passage at Cougar Dam	A permanent upstream migrant trap and haul facilities exist at CGR Dam, operated early spring to late autumn, with demonstrated collection of bull trout.
Rearing and foraging opportunity	Juveniles rear upstream of CGR reservoir. Most sub-adults and adults forage in CGR reservoir between spawning events. Some sub-adults and adults move below CGR dam. Suitable habitat exists downstream of CGR Dam and in the Sub-basin at large.

Attribute	Change from NAA	Alternative 1
Emigration rate below Cougar Dam	No Change	Same as NAA
Survival rate passing Cougar Dam	No Change	Same as NAA
Access to other local spawning populations	No Change	Same as NAA

Upstream passage at Cougar Dam	No Change	Same as NAA
Rearing and foraging opportunity	No Change	Same as NAA

Attribute	**Change from NAA**	**Alternative 2a and 4**
Emigration rate below Cougar Dam	Moderate improvement	A floating screen structure (FSS) will provide for improved attraction and collection of downstream migrants at CGR dam. There is uncertainty in how many bull trout will use the structure however a surface route available during spring to autumn expected to increase downstream migrant rate from CGR Reservoir compared to the NAA.
Survival rate passing Cougar Dam	Major improvement	A floating screen structure (FSS) will provide for a safe surface passage route downstream of CGR dam. Bul trout entering will be collected and transported below the dam with a high survival rate. It is uncertain how many bull trout will use the structure, but assumed annual downstream passage rates will increased compared to the NAA.
Access to other local spawning populations	Moderate improvement	Operation of the FSS will increase downstream passage efficiency and downstream passage survival, increasing the number of bull trout below CGR Dam and therefore the potential for individuals to migrate and spawn with other populations. Those returning will be transported upstream via truck and haul from the CGR Adult Fish Facility.
Upstream passage at Cougar Dam	No change	Same as NAA
Rearing and foraging opportunity	Moderate improvement	Operation of the FSS will increase downstream passage efficiency and downstream passage survival, increasing the number of bull trout below CGR Dam accessing additional habitat. Observed growth rates and redd count trends suggest habitat availability is not significantly limiting. Those returning will be transported upstream via truck and haul from the CGR Adult Fish Facility.

Attribute	**Change from NAA**	**Alternative 2b, 3b and 5**
Emigration rate below Cougar Dam	Major improvement	Reservoir drawdowns in spring and fall to 25 ft. over the diversion tunnel will result in a significant number of bull trout passing downstream. A high rate of survival is assumed. Some will choose to emigrate upstream of the reservoir zone during drawdown periods.

Survival rate passing Cougar Dam	Major improvement	Reservoir drawdowns in spring and fall to 25 ft. over the diversion tunnel will result a high rate of survival for individuals passing downstream of CGR Dam.
Access to other local spawning populations	Major improvement	Reservoir drawdowns in spring and fall will result in many bull trout moving below CGR Dam. These individuals can then volitionally migrate and spawn with other populations. Those surviving to return will be transported upstream via truck and haul from the CGR Adult Fish Facility.
Upstream passage at Cougar Dam	No change	Same as NAA
Rearing and foraging opportunity	No change	Reservoir drawdowns in spring and fall will result in many bull trout moving below CGR Dam, thereby resulting in a shift in rearing and forage patterns occuring in the South Fork McKenzie bull trout local population. Suitable habitat and prey species exist downstream of CGR Dam and in the Sub-basin at large. There is uncertainty if there will be a net change in rearing and foraging opportunity with a shift from reservoir to below dam rearing and foraging becuase this habitat is at least partially occupied by local rainbow trout and other species, and further is stocked with rainbow trout annually.

Attribute	Change from NAA	Alternative 3a and NTOM
Emigration rate below Cougar Dam	Negligible improvement	Measure 40 (fall deeper draft) will result in a minor increase in the rate of downstream passage because the depth to the top of the RO outlet in fall is decreasing.
Survival rate passing Cougar Dam	Minor improvement	Prioritized use of RO during spring and autumn drawdowns will provide a minor improvement in passage survival rates by decreasing passage through turbine penstocks
Access to other local spawning populations	Negligible improvement	Reservoir drawdowns in spring and fall will result in a negligible increase in the number and survival of bull trout moving below CGR Dam. These individuals can then volitionally migrate and spawn with other populations. Those surviving to return will be transported upstream via truck and haul from the CGR Adult Fish Facility.
Upstream passage at Cougar Dam	No change	Same as NAA
Rearing and foraging opportunity	Negligible improvement	Reservoir drawdowns in spring and fall will result in a negligible increase in the number and survival of bull trout moving below CGR Dam. No change for rearing upstream of the reservoir. Negligible improvement to downstream

		passage conditions will result in some increase in the number of fish rearing or foraging below CGR Reservoir.

Middle Fork Willamette River

Table. Assessment of bull trout passage and key habitat attributes under the No Action Alternative (NAA) and assessed change the attributes under the Action Alternatives compared to the NAA in the Middle Fork Sub-basin.

Attribute	Description of NAA
Emigration rate below Hills Creek Dam	Most emigration in autumn. RO is located above penstock outlet. Reservoir draw down in autumn decrease depth to RO improving attraction and passage opportunity however few pass downstream annually. Adult downstream passage rate assumed to be ~8%. Juvenile and sub-adult downstream passage rate assumed low because many observed to rear within or above HCR Reservoir.
Survival rate passing Hills Creek Dam	Most emigration in autumn. RO is located above penstock outlet. Reservoir draw down in autumn decreases depth to RO improving attraction and passage opportunity. Survival assumed to be higher through RO. Survival assumed to be similar if not lower through the HCR RO compared to CGR (65%)
Access to other local spawning populations	There are no other local spawning populations in the Middle Fork Sub-basin therefore opportunity for access between populations in the McKenzie and Middle Fork very limited to none. Accessing the nearest spawning populations (McKenzie Sub-basin) requires passage downstream of both HCR and LOP dams. Downstream passage conditions at LOP result in most fish passing through turbine penstocks where survival is low. Those returning into the Middle Fork will be transported upstream via truck and haul from the Dexter Adult Fish Facility
Upstream passage at Hills Creek Dam	No permanent upstream migrant trap and haul facilities exist at HCR Dam. Ongoing trapping to continue as part of RM&E activities using temporary trapping in HCR tailrace.
Rearing and foraging opportunity	Juveniles rear upstream of HCR reservoirs. Most sub-adults and adults forage in HCR reservoir between spawning events. Some sub-adults and adults moving below HCR dam find suitable rearing and foraging habitat downstream

Attribute	Change from NAA	Alternative 1
Emigration rate below Hills Creek Dam	No Change	Same as NAA
Survival rate passing Hills Creek Dam	No Change	Same as NAA
Access to other local	Minor improvement	There are no other local spawning populations in the Middle Fork Sub-basin. Accessing the nearest spawning populations (McKenzie Sub-basin) will be improved with implementation

spawning populations		of the Lookout Point Floating Screen Structure, and those returning from moving back into the Middle Fork will be transported upstream via truck and haul from the Dexter Adult Fish Facility
Upstream passage at Hills Creek Dam	No Change	Same operation as under NAA with no changes in structural conditions. Ongoing trapping to continue as part of RM&E activities using tempory trapping in HCR tailrace. The AM plan BA Appendix includes a decision path for a new permanent trap below Hills Creek Dam
Rearing and foraging opportunity	No Change	Same operation as under NAA with no changes in structural conditions.

Attribute	Change from NAA	Alternatives 2a, 2b and 5
Emigration rate below Hills Creek Dam	No Change	Same as NAA
Survival rate passing Hills Creek Dam	No Change	Same as NAA
Access to other local spawning populations	Minor improvement	There are no other local spawning populations in the Middle Fork Sub-basin. Accessing the nearest spawning populations (McKenzie Sub-basin) will be improved with implementation of the Lookout Point Floating Screen Structure, and those returning back into the Middle Fork will be transported upstream via truck and haul from the Dexter Adult Fish Facility
Upstream passage at Hills Creek Dam	No change	Same operation as under NAA with no changes in structural conditions. Ongoing trapping to continue as part of RM&E activities using tempory trapping in HCR tailrace. The AM plan BA Appendix includes a decision path for a new permanent trap below Hills Creek Dam
Rearing and foraging opportunity	No change	No change in rearing and foraging opportunity upstream, within and below Hills Creek Reservoir for juveniles or adults

Attribute	Change from NAA	Alternatives 3a and 3b
Emigration rate below Hills Creek Dam	Negligible improvement	Measure 40 (fall deeper draft) will negligibly change rate of downstream passage because the depth to the top of the RO outlet in auturm is decreasing by 2 ft between the NAA and alternative operations in order to achieve a 25 ft depth to outlet target.
Survival rate passing Hills Creek Dam	Minor improvement	Prioritized use of RO under the Measure 40 operation will provide a minor improvement in passage survival rates by decreasing passage through turbine penstocks
Access to other local spawning populations	Minor improvement	There are no other local spawning populations in the Middle Fork Sub-basin. Accessing the nearest spawning populations (McKenzie Sub-basin) will be improved with implementation of Measure 40 in autumn at both HCR and LOP dams, and those returning back into the Middle Fork will be transported upstream via truck and haul from the Dexter Adult Fish Facility
Upstream passage at Hills Creek Dam	Major improvement	Improved fish attraction, trapping and handling conditions for collection and transport of fish upstream with construction of an adult fish collection facility in HCR Dam tailrace.
Rearing and foraging opportunity	No change	Reservoir operations will result in negligible reductions in rearing and foraging opportunity in HCR Reservoir. No change for rearing upstream of the reservoir. Negligible improvement to downstream passage conditions will resuilt in some fish rearing or foraging below HCR Reservoir.

Attribute	Change from NAA	Alternative 4
Emigration rate below Hills Creek Dam	Moderate improvement	A floating screen structure (FSS) will provide for improved attraction and collection of downstream migrants at HCR dam. There is uncertainty in how many bull trout will use the structure however a surface route available during spring to autumn expected to increase annual downstream migrant rate from HCR Reservoir compared to the NAA.
Survival rate passing Hills Creek Dam	Major improvement	A floating screen structure (FSS) will provide for a safe surface passage route downstream of HCR dam. Bull trout entering will be collected and transported below the dam with a high survival rate. It is uncertain how many bull trout will use the structure.
Access to other local	Moderate improvement	There are no other local spawning populations in the Middle Fork Sub-basin. Accessing the nearest spawning populations (McKenzie Sub-basin) will be improved with operation of an

spawning populations		FSS at both HCR and LOP dams. Fish returning into the Middle Fork will be transported upstream via truck and haul from the Dexter Adult Fish Facility. Bul trout entering collection facilities will be collected and transported above and below the dam with a high survival rate. It is uncertain how many bull trout will use the FSS facilities at HCR and LOP dams.
Upstream passage at Hills Creek Dam	Major improvement	Improved fish attraction, trapping and handling conditions for collection and transport of fish upstream with construction of an adult fish collection facility in HCR Dam tailrace.
Rearing and foraging opportunity	Moderate improvement	A floating screen structure (FSS) will increase access to rearing and foraging habitat below HCR Dam. It is uncertain how many bull trout will use the structure.

Attribute	Change from NAA	Alternative - NTOM
Emigration rate below Hills Creek Dam	Negligible improvement	Near term operations will negligibly change rate of downstream passage because the depth to the top of the RO outlet in auturm is decreasing by 2 ft between the NAA and alternative operations in order to achieve a 25 ft depth to outlet target.
Survival rate passing Hills Creek Dam	Minor improvement	Prioritized use of RO in autumn will provide a minor improvement in passage survival rates by decreasing passage through turbine penstocks
Access to other local spawning populations	Negligible improvement	There are no other local spawning populations in the Middle Fork Sub-basin. Accessing the nearest spawning populations (McKenzie Sub-basin) will be improved with autumn drawdown and prioritized RO operations and trap and haul back via truck and haul from the Dexter Adult Fish Facility
Upstream passage at Hills Creek Dam	No change	Same operation as under NAA with no changes in structural conditions. Ongoing trapping to continue as part of RM&E activities using tempory trapping in HCR tailrace. The AM plan BA Appendix includes a decision path for a new permanent trap below Hills Creek Dam
Rearing and foraging opportunity	No change	Reservoir operations will result in negligible reductions in rearing and foraging opportunity in HCR Reservoir or for rearing upstream of the reservoir. Negligible improvement to downstream passage conditions will resuilt in some fish rearing or foraging below HCR Reservoir.

3.2.3 Population Assessment and Effects Determinations

North Santiam

Table. Assessment of bull trout population attributes and effects determinations for WVS EIS Alternatives compared to the No Action Alternative in the North Santiam Sub-basin.

Alternative	Population abundance and productivity	Distribution and habitat availability	Life history and genetic diversity	Overall effect categorization relative to NAA
NAA	It was assumed that reintroduction of bull trout above DET Dam will result in population growth and stabilization at a spawner abundance in the range occurring above HCR dams (40 redds) and CGR (75 redds).	Similar to other local populations above WVS dams, it was assumed bull trout above DET would spawn, incubates and rears upstream of DET Dam. A few sub-adults and adults would move downstream of DET and BCL dam annually, accessing additional forage habitat.	Similar to other local populations above WVS dams, it was assumed both resident and adfluvial lifehistory forms would occur above DET Dam. Due to proximity with other local populations and lack of adequate spawning habitat below DET Dam, genetic exchange among local would not be expected.	(not applicable)
1, 2a, 2b, 4 and 5	Minor improvement	Moderate improvement	Minor improvement	Minor improvement
Assumptions	No change in spawning habitat availability or	A floating screen structure (FSS) will increase	Both resident and adfluvial life history forms	Improved survival for the small percentage

	access. Moderate improvement for downstream passage with FSS operation providing access to additional forage and rearing habitat, however overall rate of downstream passage assumed to be low. Increased survival of emigrants could result in a minor increase in recruitment rates and spawner abundance if downstream emigrants return upstream at a high rate. Ongoing upstream passage with operation of the Minto adult fish collection facilty allowing adults to return upstream to spawn.	access to rearing and foraging habitat below CGR Dam. Downstream passage rates are presumed to be low, but increased compared to the NAA. Upstream passage with operation of an adult fish collection facility below CGR Dam will allow adults to return upstream to spawn.	would occur. FSS will support increase in emigrants rearing or foraging downstream of DET and BCL dams. Potential for genetic exchange very low due to distance from other local spawning population.	of fish assumed to pass downstream of DET and BCL dams and back up. Increased access to rearing and foraging habitat in the sub-basin downstream of dams. There is risk that some individuals moving downstream of dams do not return back upstream to spawn resulting in a loss of abundance for the population.

3a and 3b	Negligible improvement	Negligible to Minor improvement	Negligible improvement	Negligible improvement
Assumptions	No change in spawning habitat availability or access. No change for rearing and growth upstream of the reservoir. Negligible improvement to downstream passage conditions will result in some increase in the number of fish rearing or foraging below dams wth less exposure to trout fishery in DET Reservoir.	No change in spawning habitat availability or access. No change for rearing upstream of DET Reservoir. Reduced reservoir rearing and foraging habitat due to seasonal deep drawdowns. Negligible improvement to downstream passage conditions will result in some increase in the number of fish rearing or foraging below DET Reservoir.	Negligible improvement to downstream passage conditions will result in some increase in the number of fish rearing or foraging below DET Reservoir, with potential to then migrate out of the Sub-basin. Potential for genetic exchange very low due to distance from other local spawning population.	Moderate improvement to downstream passage conditions will result in some increase in the number of fish rearing or foraging below DET and BCL reservoirs. Ongoing operation of the Minto adult fish facility will provide upstream passage above DET Dam, allowing emigrants to re-access available spawning habitat and spawn.

McKenzie

Table. Assessment of bull trout population attributes and effects determinations for WVS EIS Alternatives compared to the No Action Alternative in the McKenzie Sub-basin.

Alternative	Population abundance and productivity	Distribution and habitat availability	Life history and genetic diversity	Overall effect categorization relative to NAA

NAA	The overall trend in redd counts since the 1990's shows a positive growth trend indicating positive recruitment trends. Spawner abundance achieved in recent years expected to maintain due to habitat conditions available.	The local S. Fk. McKenzie population spawns, incubates and rears upstream of CGR Dam. A few sub-adults and adults observed downstream of CGR Dam annually, accessing additional forage habitat. Population growth trend suggests potential additional habitat capacity available above CGR Dam.	Both resident and adfluvial life history forms occur. Observation of genetic exchange by volitional migration among local McKenzie Sub-Basin populations very limited.	(not applicable)
1	No Change	No Change	Negligible improvement	No Change
Assumptions	Same as NAA	Same as NAA	Potential for genetic exchange with other populations outside of the Middle Fork negligibly improved with implementation of the Lookout Point Floating	No change in abundance, productivity or distribution/habitat availability. Negligible improvement in potential genetic exchange with other populations.

			Screen Structure, and Dexter Adult Fish Facility. Downstream passage rates are presumed to be low.	
2a and 4	Minor improvement	Moderate improvement	Moderate improvement	Moderate improvement
Assumptions	Moderate improvement for downstream passage with FSS operation providing access to additional forage and rearing habitat, or potential to spawn with other populations. Increased survival of emigrants could result in a minor increase in recruitment rates and spawner abundance if downstream emigrants return at a high rate. Ongoing upstream	A floating screen structure (FSS) will increase access to rearing and foraging habitat below CGR Dam. Downstream passage rates are presumed to be low, but increased compared to the NAA. Upstream passage with operation of an adult fish collection facilty below CGR Dam will allow adults to return upstream to spawn.	Both resident and adfluvial life history forms occur. Potential for genetic exchange among populations by volitional migration among local McKenzie Sub-Basin populations will increase with improved downstream passage efficiency and survival and ongoing adult fish facility operation.	Improved survival for the small percentage of fish passing downstream and back upstream. Increased access to rearing and foraging habitat in the McKenzie Sub-basin downstream of CGR Dam. Individuals must return back upstream of CGR Dam to spawn otherwise emigrants effectively result in a loss of abundance for population.

	passage with operation of an adult fish collection facility below CGR Dam allowing adults to return upstream to spawn.			
2b, 3b and 5	Minor negative impact	Minor improvement	Moderate improvement	Minor negative impact
Assumptions	A significant shift in rearing and foraging habitat will occur due to deep reservoir drawdowns in spring and fall. Rearing and foraging habitat exists downstream however growth rates potentially will be lower than compared to in-reservoir due to prey availability. Risks increase for injury or mortality in local trout fisheries	A significant shift in distribution will occur for rearing and foraging due to deep reservoir drawdowns in spring and fall. Most individuals will move downstream and rearing in flow reaches compared rearing and foraging in CGR Reservoir. It is unclear if this results in a net change in habitat availability given downstream reaches are	A significant increase in stream rearing and decrease in reservoir rearing and foraging will occur. Potential for genetic exchange among populations by volitional migration among local McKenzie Sub-Basin populations will increase with improved downstream passage efficiency and survival and ongoing adult fish facility operation.	A significant shift in rearing and foraging habitat will occur due to deep reservoir drawdowns in spring and fall. Rearing and foraging habitat exists downstream however growth rates potentially will be lower than compared to in-reservoir due to prey availability differences. Potential for improved genetic diversity with improved ability of adult spawning to occur among populations. Risk increases for injury or mortality in local trout fisheries

	occurring in the McKenzie.	occupied by native rainbow trout and stocked hatchery trout. Upstream passage with operation of an adult fish collection facility below CGR Dam will allow adults to return upstream to spawn.		occurring in the McKenzie.
3a and NTOM	Negligible improvement	Negligible improvement	Negligible improvement	Negligible improvement
Assumptions	Reservoir drawdowns in spring and fall will result in a negligible increase in the number and survival of bull trout moving below CGR Dam. No change for rearing upstream of the reservoir. Negligible improvement to downstream passage conditions will result in some	No change for rearing upstream of or within CGR Reservoir. Negligible improvement to downstream passage conditions will result in some increase in the number of fish rearing or foraging below CGR Reservoir, however risks of injury and mortality in the McKenzie trout fishery	Negligible improvement to downstream passage conditions will result in some increase in the number of fish rearing or foraging below CGR Reservoir, with potential to then migrate and spawn in other local McKenzie Sub-basin populations.	Negligible improvement to downstream passage conditions will result in some increase in the number of fish rearing or foraging below CGR Reservoir, with potential to then migrate and spawn in other local McKenzie Sub-basin populations. Ongoing operation of the adult fish facility will provide upstream passage at CGR Dam, allowing emigrants

	increase in the number of fish rearing or foraging below CGR Reservoir, however risks of injury and mortality in the McKenzie trout fishery increases below CGR Dam.	increases below CGR Dam.		to re-enter and spawn.

Middle Fork Willamette River

Table. Assessment of bull trout population attributes and effects determinations for WVS EIS Alternatives compared to the No Action Alternative in the Middle Fork Sub-basin.

Alternative	Population abundance and productivity	Distribution and habitat availability	Life history and genetic diversity	Overall effect categorization relative to NAA
NAA	Population growth trend over the previous 9 years. Spawner abundance expected to stabilize with habitat availability. No major limiting factors identified that would reduce recruitment	Distributed in the Middle Fork Sub-basin above HCR Dam. Reservoir and tributaries provide for spawning, incubation, rearing and foraging. Recent population growth trend suggests	Both resident and adfluvial life history forms occur. Genetic exchange by volitional emigration blocked by dams and limited by poor habitat and other limiting factors at low elevations.	(not applicable)

	rates and average spawner abundance from currently levels.	additional habitat capacity available.		
1	No Change	No Change	Negligible improvement	No Change
Assumptions	Same as NAA	Same as NAA	Potential for genetic exchange with other populations outside of the Middle Fork negligibly improved with implementation of the Lookout Point Floating Screen Structure, and Dexter Adult Fish Facility. Downstream passage rates are presumed to be low.	No change in abundance, productivity or distribution/habitat availability. Negligible improvement in potential genetic exchange with other populations.
2a, 2b and 5	No Change	No Change	Negligible improvement	No Change
Assumptions	Same as NAA	Same as NAA	Potential for genetic exchange with other populations outside of the Middle Fork negligibly improved with	No change in abundance, productivity or distribution/habitat availability. Negligible improvement in potential genetic

			implementation of the Lookout Point Floating Screen Structure, and Dexter Adult Fish Facility. Downstream passage rates are presumed to be low.	exchange with other populations.
3a and 3b	Minor improvement	Negligible improvement	Negligible improvement	Negligible improvement
Assumptions	Minor improvement with combination of up and downstream passage conditions: negligible improvement in downstream passage with prioritized use of the RO in autumn and major improvement in upstream passage with operation of an adult fish collection facility allowing aduls to return upstream to spawn.	Negligible net improvement in rearing and foraging habitat availability: Reservoir operations will result in negligible reductions in rearing and foraging opportunity in HCR Reservoir. No change for rearing upstream of the reservoir. Negligible improvement to downstream passage conditions will resuilt in some fish rearing or	Potential for genetic exchange with other populations outside of the Middle Fork negligibly improved with implementation of operations in autumn at both HCR and LOP dams, and those returning back into the Middle Fork will be transported upstream via truck and haul from the Dexter Adult Fish Facility. However downstream passage rates are	Major improvement in upstream passage conditions, however downstream passage rates are presumed low. Negligible improvement in rearing and forage habitat access below HCR Dam, and potential for genetic exchange.

		foraging below HCR Reservoir.	presumed to be low.	
4	Moderate improvement	Moderate improvement	Moderate improvement	Moderate improvement
Assumptions	Moderate improvement for downstream passage with FSS operation, and major improvement for upstream passage with operation of an adult fish collection facility below HCR Dam allowing adults to return upstream to spawn. Downstream passage rates are presumed to be low.	A floating screen structure (FSS) will increase access to rearing and foraging habitat below HCR Dam. Downstream passage rates are presumed to be low. Upstream passage with operation of an adult fish collection facility below HCR Dam will allow adults to return upstream to spawn.	There are no other local spawning populations in the Middle Fork Sub-basin. Accessing the nearest spawning populations (McKenzie Sub-basin) will be improved with operation of an FSS at both HCR and LOP dams. Fish returning into the Middle Fork will be transported upstream via truck and haul from the Dexter Adult Fish Facility. Bul trout entering collection facilities will be collected and transported above and below the dam with a high survival rate. Downstream	Improved survival for the small percentage of fish passing downstream and back upstream. Increased access to rearing and foraging habitat in the North Fork Middle; however, individuals must return back upstream of HCR to spawn otherwise emigrants effectively result in a loss of abundance for population. Increased survival for fish attempting to migrate to and from nearby populations in McKenzie Sub-basin.

			passage rates from HCR Reservoir are presumed to be low.	
NTOM	Negligible improvement	Negligible improvement	Negligible improvement	Negligible improvement
Assumptions	Negligible net improvement with combination of up and downstream passage conditions: prioritized use of the RO in autumn and adult trapping from tailrace.	Negligible net improvement in rearing and foraging habitat availability: Reservoir operations will result in negligible reductions in rearing and foraging opportunity in HCR Reservoir. No change for rearing upstream of the reservoir. Negligible improvement to downstream passage conditions will result in some fish rearing or foraging below HCR Reservoir.	Potential for genetic exchange with other populations outside of the Middle Fork negligibly improved with implementation of operations in autumn at both HCR and LOP dams, and those returning back into the Middle Fork will be transported upstream via truck and haul from the Dexter Adult Fish Facility. However downstream passage rates are presumed to be low.	Negligible improvement in passage conditions at HCR Dam. Downstream passage rates are presumed low. Negligible improvement in rearing and forage habitat access below HCR Dam, and potential for genetic exchange.

3.2.4 References

Kock, T.J., Perry, R.W., Hansen, G.S., Haner, P.V., Pope, A.C., Plumb, J.M., Cogliati, K.M., and Hansen, A.C., 2017, Evaluation of Chinook Salmon Fry Survival at Lookout Point Reservoir, Oregon, 2017: U.S. Geological Survey report.

Monzyk, F.R., J.D. Romer, R. Emig, and T.A. Friesen. 2014. Life-history characteristics of juvenile spring Chinook salmon rearing in Willamette Valley reservoirs. Annual Report to U.S. Army Corps of Engineers, Portland, Oregon. Task Order W9127N-10-2-00080007. Oregon Department of Fish and Wildlife, Corvallis, OR.

McElhany P, Ruckelshaus MH, Ford MJ, Wainwright TC, Bjorkstedt EP. 2000. Viable salmonid populations and the conservation of evolutionarily sigificant units. U.S. Dept. Commer. NOAA Tech. Memo. NMFSNWFSC-42. Seattle, WA.

Murphy, CA, Taylor, G, Pierce, T, Arismendi, I, Johnson, SL. Short-term reservoir draining to streambed for juvenile salmon passage and non-native fish removal. Ecohydrology. 2019; 12:e2096. https://doi.org/10.1002/eco.2096

CHAPTER 4 - ASSESSMENT OF CLIMATE CHANGE ON FISH

4.1 INTRODUCTION

Climate change is a large-scale environmental factor that is part of the environmental baseline described in Chapter 2. Also see a description of climate change under the baseline in section 4.17.1. This analysis describes the expected performance of and effects on fish under the EIS alternatives.

Hydrologic models configured with climate changed meteorology are unable to adequately capture the effects of regulation in the Willamette Valley. Current climate changed projections are unlikely to be actionable in terms of if they can be applied at a fine enough spatial and temporal (time step) resolution to adequately give insight into habitat response. There is a great deal of uncertainty surrounding climate change hydrology and meteorology that would be difficult to capture in an environmental impact assessment. We therefore applied a more qualitative assessment approach relying on methods and results presented in the peer reviewed assessment completed by Crozier et al. (2019).

Crozier et al. (Crozier et al. 2019; herein Crozier) conducted a comprehensive climate vulnerability assessment for Pacific salmon and steelhead (Oncorhynchus spp.) for distinct population segments (DPSs) in the U.S. They followed the climate vulnerability assessment method developed by Hare et al. (Hare et al. 2016), which is now being implemented for U.S. marine and anadromous species by NOAA Fisheries (Link, Griffis, and Busch 2015). The Crozier assessment was based on three components of vulnerability (i.e., relative threats) to climate change for each DPS: 1) biological sensitivity, which is a function of individual species characteristics; 2) climate exposure, which is a function of geographical location and projected future climate conditions; and 3) adaptive capacity, which describes the ability of a DPS to adapt to rapidly changing environmental conditions.

Crozier found that in general, DPSs with the highest sensitivity and exposure and lowest adaptive capacity were the most vulnerable to climate change. For spring Chinook DPSs assessed, their findings suggest a potential range contraction toward the coast for anadromous life histories unless access to higher-elevation habitats is restored and habitat quality in rearing areas and migration corridors is improved (Herbold et al. 2018). Steelhead DPSs tended to score lower in sensitivity than Chinook in the same region and were found to have an intermediate vulnerability between high and moderate. Results from Crozier for Upper Willamette River (UWR) Spring Chinook and winter steelhead are presented in Table 5.2-9.

Table 4.1-1. UWR Chinook and Steelhead Climate Change Vulnerability Assessment *

Vulnerability	UWR Chinook	UWR steelhead
Overall vulnerability	Very high	High
Biological sensitivity	Very high	High
Climate exposure	High	High
Adaptive capacity	Moderate	Moderate

Note: * Climate change vulnerability assessment results from Crozier et al. (2019) for UWR Chinook and UWR steelhead.

Upper Willamette River spring Chinook (UWR Chinook) endure a temperature-stressed adult migration and summer holding period and were specifically found to be highly vulnerable to temperature increases due to long adult migrations in spring and summer through highly modified rivers, along with exposure to high summer stream temperatures during the holding period prior to spawning. Under existing fish passage conditions at dams in the Willamette, this DPS was found to have a very high overall vulnerability, very high biological sensitivity, high climate exposure and a moderate adaptive capacity. Access for salmonids to high elevation habitat to reduce effects of climate change has been found important by others (Myers et al. 2018). Myers et al. (2018) summarized that climate change is expected to reduce UWR Chinook adult abundance and increase the risk of extinction in the North Santiam River, South Santiam River, McKenzie River, and Middle Fork Willamette River.

CHAPTER 4 - METHODS

The assessment framework from Crozier et al. (2019) was applied to score vulnerability of UWR Chinook for each EIS alternative under climate change. Spring Chinook were chosen as the focal species and results are assumed to be representative of other native fish species in the Willamette for the following reasons. Vulnerability was assessed as higher for UWR Chinook than for UWR steelhead by Crozier, and we assumed results from an assessment of Chinook would therefore be conservative when applying those results to steelhead. For bull trout we assumed the scoring for spring Chinook would be relatively similar for bull trout considering the effects of climate change on habitat attributes will be similar among salmonid species (e.g., Falke et al. 2014), although somewhat of an underestimate for bull trout due to their greater dependence on cold water (Reiman and McIntyre 1993).

For Pacific lamprey, lacking reintroduction plans, we assumed this species would continue to reside below WVS dams, with the exception of Fall Creek Dam. As for bull trout and steelhead we also assumed results for Chinook salmon would be reasonably applicable due to similar effects of climate change on aquatic habitat used by Pacific lamprey. For example, Wang et al. (2020) found that vulnerability of Pacific lamprey generally increased in three Global Climate Models which was attributed to degraded stream temperature and hydrologic conditions, a similar finding to Crozier for anadromous salmonids. Finally, since Alternatives 2B and 5 are comprised of the same measures (only differing in minimum flow targets), and hydrologic modeling showed very little to no differences in resulting reservoir and downstream river flows, these two alternatives were treated as equivalent for purposes of this assessment.

Several attributes assessed by Crozier are not affected by the WVS, and therefore results would not differ among alternatives for these attributes. For completing the assessment, we assumed the following specific attributes as defined by Crozier would not differ among EIS alternatives, and therefore applied results for these from Crozier:

- **a.** Ocean Acidification
- **b.** Sea Surface Temperature

c. Hydrologic Regime (above dam only)

d. Cumulative Life-Cycle Effects

e. Adaptive Capacity

Other attributes considered by Crozier were considered to be directly affected by WVS alternatives, and criteria were developed to categorize each attribute for each EIS alternative from a low to very high. Criteria for assigning these categories are provided below. Regarding the 'hydrologic regime' attribute, it was assumed the unregulated hydrologic regime (precipitation inputs and natural stream flows flowing into WVS reservoirs or contributing to flows below WVS dams) is the same across alternatives.

We account for effects from below dams on stream flows and water temperatures associated with each alternative under the attributes 'stream temperature' and 'summer water deficit'. The categorized bins were then assigned a numerical value (low = 1, moderate = 2, high = 3, very high = 4), consistent with Crozier. Finally overall vulnerability was determined by multiplying the numeric values for sensitivity, exposure and adaptive capacity, and assigning a total score for each alternative based on the product. The product values were converted to cumulative vulnerability categories using the scoring logic presented in Crozier et al (2019) Table 3. Specific methods and scoring approaches for individual attribute are presented below.

4.2 STREAM TEMPERATURES

We used the estimated percent change in above dam redd capacity calculated from redd capacity results included in Bond et al. (2017) Table 1.5 has an indicator of effects from stream temperatures above dams. Water temperature effects below dams are accounted for in extinction risk estimates from life cycle models applied for assessing population viability (see Population Viability section below). Criteria for categorizing the vulnerability of UWR Chinook to stream temperatures based on the percentage of spawning habitat available under each alternative assuming is described in Table 2.1-1.

Table 4.2-1. Vulnerability criteria relating to the percent of accessible future Chinook spawning habitat above WVS dams.

Percent	<25%	25-49%	50-74%	>=75%
Vulnerability criteria	Very High	High	Moderate	Low

4.3 SUMMER WATER DEFICIT

Crozier used the evapotranspiration differential (potential minus actual), also known as the summer water deficit. For above dam reaches, we applied results from Crozier (a moderate categorization) for summer water deficit for all sub-basins. For below dam reaches, reservoirs have an important effect on summer flows and therefore we applied a qualitative assessment of reservoir storage availability with future climate change as a proxy for stream flow below dams, categorizing the change in reservoir water storage as similar, less, much less, or no storage (see WVS EIS Appendix B, Chapter 6, Qualitative Assessment of Climate Change Impacts to Hydrology). The most common category applied for WVS summer reservoir storage change was applied for each alternative. Criteria for categorizing the vulnerability of UWR Chinook to summer water deficit based on the change in reservoir storage under each alternative is described in Table 2.1-1a.

Table 2.1-1a. Vulnerability criteria for change in reservoir storage compared to the NAA.

Change in reservoir storage	No storage	Much less	Less	Similar
Vulnerability criteria	Very High	High	Moderate	Low

When developing this approach, we also considered including changes in summer temperatures, and the availability of High Cascade base flows, in the Santiam, McKenzie and Middle Fork Willamette sub-basins. There was little difference in the estimated change in summer temperatures between subbasins (WVS EIS Appendix F1 Summary and Conclusions, WVS EIS Appendix F2 3.2.3, Figures 11-54). Furthermore, redd capacities changed very little above WVS dams under future climate change temperature scenarios (Myers et al. 2018) where significant contributions from High Cascade base flows occur (see Tague and Grant, 2004), and so we assumed a resiliency to summer water deficit, due to the greater contribution of High Cascade base flow in these sub-basins, is reasonably reflected in the assessment under the attributes where redd capacities are applied.

4.4 ADULT FRESHWATER STAGE

The adult freshwater stage attribute as assessed by Crozier considered stressors encountered during upstream migration, holding and spawning. Considerations included migration distance and duration and climate stressors encountered including temperature and flow constraints. Resiliency (i.e., the ability to anticipate, prepare for, and adapt to changing conditions) for fish passage and temperature management at dams was considered in terms of operational flexibility for the purposes of this assessment. Downstream fish passage resiliency of the alternatives was assessed based on the type of downstream fish passage operations included (specifically the number of spring deep drawdowns) and the number of downstream fish passage structures.

Table 4.4-1. Vulnerability criteria relating to the resiliency of downstream fish passage at dams to climate change.

Vulnerability	Very High to High	Moderate	Low
Resiliency	Very Low to Low	Moderate	High
Flexibility in DSP ops	spring deep drawdowns at 1 or fewer dams	spring deep drawdowns at 2-3 dams	spring deep drawdowns at 4-5 or more dams

Vulnerability	Very High to High	Moderate	Low
# of DSP structures	0-1 dams	2-2.5 dams	3 or more dams

4.5 POPULATION VIABILITY

We assumed 3 populations need to be at low extinction risk for a low multi-population vulnerability criteria score. We assumed this as a conservative application of the UWR 2011 Recovery Plan delisting criteria relating to population viability. We then assigned a moderate vulnerability when 2 populations were at a low risk of extinction, high vulnerability when 1 population was at a low risk of extinction, and very high vulnerability when no populations were at a low risk of extinction.

Criteria for categorizing the vulnerability of UWR Chinook viability based on the number of populations affected by the WVS at low risk of extinction in each WVS EIS alternative (Table 3.8-80).

Table 4.5-1. UWR Chinook Vulnerability Category Criteria for Climate Change.

Number of Populations at Low Risk	Climate Vulnerability Criteria
3	Low
2	Moderate
1	High
0	Very High

4.6 HATCHERY INFLUENCE

The same scores applied for Population Viability were applied for hatchery influence. When population extinction risk is low when estimated in UBC and NWFSC lifecycle models, this reflects that cohort replacement for natural origin spawners is near 1 and that fish passage has improved allowing release of hatchery fish above dams to be reduced.

4.7 OTHER STRESSORS

Changes in attributes highlighted by Crozier for other stressors were also assessed for UWR Chinook: above dam habitat access, survival of transported fish, PSM, non-native fishes and contaminants. We applied above dam future habitat availability under future temperature scenarios from Bond et al. 2016 for above dam habitat access where fish passage is improved in an EIS alternative (see criteria under “stream temperatures” above). For PSM, we assessed the number of new adult traps at WVS dams meeting NMFS criteria as a proxy for managing transport survival and timing in each alternative (see table below). For resiliency in temperature management at dams, we assessed the number of structures included in each alternative, assuming structures allow for more flexibility in managing water temperature discharged at a range of pool elevations compared to operations using existing dam outlets. For contaminants and non-natives, we based scores on results from Crozier et al. 2019.

Table 4.7-13. Vulnerability criteria for Chinook pre-spawn mortality relating to the number of adult trapping facilities meeting NMFS criteria below dams in each alternative.

	Number of adult traps		
	≤5	6	7
Vulnerability criteria	High	Moderate	Low

Table 4.7-24. Vulnerability criteria relating to resiliency in water temperature management at WVS dams relating to the number of structures for temperature management present across dams in each alternative.

	Number of temperature structures		
	1	2	3
Vulnerability criteria	High	Moderate	Low

4.8 RESULTS

The cumulative vulnerability of UWR Chinook was rated as high to very high across the alternatives (Table 2.6-1). These high and very high ratings reflect scores included for ocean acidification, seas surface temperature, hydrologic regime and cumulative life-cycle effects. Among the alternatives, 2a and 4 received the lowest cumulative vulnerability scores (10.0), Alternative 2b had the next lowest score (12.0), followed by Alternative 1 (12.8) (Table 2.6-2). Results were driven by better (lower) population viability and hatchery influence scores as compared to other alternatives. These alternatives include structural measures for downstream passage and temperature control. These structural measures allow for water storage operations used to augment low river flows in summer, and permit operational flexibility compared to operational measures for fish passage and water temperatures. Alternative 2b includes a drawdown of Cougar Reservoir to the diversion tunnel each spring and fall. Although water storage is impacted by these operations, base flows below Cougar Dam in the mainstem McKenzie River will remain stable due to ground water inputs within this subbasin. As a result, Chinook habitat access and migration will improve at Cougar Dam, and more natural water temperatures below Cougar Dam will occur. Alternative 3a and 3b had the highest vulnerability scores (14.9). Vulnerability scores for 3a and 3b reflect poor results for summer water deficit below dams, population viability, and hatchery influence attributes when compared to other alternatives. Reservoir drawdowns included in Alternative 3a and 3b reduce the availability of storage water to augment low flows in summer and water quality below WVS dams, and only provide limited improvement in fish passage conditions at WVS dams, constraining UWR Chinook population viability. Operational measures reduce operational flexibility, reducing resiliency to climate change.

Table 4.8-1. UWR Spring Chinook Climate Vulnerability under NAA and EIS alternatives (Alt.).

Attribute	NAA[1]	Alt. 1	Alt. 2a	Alt. 2b	Alt. 3a	Alt. 3b	Alt. 4
Exposure Attributes							
ocean acidification[1]	Very high	Very high	Very high	Very high	Very high	Very high	Very high
stream temperature	Very High	Moderate	Low	Low	Low	Low	Low
sea surface temperature[1]	High	High	High	High	High	High	High
hydrologic regime[1]	High	High	High	High	High	High	High
summer water deficit_above dams[1]	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
summer water deficit_below dams	Moderate	Moderate	Moderate	Moderate	High	High	Moderate
Sensitivity Attributes							
adult freshwater stage	Very High	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
cumulative life-cycle effects[1]	Very High	Very High	Very High	Very High	Very High	Very High	Very High
population viability	Very High	Moderate	Low	Moderate	High	High	Low
hatchery influence	Very High	Moderate	Low	Moderate	High	High	Low
other stressors	High	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Adaptive Capacity[1]	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate

Table footnote 1. Results for the NAA and attributes marked with a (1) are adopted from Crozier et al. 2019.

Table 4.8-2. Climate Change Vulnerability for UWR Chinook Salmon by Attribute.

Attribute	NAA[1]	Alt1	Alt2a	Alt2b	Alt3a	Alt3b	Alt4
Exposure Attributes	3.0	2.7	2.5	2.5	2.7	2.7	2.5
ocean acidification[1]	4.0	4.0	4.0	4.0	4.0	4.0	4.0
stream temperature	4.0	2.0	1.0	1.0	1.0	1.0	1.0
sea surface temperature[1]	3.0	3.0	3.0	3.0	3.0	3.0	3.0
hydrologic regime[1]	3.0	3.0	3.0	3.0	3.0	3.0	3.0
summer water deficit above dams[1]	2.0	2.0	2.0	2.0	2.0	2.0	2.0
summer water deficit below dams	2.0	2.0	2.0	2.0	3.0	3.0	2.0
Sensitivity Attributes	3.8	2.4	2.0	2.4	2.8	2.8	2.0
adult freshwater stage	4.0	2.0	2.0	2.0	2.0	2.0	2.0
cumulative life-cycle effects[1]	4.0	4.0	4.0	4.0	4.0	4.0	4.0
population viability	4.0	2.0	1.0	2.0	3.0	3.0	1.0
hatchery influence	4.0	2.0	1.0	2.0	3.0	3.0	1.0
other stressors	3.0	2.0	2.0	2.0	2.0	2.0	2.0
Adaptive Capacity[1]	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Overall Vulnerability	**22.8**	**12.8**	**10.0**	**12.0**	**14.9**	**14.9**	**10.0**
	Very High	**Very High**	**High**	**Very High**	**Very High**	**Very High**	**High**

Table Notes: Overall vulnerability results are based on conversion of assessment categories to numeric scores. Results from Crozier et al. (2019) are applied for the NAA. Results for attributes noted with a superscript 1 are also from Crozier et al. (2019), assuming these attributes would not be changing under each WVS EIS alternative.

4.9 REFERENCES

Bond, M, T Nodine, M Sorel, T Beechie, G Pess, J Myers, and R Zabel. 2017. Estimates of UWR Chinook and Steelhead spawning and rearing capacity above and below Willamette Project (WP) Dams. STUDY CODE: APH-15-04-DET. Northwest Fisheries Science Center, National Marine Fisheries Service, Seattle, Washington.

Crozier LG, MM McClure, T Beechie, SJ Bograd, DA Boughton, M Carr, et al. 2019. Climate vulnerability assessment for Pacific salmon and steelhead in the California Current Large Marine Ecosystem. PLoS ONE 14(7): e0217711.

Falke, JA, RL Flitcroft, JB Dunham, KM McNyset, PF Hessburg, and GH Reeves. 2015. Climate change and vulnerability of bull trout (Salvelinus confluentus) in a fire-prone landscape. Canadian Journal of Fisheries and Aquatic Sciences. 72(2): 304-318. https://doi.org/10.1139/cjfas-2014-0098.

Hare JA, WE Morrison, MW Nelson, MM Stachura, EJ Teeters, RB Griffis, et al. 2016. A vulnerability assessment of fish and invertebrates to climate change on the northeast U.S. continental shelf. PLoS ONE. 2016; 11(2):e0146756. https://doi.org/10.1371/journal.pone.0146756.

Herbold B, SM Carlson, R Henery. 2018. Managing for salmon resilience in California's variable and changing climate. San Fran Est Wat Sci. 2018; 16(2). https://doi.org/10.15447/sfews.2018v16iss2art3.

Kock, TJ, NE Verretto, NK Ackerman, RW Perry, JW Beeman, MC Garello, and SD Fielding 2019. Assessment of Operational and Structural Factors Influencing Performance of Fish Collectors in Forebays of High-Head Dams. Trans Am Fish Soc, 148: 464-479. https://doi.org/10.1002/tafs.10146

Link JS, R Griffis, and S Busch. 2015. NOAA Fisheries climate science strategy. Silver Spring, MD: National Marine Fisheries Service, 2015 NOAA Technical Memorandum NMFS-F/SPO-155.

Myers J, J Jorgensen, M Sorel, M Bond, T Nodine, R Zabel . 2018. Upper Willamette River life cycle modeling and the potential effects of climate change. U.S. Dep Commerce, NOAA Fisheries Northwest Fisheries Science Center, Seattle, Washington, 2018 Report to the U.S. Army Corps of Engineers.

Rieman, BE and JD McIntyre. 1993. Demographic and habitat requirements for conservation of bulltrout. U.S. For. Serv. Intermountain Res.Stn.Gen.Tech.Rep.INT-308.

Tague, C, and GE Grant. 2004. A geological framework for interpreting the low-flow regimes of Cascade streams, Willamette River Basin, Oregon, Water Resour. Res., 40, W04303, doi:10.1029/2003WR002629.

Wang, CJ, HA Schaller, KC Coates, MC Hayes and RK Rose. 2020. Climate change vulnerability assessment for Pacific Lamprey in rivers of the Western United States, Journal of Freshwater Ecology, 35:1, 29-55, DOI: 10.1080/02705060.2019.1706652.

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WILLAMETTE VALLEY SYSTEM OPERATIONS AND MAINTENANCE

FINAL ENVIRONMENTAL IMPACT STATEMENT

APPENDIX E: FISH AND AQUATIC HABITAT ANALYSES

PART 2 – CHAPTER 5 THROUGH CHAPTER 8

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CHAPTER 5 - EFFECTS OF FLOW BELOW WILLAMETTE VALLEY SYSTEM DAMS ON CHINOOK SALMON AND STEELHEAD HABITAT AND SURVIVAL

5.1 INTRODUCTION

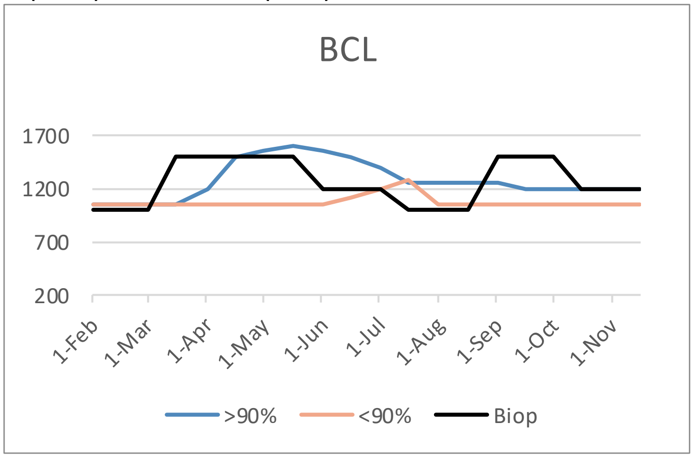
For managing discharge of water from WVS dams, an instream flow regime was developed to protect habitat needs of UWR Chinook and steelhead. Populations of these species occur below WVS dams in the Santiam, McKenzie and Middle Fork rivers. The NAA applies minimum flow levels defined in NMFS 2008 Biop on the Willamette Project. For EIS Alternatives 1 through 4, the minimum flow levels applied in the alternatives are defined under EIS Measure 30a. Measure 30a was revised based on EIS cooperator input as Measure 30b and is applied under Alternative 5.

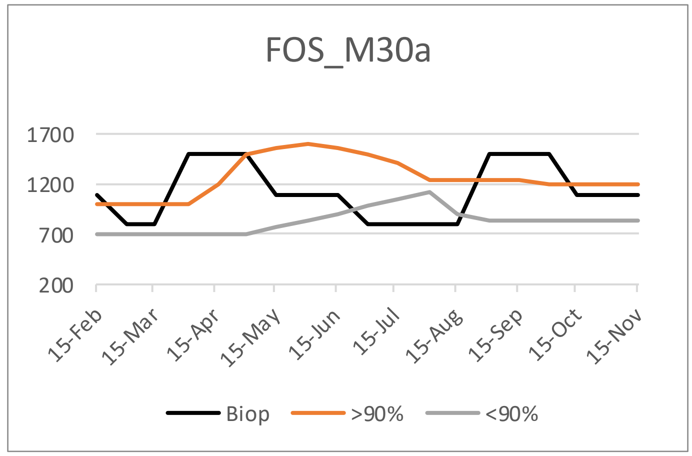
5.2 MINIMUM FLOWS

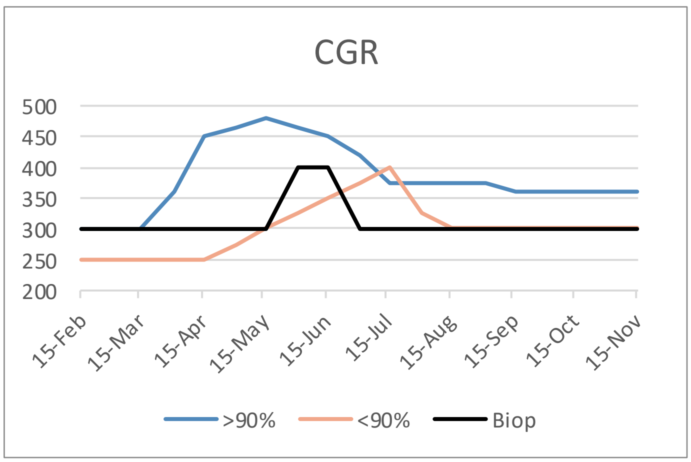
Under Measure 30a, the mainstem Willamette River minimum flow levels at Salem (5000 cfs) and Albany (4500 cfs) would be in place in all water year types and in all months except April 1 to June 30. Minimum flows during April and May at Salem will be 10,000 cfs, and 8,000 cfs in June for purposes of water temperature management in the mainstem. In addition, flow from the WVS reservoirs would also be used adaptively during April-June in each year to reduce and stabilize water temperature during important migration timeframes for UWR spring Chinook and UWR steelhead, mitigating warmer air temperatures to the extent possible. Minimum flow levels are met or exceeded using stored water to supplement natural flow during the conservation season. Flow in addition to meeting the minimum flow levels would also be released from storage to achieve specified temperature targets.

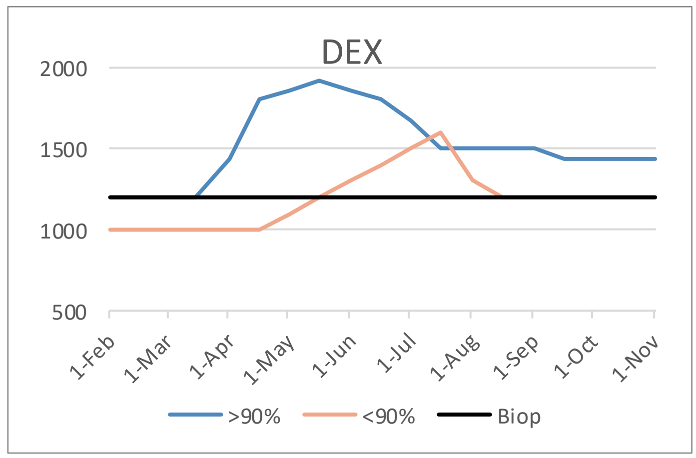
For the tributaries under Measure 30a, two minimum flow level regimes were defined for release below the lower dams in the four tributaries directly affecting UWR Chinook and steelhead. Between the two regimes for each tributary, the minimum flow regime to be applied would be assessed according to the storage achieved in real-time (less than or greater than 90 percent of the rule curve) every 2 weeks between February 1 and June 1. After June 1, the tributary minimum flow regime applied on June 1 would be followed for the remainder of the conservation season.

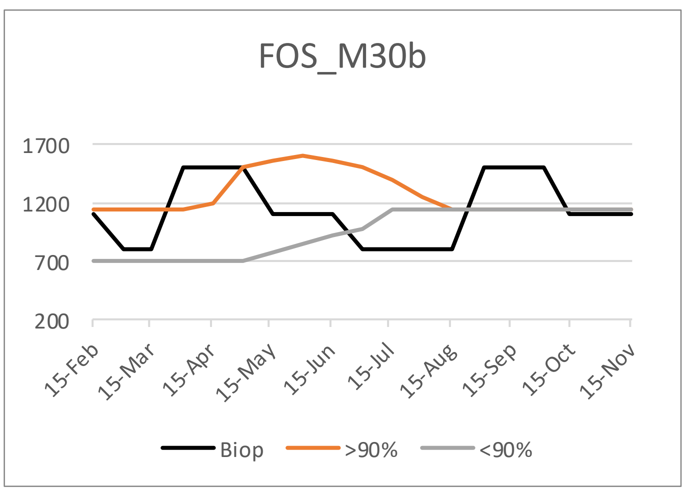
Figure 5-1. Minimum tributary releases (cfs) below WVS dams defined for EIS Measure 30a and 30b. Minimum targets are the same under Measure 30a and 30b for Big Cliff (BCL), Cougar (CGR) and Dexter (DEX) dams.











Note differences axis values.

Table 5-1. Threshold Flows (kcfs) at which flow augmentation could provide cooler temperatures in each time-frame and an associating water temperature threshold of which not to exceed. Flows provided in Kcfs; temperature estimate in degrees F based on Stratton ,et.,al.(in press). Applied in both EIS Measure 30a and 30b.

	Apr-May	Jun01-15	Jun15-30
Air Temperature Threshold (F)	Flow (kcfs) Needed To Keep Below 64ºF Water Temperature	Flow (kcfs) Needed To Keep Below 68ºF Water Temperature	Flow (kcfs) Needed To Keep Below 69ºF Water Temperature
74	8.7	6.4	5.9
75	9.0	6.6	6.0
76	9.3	6.9	6.2
77	9.6	7.2	6.5
78	9.9	7.5	6.7
79	10.3	7.8	6.9
80	10.7	8.1	7.2
81	11.2	8.5	7.5
82	11.7	8.9	7.9
83	12.2	9.4	8.2
84	12.7	9.9	8.6
85	13.4	10.4	9.0
86	14.0	11.0	9.5
87	14.7	11.8	10.1
88	15.4	12.7	10.6
89	16.4	13.7	11.3
90	17.4	14.9	12.0
91	18.6	16.1	12.9
92	19.8	17.7	14.0
93		19.6	14.8

Table 5-2. Mainstem Minimum Flow Thresholds included under Measure 30b.

Time Period	Water Supply Forecast Percent of 30 Year Average	Salem Minimum Flow, cfs (7 Day Moving Average)	Salem Minimum Flow, cfs (Instantaneous)	Albany Minimum Flow, cfs
April	<80%	12,000	12,000	–
–	80-100%	15,000	13,000	–
–	>100%	17,800	14,300	–
May	<80%	10,000	8,000	–
–	80-100%	13,000	12,000	–
–	>100%	15,000	12,000	–
June 1 - 15	<80%	8,000	8,000	4,500
–	80-100%	10,000	10,000	4500
–	>100%	13,000	10,500	4500
June 16 - 30	<80%	5,500	5,500	4,500
–	>=80%	7,000	7,000	4500
July	<80%	5,000	5,000	4,500
–	>=80%	6,000	5,500	4500
August	<80%	5,000	5,000	4,500
–	>=80%	6,500	6,000	4500
September	<80%	5,000	5,000	4,500
–	>=80%	7,000	6,500	4500
October	<80%	7,500	6,000	4,500
–	>=80%	10,000	8,000	4500

5.3 FLOWS RESULTING FROM EIS ALTERNATIVES

[insert] – information should demonstrate the differences in flow levels below dams between the NAA and each alternative. Refer reader to outflow plots from Appendix D, Section 1.5, and DEIS Table 3.2-2, etc, or copy into this section?

5.4 METHODS - FISH EFFECTS FROM FLOWS

5.4.1 Flow-Habitat Relationships

For juvenile spring Chinook in the North Santiam and McKenzie, habitat availability s a function of flow was modeled by USGS for the WVS EIS alternatives for all years in the period of record (1936 to 2019) using methods documented in White et al. (2022; also see Peterson et al. 2022). For juvenile Chinook and steelhead USGS used habitat suitability criteria developed by Hansen et al. (2023). Years were categorized as high, normal or low water years based on the 25th and

75th percentiles of Willamette-at-Salem unregulated flow estimated for the Mar 15-Oct 15 timeframe in each year. Habitat modeling included flows modeled under the EIS NAA, each EIS alternative, and the EIS near term operational measure (NTOM).

Adult Chinook and steelhead spawning habitat was estimated for all years in the period of record (1936 to 2019) using weighted usable area relationships from R2 (R2 Resources 2013) and RDG (RDG 2015) below WVS dams for each alternative and compared to the NAA. Years were categorized as high, normal or low water years based on the estimated unregulated flow at Salem for the March 15 - October 15 timeframe in each year. Habitat availability was compared by summarizing the percentage of days flows were greater than those providing 80%, 90% or 100% of the maximum weighted usable area (MWUA) determined by R2 and RDG for reaches where spawning densities are typically highest below WVS dams based on Sharpe et al. 2015, 2016, and 2018: Reach 1 on the North Santiam, Reach 1 on the South Santiam, Transect 7 on the South Fork McKenzie, and Transect 10 on the Middle Fork (Table 1).

Table 5-3. Flows (cfs) providing 80%, 90% and 100% of the maximum weighted usable area (WUA) of the available spawning habitat for spring Chinook salmon and winter steelhead below WVS Dams. Flows are for Reach 1 on the North Santiam (R2 Resources 2013), Reach 1 on the South Santiam (R2 Resources 2013), Transect 7 on the South Fork McKenzie (RDG 2015), and Transect 10 on the Middle Fork (RDG 2015) for the lower bound of each habitat-flow curve.

WUA level	Chinook salmon spawning, Aug15-Nov01				Winter steelhead spawning, Mar15-Jun01	
	Big Cliff	Foster	Cougar	Dexter	Big Cliff	Foster
80%	889	449	242	1800	867	533
90%	1011	567	319	2176	1000	685
100%	1286	1140	472	2800	1286	1140

Note: Flows are for Reach 1 on the North Santiam (R2 Resources 2013), Reach 1 on the South Santiam (R2 Resources 2013), Transect 7 on the South Fork McKenzie (RDG 2015), and Transect 10 on the Middle Fork (RDG 2015) for the lower bound of each habitat-flow curve.

5.4.2 Flow-Survival Relationships

Juvenile and adult fish survival below the dam is affected by downstream factors including flow, temperatures, and physical channel conditions. Often, water management decisions involve tradeoffs among multiple objectives or legal authorities. The USGS, Oregon Cooperative Fish and Wildlife Research Unit, Department of Fish and Wildlife, and Oregon State University developed models of UWR spring Chinook and winter steelhead to characterize water management tradeoffs and effects on key habitat features (Peterson et al. 2022). These models, dependent on a given hydrology and water temperature regime, predict four different life history outcomes: 1) the number of Chinook reaching emergence and surviving to swim-up, 2) the number of Chinook adult equivalents, 3) the number of outmigrating winter steelhead, and 4) the survival rate of age-1 juvenile steelhead. Model predictions were driven by a number of life history and habitat inputs such as temperature, habitat-discharge relationships, and territory size. Descriptions and assumptions of the four models can be found in Peterson et al. (Peterson et al. 2022) and in Chapter 5 of Appendix E. All models operated on a weekly time step that began in the eighth week of the year and ran through April of the following year. Models are only assessing below dam spawning and juvenile rearing. Hydrology inputs were based on ResSim model results provided by the Corps for the alternatives. Water temperature inputs were based on CE-QUAL-W2 model results provided by the alternatives. The models produced predictions for each sub-basin for each alternative, in each year of three representative water years in which water temperatures and hydrology inputs were applied (2011, 2015 and 2016). Model predictions (using median habitat criteria results provided by Peterson et al.) for alternatives were compared to the NAA (BiOp flows). Results were compared by summarizing the alternative results as a percentage of the NAA due to the multiple survival models and differences in their output units, survival.

Survival of Chinook and steelhead was modeled for WVS EIS Alternatives 1 through 4, and the No Action Alternative (NAA). Results for Alternative 2b were considered representative of Alternative 5 due to similarity in the river hydrology and water temperatures for these alternatives.

5.5 RESULTS - FISH EFFECTS FROM FLOWS

5.5.1 North Santiam

Juvenile habitat

For juvenile spring Chinook, there was little difference found in habitat availability between the alternatives and the NTOM when compared to the NAA in the North Santiam below Big Cliff Dam. The greatest differences was for Alternative 3a which had less juvenile habitat available during summer months, likely due to delaying refill of some reservoirs associated with fish passage measures included in this alternative.

Table 5-4. Habitat available, as a percentage of the habitat available under the No Action Alternative (NAA), for juvenile spring Chinook in the North Santiam under each WVS EIS alternative and the near-term operational measures (NTOM). Highlighted cells indicate if percentage is less than or greater than 5% different from the NAA.

	alt1	alt2a	alt2b	alt3a	alt4	alt5	NTOM
Water Year Type: High							
Jan	100.0	100.0	100.0	100.6	100.0	100.0	100.0
Feb	100.0	100.0	100.0	97.9	100.0	100.0	100.0
Mar	100.0	100.0	100.0	95.0	100.0	100.0	100.0
Apr	101.4	100.2	100.2	97.2	100.2	100.2	100.2
May	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Jun	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Jul	100.0	102.6	102.6	100.0	102.6	102.6	102.6
Aug	99.8	103.4	103.4	99.8	103.4	103.4	103.4
Sep	100.0	96.8	96.8	92.0	96.8	96.8	96.8
Oct	100.0	100.0	100.0	96.5	100.0	100.0	100.0
Nov	100.0	100.0	100.0	101.1	100.0	100.0	100.0
Dec	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Water Year Type: Low							
Jan	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Feb	100.0	100.0	100.0	99.9	100.0	100.0	100.0
Mar	100.0	100.0	100.0	92.9	100.0	100.0	100.0
Apr	102.8	101.6	101.6	97.4	101.6	101.6	101.6
May	98.8	99.6	99.6	96.8	99.6	99.6	99.6
Jun	97.8	99.2	99.2	98.7	99.2	99.2	99.2
Jul	99.7	103.4	103.4	90.2	103.4	103.4	103.4
Aug	99.8	100.7	100.7	85.5	100.7	100.7	100.7
Sep	93.8	95.3	95.3	93.9	95.3	95.3	95.3
Oct	100.3	99.0	99.0	97.8	99.0	99.0	99.0
Nov	100.0	100.0	100.0	100.5	100.0	100.0	100.0
Dec	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Water Year Type: Normal							
Jan	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Feb	100.0	100.0	100.0	97.3	100.0	100.0	100.0
Mar	100.0	100.0	100.0	95.1	100.0	100.0	100.0
Apr	101.4	100.2	100.2	96.3	100.2	100.2	100.2
May	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Jun	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Jul	99.9	102.9	102.9	99.7	102.9	102.9	102.9
Aug	99.8	103.4	103.4	92.0	103.4	103.4	103.4
Sep	97.9	96.8	96.8	85.9	96.8	96.8	96.8
Oct	100.0	100.0	100.0	96.2	100.0	100.0	100.0
Nov	100.0	100.0	100.0	101.1	100.0	100.0	100.0
Dec	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Adult Habitat

The number and percentage of days spawning habitat was available for Chinook salmon at flows providing >80% and >90% of the MWUA was similar (within 5%) to the NAA under the alternatives during normal and high water year types compared to the NAA, except for Alternative 3a. In low water year types, there were more days above the MWUA levels under these alternatives compared to the NAA. Alternative 3a was a notable exception to this pattern, providing less days compared to the NAA at all MWUA flow levels in all water year types compared to the NAA.

For winter steelhead, flows were at or above the 80% and 90% MWUA levels for the entire 79 day period of March 15 to June 1 under the NAA and under the alternatives in all water year types, with the exception of Alternative 3a which had fewer days under the low flow years. The number of days at or above the 100% MWUA level was less than 79 under both the NAA and the alternatives, with generally fewer days under the alternatives compared to the NAA.

Table 5-5. Number of days flows were at or above maximum weighted usable area (MWUA) levels for Chinook salmon spawning during August 15 to November 1 (79 day period) below Big Cliff Dam under three water year categories for each alternative.

	Number of days at or above MWUA flow level					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
NAA						
High	79	79	48	79.0	79.0	61.0
Low	3	2	1	66.3	65.5	43.9
Normal	46	46	29	78.2	78.2	59.5
Alt 1						
High	79	79	37	79.0	79.0	53.2
Low	63	62	0	78.2	78.2	24.7
Normal	46	46	0	78.2	78.2	46.7
Alt 2a						
High	79	79	32	79.0	79.0	64.8
Low	48	47	0	77.5	77.5	20.3
Normal	46	46	32	78.2	78.2	56.4
Alt 2b						
High	79	79	32	79.0	79.0	64.8
Low	48	47	0	77.5	77.5	20.3
Normal	46	46	32	78.2	78.2	56.5
Alt 3a						
High	0	0	0	47.5	46.5	4.5
Low	0	0	0	18.9	16.7	0.9
Normal	0	0	0	28.9	27.3	2.3
Alt 3b						
High	79	79	76	79.0	79.0	77.8
Low	60	60	6	78.1	78.1	54.6

Normal	46	46	45	78.2	78.2	76.8
Alt 4						
High	79	79	32	79.0	79.0	64.8
Low	48	47	0	77.5	77.5	20.3
Normal	46	46	32	78.2	78.2	56.4
Alt 5						
High	79	79	32	79.0	79.0	64.8
Low	48	47	0	77.5	77.5	20.3
Normal	46	46	32	78.2	78.2	56.4

Table Note: Flows providing 80%, 90% and 100% of the MWUA are listed in Table.

Table 5-6. The minimum and average number of days, as a percentage of the WVS EIS No Action Alternative (NAA), flows were greater than flow levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for Chinook salmon spawning during August 15 to November 1 (79 day period) below Big Cliff Dam under three water year categories.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1						
High	100%	100%	77%	100%	100%	87%
Low	2100%	3100%	0%	118%	119%	56%
Normal	100%	100%	0%	100%	100%	79%
Alt 2a						
High	100%	100%	67%	100%	100%	106%
Low	1600%	2350%	0%	117%	118%	46%
Normal	100%	100%	110%	100%	100%	95%
Alt 2b						
High	100%	100%	67%	100%	100%	106%
Low	1600%	2350%	0%	117%	118%	46%
Normal	100%	100%	110%	100%	100%	95%
Alt 3a						
High	0%	0%	0%	60%	59%	7%
Low	0%	0%	0%	28%	26%	2%

Normal	0%	0%	0%	37%	35%	4%
Alt 3b						
High	100%	100%	158%	100%	100%	127%
Low	2000%	3000%	600%	118%	119%	125%
Normal	100%	100%	155%	100%	100%	129%
Alt 4						
High	100%	100%	67%	100%	100%	106%
Low	1600%	2350%	0%	117%	118%	46%
Normal	100%	100%	110%	100%	100%	95%
Alt 5						
High	100%	100%	67%	100%	100%	106%
Low	1600%	2350%	0%	117%	118%	46%
Normal	100%	100%	110%	100%	100%	95%

Table Notes: Colored cells indicates the Alternative differs by more than 5% from the No Action Alternative. Flows providing 80%, 90% and 100% of the MWUA are listed in Table. When there were zero days of occurrence under the NAA, a percentage could not be calculated and "na" was entered.

Table 5-7. Number of days flows were at or above maximum weighted usable area (MWUA) for winter steelhead salmon spawning during March 15 to June 1 (79 day period) below Big Cliff Dam under three water year categories for each alternative.

	Number of days at or above MWUA flow level					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
NAA						
High	79	79	77	79.0	79.0	78.1
Low	79	79	68	79.0	79.0	76.7
Normal	79	79	75	79.0	79.0	78.0
Alt 1						
High	79	79	15	79.0	79.0	50.0
Low	79	79	0	79.0	79.0	9.2
Normal	79	79	0	79.0	79.0	44.5
Alt 2a						
High	79	79	17	79.0	79.0	53.5
Low	79	79	0	79.0	79.0	18.0

Normal	79	79	1	79.0	79.0	50.5
Alt 2b						
High	79	79	17	79.0	79.0	53.5
Low	79	79	0	79.0	79.0	18.0
Normal	79	79	1	79.0	79.0	50.5
Alt 3a						
High	79	79	73	79.0	79.0	77.8
Low	63	48	37	77.6	75.4	68.9
Normal	77	77	63	79.0	78.9	77.9
Alt 3b						
High	79	79	17	79.0	79.0	52.7
Low	79	79	0	79.0	79.0	16.2
Normal	77	75	0	79.0	78.9	48.9
Alt 4						
High	79	79	17	79.0	79.0	53.5
Low	79	79	0	79.0	79.0	18.0
Normal	79	79	1	79.0	79.0	50.6
Alt 5						
High	79	79	17	79.0	79.0	53.5
Low	79	79	0	79.0	79.0	18.0
Normal	79	79	1	79.0	79.0	50.5

Table Note: Flows providing 80%, 90% and 100% of the MWUA are listed in Table.

Table 5-8. The minimum and average number of days, as a percentage of the WVS EIS No Action Alternative (NAA), flows were greater than flow levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for winter steelhead spawning during March 15 to June 1 (79 day period) below Big Cliff Dam under three water year categories.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1						
High	100%	100%	19%	100%	100%	64%
Low	100%	100%	0%	100%	100%	12%

Normal	100%	100%	0%	100%	100%	57%
Alt 2a						
High	100%	100%	22%	100%	100%	68%
Low	100%	100%	0%	100%	100%	23%
Normal	100%	100%	1%	100%	100%	65%
Alt 2b						
High	100%	100%	22%	100%	100%	69%
Low	100%	100%	0%	100%	100%	23%
Normal	100%	100%	1%	100%	100%	65%
Alt 3a						
High	100%	100%	95%	100%	100%	100%
Low	80%	61%	54%	98%	95%	90%
Normal	97%	97%	84%	100%	100%	100%
Alt 3b						
High	100%	100%	22%	100%	100%	67%
Low	100%	100%	0%	100%	100%	21%
Normal	97%	95%	0%	100%	100%	63%
Alt 4						
High	100%	100%	22%	100%	100%	68%
Low	100%	100%	0%	100%	100%	23%
Normal	100%	100%	1%	100%	100%	65%
Alt 5						
High	100%	100%	22%	100%	100%	69%
Low	100%	100%	0%	100%	100%	23%
Normal	100%	100%	1%	100%	100%	65%

Table Notes: Colored cells indicates the Alternative differs by more than 5% from the No Action Alternative. Flows providing 80%, 90% and 100% of the MWUA are listed in Table.

Survival

For Chinook in the North Santiam, survival modeling results were mixed when compared to the NAA. For Chinook spawning effectiveness (Chinook redds surviving until swim-up model), Alternatives 2a, 2b and 4 provided similar (within 5%) to better survival compared to the NAA in all water years. In the dry (2015) and moderate (2016) years, Alternatives 1, 3a and 3b provided lower survival, but higher survival in the wet year (2011).
For juvenile Chinook in wet or dry years, similar to better survival was estimated for Alternatives 1, 3a, 3b and 4 compared to the NAA.

For steelhead juveniles (Steelhead trout Age-1 model), results were similar (within 5%) or better compared to the NAA in the dry and moderate water years modeled under Alternatives 1, 2a, 2b and 4. Survival was poor for juveniles under Alternative 3a in all water years modeled. For steelhead smolt survival, results were similar for all alternatives and water years compared to the NAA.

Table 5-9. Percent difference from the NAA in estimated survival scores of spring Chinook and winter steelhead in the North Santiam below Big Cliff Dam for three simulation years.

	Chinook redds surviving until swim-up	Chinook salmon adult equivalents	Steelhead trout smolt survival	Steelhead trout Age-1
Alt1				
2011	25%	-4%	0%	-7%
2015	-38%	15%	-3%	20%
2016	-5%	-59%	-3%	-1%
Alt2a				
2011	35%	-5%	0%	-6%
2015	3%	-28%	-2%	16%
2016	4%	-49%	-1%	3%
Alt2b				
2011	32%	-3%	0%	2%
2015	-4%	-11%	-2%	19%
2016	2%	-54%	-1%	1%
Alt3a				
2011	61%	-4%	0%	-4%
2015	-30%	-3%	-5%	-43%
2016	-8%	-43%	-3%	-7%
Alt3b				
2011	5%	4%	0%	-10%
2015	-8%	-4%	0%	45%
2016	-17%	-58%	-2%	37%
Alt4				
2011	33%	-2%	0%	-2%
2015	-2%	17%	-2%	1%
2016	-1%	-58%	-2%	-9%

Table Notes: Colored cells indicate the Preferred Alternative is different by 5% or more from the No Action Alternative. Percentages calculated from results presented in WVS EIS Appendix E, Chapter 5, Tables 5-5, 5-6 and 5-7.

5.5.2 South Santiam

Juvenile Habitat

Habitat available for juvenile spring Chinook in the North Santiam and McKenzie was modeled by USGS for the WVS EIS Alternatives for all years in the period of record (1936 to 2019) using methods documented in White et al. (2022) and Peterson et al. (2022), applying habitat suitability criteria developed by Hansen et al. (2023). Models are currently being completed by USGS to provide similar modeling in the South Santiam and Middle Fork, and will be applied to help validate assumptions used for development of Measure 30 a and b as part of the adaptive management plan (Appendix N). Although results are not available at this time, habitat for juvenile Chinook and steelhead does not appear to be limiting below WVS dams in the Willamette (Myers et al. 2022; Peterson et al. 2022; Scheuerell et al. 2021). NOAA NWFSC did not include juvenile rearing capacity in models of population performance (see Myers et al. 2022 included as Appendix E, Chapter 7), either under existing or the proposed improved fish passage conditions and when considering the adult return levels predicted under the DPEIS alternatives as modeled. Their conclusion assumed that many juveniles emigrate from the headwater (above dam) reaches to rear downstream, and that hatchery salmon and steelhead released below dams emigrate quickly to the ocean and do not affect rearing natural origin juveniles (email communication from J. Myers to R. Piaskowski, 11/03/22). Peterson et al. (2022), similarly indicates habitat availability may not be a limiting factor for juveniles when evaluating survival of Chinook and steelhead in the Willamette with respect to stream flows below dams. R2 found habitat for juvenile Chinook and steelhead rearing decreased with increasing flow (R2 Resources 2014). Scheuerell et al. (2021) found a negative effect of winter-spring flows during the year Chinook smolts would have been migrating to sea on the overall productivity of the population.

Adult Habitat

The number and percentage of days spawning habitat was available for Chinook salmon at flows providing >80% and >90% of the MWUA was similar (within 5%) of the NAA under the alternatives during normal and high water year types compared to the NAA. In low water year types, there were more days above the 80%, 90% and 100% MWUA flow levels under all alternatives compared to the NAA, with the exception of Alternative 3b. In normal water years there were few days under Alternative 3a, 3b and 5 at or above the 90% MWUA flow level compared to the NAA. At the 100% MWUA flow level, there were fewer days under all the alternatives compared to the NAA.

For winter steelhead, the number and percentage of days spawning habitat was available at flows providing >80% and >90% of the MWUA was also similar (within 5%) of the NAA under the alternatives during normal and high water year types compared to the NAA. In low water year types, there were more days above the 90% MWUA flow level under all alternatives compared to the NAA, with the exception of Alternative 3b. In normal water years there were few days under Alternative 3a, 3b and 5 at or above the 90% MWUA flow level compared to the NAA. At the 100% MWUA flow level, there were fewer days under all the alternatives compared to the NAA.

Table 5-10. Number of days flows were at or above maximum weighted usable area (MWUA) for Chinook salmon spawning during August 15 to November 1 (79 day period) below Foster Dam under three water year categories for each alternative.

	Number of days at or above MWUA flow level					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
NAA						
High	79	79	45	79.0	79.0	51.9
Low	3	1	0	73.1	72.2	38.7
Normal	46	46	29	78.2	77.8	50.4
Alt 1						
High	78	78	10	78.9	78.9	33.6
Low	78	78	0	79.0	79.0	19.1
Normal	46	46	0	78.1	78.1	26.4
Alt 2a						
High	78	78	78	79.0	79.0	78.9
Low	79	79	30	79.0	79.0	63.8
Normal	46	46	14	78.2	78.2	74.5
Alt 2b						
High	78	78	78	79.0	79.0	78.9
Low	79	79	30	79.0	79.0	63.8
Normal	46	46	14	78.2	78.2	74.5
Alt 3a						
High	78	78	78	79.0	79.0	78.9
Low	79	79	30	79.0	79.0	63.8
Normal	46	46	14	78.2	78.2	74.5
Alt 3b						
High	7	6	0	67.6	66.3	11.6
Low	0	0	0	34.6	33.1	3.9
Normal	1	1	0	47.0	45.7	6.0
Alt 4						
High	79	79	79	79.0	79.0	79.0
Low	79	79	0	79.0	79.0	49.7

Normal	46	46	0	78.2	78.2	68.5
Alt 5						
High	78	78	78	79.0	79.0	78.9
Low	79	79	59	79.0	79.0	77.4
Normal	46	46	46	78.2	78.2	78.1

Table 5-11. The minimum and average number of days, as a percentage of the WVS EIS No Action Alternative (NAA), flows were greater than flow levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for Chinook salmon spawning during August 15 to November 1 (79 day period) below Foster Dam under three water year categories.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1						
High	99%	99%	22%	100%	100%	65%
Low	2600%	7800%	na	108%	109%	49%
Normal	100%	100%	0%	100%	100%	52%
Alt 2a						
High	99%	99%	173%	100%	100%	152%
Low	2633%	7900%	na	108%	109%	165%
Normal	100%	100%	48%	100%	101%	148%
Alt 2b						
High	99%	99%	173%	100%	100%	152%
Low	2633%	7900%	na	108%	109%	165%
Normal	100%	100%	48%	100%	101%	148%
Alt 3a						
High	99%	99%	173%	100%	100%	152%
Low	2633%	7900%	na	108%	109%	165%
Normal	100%	100%	48%	100%	101%	148%
Alt 3b						
High	9%	8%	0%	86%	84%	22%
Low	0%	0%	na	47%	46%	10%
Normal	2%	2%	0%	60%	59%	12%

Alt 4						
High	100%	100%	176%	100%	100%	152%
Low	2633%	7900%	na	108%	109%	128%
Normal	100%	100%	0%	100%	101%	136%
Alt 5						
High	99%	99%	173%	100%	100%	152%
Low	2633%	7900%	na	108%	109%	200%
Normal	100%	100%	159%	100%	101%	155%

Notes: Colored cells indicates the Alternative differs by more than 5% from the No Action Alternative. Flows providing 80%, 90% and 100% of the MWUA are listed in Table. When there were zero days of occurrence under the NAA, a percentage could not be calculated and "na" was entered.

Table 5-12. Number of days flows were at or above maximum weighted usable area (MWUA) for winter steelhead salmon spawning during March 15 to June 1 (79 day period) below Foster Dam under three water year categories for each alternative.

	Number of days at or above MWUA flow level					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
NAA						
High	79	79	76	79.0	79.0	78.6
Low	79	70	38	79.0	78.6	65.0
Normal	79	79	62	79.0	79.0	73.8
Alt 1						
High	79	79	62	79.0	79.0	75.8
Low	79	79	0	79.0	79.0	26.5
Normal	79	79	29	79.0	79.0	59.9
Alt 2a						
High	79	79	65	79.0	79.0	76.0
Low	79	76	0	79.0	78.6	36.9
Normal	79	78	49	79.0	79.0	71.7
Alt 2b						
High	79	79	65	79.0	79.0	76.0
Low	79	76	0	79.0	78.6	36.9
Normal	79	78	49	79.0	79.0	71.7

Alt 3a						
High	79	79	65	79.0	79.0	76.0
Low	79	72	0	79.0	78.0	36.9
Normal	79	74	49	79.0	78.9	71.7
Alt 3b						
High	79	79	69	79.0	79.0	76.0
Low	79	60	40	79.0	76.0	61.3
Normal	79	64	51	79.0	78.4	68.1
Alt 4						
High	79	79	65	79.0	79.0	76.6
Low	79	79	0	79.0	79.0	38.0
Normal	79	79	49	79.0	79.0	71.7
Alt 5						
High	79	79	68	79.0	79.0	76.4
Low	79	75	0	79.0	78.6	38.8
Normal	79	73	56	79.0	78.9	73.5

Table 5-13. The minimum and average number of days, as a percentage of the WVS EIS No Action Alternative (NAA), flows were greater than flow levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for winter steelhead spawning during March 15 to June 1 (79 day period) below Foster Dam under three water year categories.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1						
High	100%	100%	82%	100%	100%	96%
Low	100%	113%	0%	100%	101%	41%
Normal	100%	100%	47%	100%	100%	81%
Alt 2a						
High	100%	100%	86%	100%	100%	97%
Low	100%	109%	0%	100%	100%	57%
Normal	100%	99%	79%	100%	100%	97%
Alt 2b						

High	100%	100%	86%	100%	100%	97%
Low	100%	109%	0%	100%	100%	57%
Normal	100%	99%	79%	100%	100%	97%
Alt 3a						
High	100%	100%	86%	100%	100%	97%
Low	100%	103%	0%	100%	99%	57%
Normal	100%	94%	79%	100%	100%	97%
Alt 3b						
High	100%	100%	91%	100%	100%	97%
Low	100%	86%	105%	100%	97%	94%
Normal	100%	81%	82%	100%	99%	92%
Alt 4						
High	100%	100%	86%	100%	100%	98%
Low	100%	113%	0%	100%	101%	58%
Normal	100%	100%	79%	100%	100%	97%
Alt 5						
High	100%	100%	89%	100%	100%	97%
Low	100%	107%	0%	100%	100%	60%
Normal	100%	92%	90%	100%	100%	100%

Survival

For Chinook spawning effectiveness (Chinook redds surviving until swim-up model), results were better than the NAA in all water years under Alternative 4. Results were also better in dry years compared to the NAA for Alternatives 1, 2a, 2b, and 3a. In most other cases results were poorer under the alternatives compared to the NAA.

For Chinook juvenile (Chinook salmon adult equivalents), results for the alternatives were similar (within 5%) or better than the NAA in most cases. The exceptions were under Alternative 2a in the moderate (2016) and wet (2015) years modeled, and in the wet year under Alternative 2b.

For steelhead smolt survival, results for the alternatives were similar (within 5%) or better than the NAA in all cases.

For juvenile steelhead (Steelhead trout Age-1), results were similar or worse in each water year modeled under Alternatives 1, 2a and 3b compared to the NAA. Results were similar or better in each water year modeled under Alternatives 4. In other alternatives results were mixed, depending on water year, when compared to the NAA.

Table 5-14. Percent difference from the NAA in estimated survival of spring Chinook and winter steelhead in the South Santiam below Foster Dam for three simulation years.

	Chinook redds surviving until swim-up	Chinook salmon adult equivalents	Steelhead trout smolt survival	Steelhead trout Age-1
Alt1				
2011	11%	0%	0%	-17%
2015	37%	16%	-4%	-11%
2016	-11%	-5%	-5%	-15%
Alt2a				
2011	-39%	-12%	0%	-19%
2015	54%	29%	-3%	3%
2016	-39%	-19%	-3%	-21%
Alt2b				
2011	-37%	-25%	0%	-20%
2015	51%	51%	-3%	12%
2016	-36%	13%	-3%	-21%
Alt3a				
2011	-37%	0%	0%	-25%
2015	54%	7%	-4%	84%
2016	-39%	-3%	-4%	31%
Alt3b				
2011	40%	48%	0%	0%
2015	-100%	1%	-4%	-9%
2016	-60%	17%	-4%	-40%
Alt4				
2011	51%	1%	0%	5%
2015	37%	7%	-3%	15%
2016	0%	5%	-3%	0%

Table Notes: Colored cells indicate the Preferred Alternative is different by 5% or more from the No Action Alternative. Percentages calculated from results presented in WVS EIS Appendix E, Chapter 5, Tables 5-5, 5-6 and 5-7.

5.5.3 McKenzie

Juvenile Habitat

For habitat for spring Chinook juvenile in the McKenzie River, there was little difference found between the alternatives and the NTOM when compared to the NAA. Habitat was less than 5% of the that occurring under the NAA in either March or April (or both) under Alternatives 2b and 5 depending on water year type. Otherwise, habitat was within 5% of that available under the NAA in all other months for all alternatives and the NTOM (with a minor exception under Alternative 3a compared to the NAA when habitat available was about 6% greater in November).

Table 5-15. Habitat available, as a percentage of the habitat available under the No Action Alternative (NAA), for juvenile spring Chinook in the McKenzie and South Fork McKenzie below Cougar Dam under each WVS EIS alternative and the near-term operational measures (NTOM). Highlighted cells indicate if percentage is less than or greater than 5% different from the NAA.

	alt1	alt2a	alt2b	alt3a	alt4	alt5	NTOM
Water Year Type: High							
Jan	100.0	100.0	101.0	100.0	100.0	101.1	100.0
Feb	100.0	100.0	97.1	96.5	100.0	96.8	95.6
Mar	100.0	100.0	90.3	95.1	100.0	88.6	95.5
Apr	100.0	100.0	92.7	95.3	100.0	94.6	98.3
May	100.0	100.0	98.2	100.0	100.0	98.0	101.0
Jun	100.0	100.0	100.7	100.7	100.0	100.9	100.0
Jul	100.0	100.0	100.0	100.0	100.0	100.0	99.6
Aug	100.0	99.9	99.8	99.9	99.9	99.8	100.0
Sep	100.0	100.0	99.9	100.0	100.0	99.9	100.2
Oct	100.0	100.0	101.1	101.3	100.0	100.8	100.7
Nov	100.0	100.0	104.0	105.8	100.0	104.3	101.8
Dec	100.0	100.0	101.9	100.8	100.0	101.8	100.0
Water Year Type: Low							
Jan	100.0	100.0	100.7	100.0	100.0	100.7	100.0
Feb	100.0	100.0	98.6	98.3	100.0	97.9	97.2
Mar	100.0	100.0	93.2	97.5	100.0	95.9	97.2
Apr	102.6	102.6	99.8	100.7	102.6	100.2	101.2
May	101.7	100.9	100.5	100.6	100.9	100.7	101.9
Jun	100.1	100.0	100.0	100.0	100.0	100.0	100.0
Jul	100.2	100.0	99.9	99.9	100.0	99.9	100.0
Aug	100.2	100.1	99.5	99.5	100.1	99.5	99.9
Sep	100.4	100.2	99.3	100.0	100.3	99.2	100.0
Oct	99.4	100.2	99.7	99.7	100.1	99.5	100.0
Nov	100.0	100.0	100.1	100.0	100.0	100.0	100.0
Dec	100.0	100.0	102.4	101.5	100.0	102.1	100.0
Water Year Type: Normal							

Jan	100.0	100.0	101.0	100.0	100.0	101.6	100.0
Feb	100.0	100.0	96.7	96.9	100.0	96.7	95.8
Mar	100.0	100.0	90.9	95.3	100.0	91.4	95.6
Apr	100.2	100.2	94.0	95.8	100.2	95.6	100.1
May	100.0	100.0	99.1	100.0	100.0	99.6	102.4
Jun	100.0	100.0	100.1	100.1	100.0	100.2	100.2
Jul	100.1	100.0	99.9	100.0	100.0	99.9	100.0
Aug	100.0	99.9	99.6	99.6	99.9	99.6	99.8
Sep	100.0	100.0	99.6	100.0	100.0	99.7	100.2
Oct	100.0	100.0	100.0	99.9	100.0	99.9	100.3
Nov	100.0	100.0	102.6	103.0	100.0	102.4	100.9
Dec	100.0	100.0	101.0	100.1	100.0	100.7	100.0

Adult Habitat

The percentage of days spawning habitat was available for Chinook salmon at flows >80%, >90%, and >100% MWUA levels was much lower under the alternatives compared to the NAA in all water year types. This reflects that under Alternatives 2b, 3a, 3b and 5 there is a deep draft of the reservoir in spring, to near the elevation of the diversion tunnel to provide downstream passage for fish, resulting in limited to no water storage available to augment stream flows during the later summer and fall Chinook salmon spawning season. Alternatives 1, 2a and 4 provide similar habitat availability as the NAA, particularly in normal and high water years.

Table. 5-16 Number of days flows were at or above maximum weighted usable area (MWUA) for Chinook salmon spawning during August 15 to November 1 (79 day period) below Cougar Dam under three water year categories for each alternative.

	Number of days at or above MWUA flow level					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
NAA						
High	79	79	50	79.0	79.0	64.0
Low	27	25	0	71.6	70.8	24.3
Normal	46	46	6	78.2	78.2	53.4
Alt 1						
High	79	79	44	79.0	79.0	62.7
Low	14	12	10	71.0	70.0	36.6
Normal	46	46	28	78.2	78.2	51.4
Alt 2a						
High	79	79	42	79.0	79.0	61.3
Low	4	0	0	70.3	68.0	40.6

Normal	46	46	23	78.2	78.2	52.2
Alt 2b						
High	75	0	0	78.8	19.9	19.5
Low	0	0	0	39.0	3.6	3.4
Normal	8	0	0	56.8	8.9	8.7
Alt 3a						
High	21	13	0	68.6	57.9	6.4
Low	0	0	0	32.7	21.6	0.0
Normal	3	0	0	43.9	33.8	2.2
Alt 3b						
High	75	0	0	78.8	19.9	19.6
Low	0	0	0	39.0	3.6	3.4
Normal	8	0	0	56.8	8.9	8.7
Alt 4						
High	79	79	44	79.0	79.0	61.0
Low	4	0	0	70.6	68.7	40.3
Normal	46	46	23	78.2	78.2	52.8
Alt 5						
High	75	0	0	78.7	19.2	18.8
Low	0	0	0	39.0	3.6	3.4
Normal	8	0	0	56.5	8.8	8.6

Table 5-17. The minimum and average number of days, as a percentage of the WVS EIS No Action Alternative (NAA), flows were greater than flow levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for Chinook salmon spawning during August 15 to November 1 (79 day period) below Cougar Dam under three water year categories.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1						
High	100%	100%	88%	100%	100%	98%
Low	52%	48%	na	99%	99%	150%
Normal	100%	100%	467%	100%	100%	96%

Alt 2a						
High	100%	100%	84%	100%	100%	96%
Low	15%	0%	na	98%	96%	167%
Normal	100%	100%	383%	100%	100%	98%
Alt 2b						
High	95%	0%	0%	100%	25%	30%
Low	0%	0%	na	55%	5%	14%
Normal	17%	0%	0%	73%	11%	16%
Alt 3a						
High	27%	16%	0%	87%	73%	10%
Low	0%	0%	na	46%	30%	0%
Normal	7%	0%	0%	56%	43%	4%
Alt 3b						
High	95%	0%	0%	100%	25%	31%
Low	0%	0%	na	55%	5%	14%
Normal	17%	0%	0%	73%	11%	16%
Alt 4						
High	100%	100%	88%	100%	100%	95%
Low	15%	0%	na	99%	97%	166%
Normal	100%	100%	383%	100%	100%	99%
Alt 5						
High	95%	0%	0%	100%	24%	29%
Low	0%	0%	na	55%	5%	14%
Normal	17%	0%	0%	72%	11%	16%

Notes: Colored cells indicates the Alternative differs by more than 5% from the No Action Alternative. Flows providing 80%, 90% and 100% of the MWUA are listed in Table. When there were zero days of occurrence under the NAA, a percentage could not be calculated and "na" was entered.

Survival

For Chinook adults (Chinook redds surviving until swim-up model), results were similar (within 5%) or higher compared the NAA in Alternatives 1, 2a and 4. For other alternatives results were similar or lower, depending on water year.

For Chinook juvenile (Chinook salmon adult equivalents), results were similar or higher compared to the NAA for Alternatives 3a and 3b, and similar to lower for other alternatives, depending on water year. Notably, for Alternatives 3a and 3b results were better in all water years compared to the NAA.

Table 5-18. Percent difference from the NAA in estimated survival of spring Chinook in the South Fork and mainstem McKenzie below Cougar Dam for three simulation years.

	Chinook redds surviving until swim-up	Chinook salmon adult equivalents
Alt1		
2011	-1%	1%
2015	7%	-36%
2016	-3%	-9%
Alt2a		
2011	-2%	1%
2015	9%	-34%
2016	2%	-4%
Alt2b		
2011	-7%	1%
2015	4%	-32%
2016	-9%	3%
Alt3a		
2011	-1%	4%
2015	0%	8%
2016	-9%	11%
Alt3b		
2011	-7%	6%
2015	0%	20%
2016	-8%	3%
Alt4		
2011	-1%	-10%
2015	7%	22%
2016	0%	1%

Table Notes: Colored cells indicate the Preferred Alternative is different by 5% or more from the No Action Alternative. Percentages calculated from results presented in WVS EIS Appendix E, Chapter 5, Tables 5-5, 5-6 and 5-7.

5.5.4 Middle Fork WILLAMETTE RIVER

Juvenile Habitat

Habitat available for juvenile spring Chinook in the North Santiam and McKenzie was modeled by USGS for the WVS EIS Alternatives for all years in the period of record (1936 to 2019) using methods documented in White et al. (2022) and Peterson et al. (2022), applying habitat suitability criteria developed by Hansen et al. (2023). Models are currently being completed by USGS to provide similar modeling in the South Santiam and Middle Fork, and will be applied to help validate assumptions used for development of Measure 30 a and b as part of the adaptive management plan (Appendix N). Although results are not available at this time, habitat for juvenile Chinook and steelhead does not appear to be limiting below WVS dams in the Willamette (Myers et al. 2022; Peterson et al. 2022; Scheuerell et al. 2021). NOAA NWFSC did not include juvenile rearing capacity in models of population performance (see Myers et al. 2022 included as Appendix E, Chapter 7), either under existing or the proposed improved fish passage conditions and when considering the adult return levels predicted under the DPEIS alternatives as modeled. Their conclusion assumed that many juveniles emigrate from the headwater (above dam) reaches to rear downstream, and that hatchery salmon and steelhead released below dams emigrate quickly to the ocean and do not affect rearing natural origin juveniles (email communication from J. Myers to R. Piaskowski, 11/03/22). Peterson et al. (2022), similarly indicates habitat availability may not be a limiting factor for juveniles when evaluating survival of Chinook and steelhead in the Willamette with respect to stream flows below dams. R2 found habitat for juvenile Chinook and steelhead rearing decreased with increasing flow (R2 Resources 2014). Scheuerell et al. (2021) found a negative effect of winter-spring flows during the year Chinook smolts would have been migrating to sea on the overall productivity of the population.

Adult Habitat

For spawning habitat availability for Chinook salmon below Dexter Dam, in low and normal years, the number of days flows under all alternatives at 80% and 100% were greater than the number of days at the levels under the NAA. Alternative 3a had fewer days at each MWUA level compared to the NAA in all water year types. Compared to the NAA, Alternative 5 performed the best, and generally outperformed the NAA in low and normal water year types.

Table 5-19. Number of days flows were at or above maximum weighted usable area (MWUA) for Chinook salmon spawning during August 15 to November 1 (79 day period) below Big Cliff Dam under three water year categories for each alternative.

	Number of days at or above MWUA flow level					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
NAA						
High	60	47	10	72.9	47.0	33.8
Low	0	47	0	28.3	47.0	2.6
Normal	2	47	0	64.1	47.0	22.1
Alt 1						
High	46	34	11	59.2	48.2	30.5
Low	12	9	4	39.0	32.3	16.3

Normal	39	18	5	52.2	44.2	24.2
Alt 2a						
High	38	27	5	55.9	46.7	37.2
Low	4	2	0	38.5	23.7	5.8
Normal	21	9	0	54.8	40.5	24.8
Alt 2b						
High	48	30	2	63.6	51.2	35.4
Low	0	0	0	47.5	34.6	7.0
Normal	20	11	0	62.9	49.5	24.6
Alt 3a						
High	11	5	2	39.1	24.7	23.3
Low	0	0	0	8.9	2.9	2.2
Normal	0	0	0	25.5	14.2	12.8
Alt 3b						
High	62	53	14	70.6	61.9	49.2
Low	8	1	0	49.8	36.5	10.9
Normal	32	11	0	69.0	58.3	34.6
Alt 4						
High	42	29	7	56.4	46.9	37.8
Low	4	2	0	37.4	21.4	6.1
Normal	22	8	0	54.6	39.9	25.0
Alt 5						
High	56	38	14	67.4	53.6	36.4
Low	0	0	0	42.1	32.5	6.2
Normal	35	22	0	67.7	53.9	32.8

Table 5-20. The minimum and average number of days, as a percentage of the WVS EIS No Action Alternative (NAA), flows were greater than flow levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for Chinook salmon spawning during August 15 to November 1 (79 day period) below Big Cliff Dam under three water year categories.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1						
High	77%	72%	110%	81%	103%	90%
Low	na	19%	na	138%	69%	622%
Normal	1950%	38%	na	81%	94%	109%
Alt 2a						
High	63%	57%	50%	77%	99%	110%
Low	na	4%	na	136%	50%	222%
Normal	1050%	19%	na	85%	86%	112%
Alt 2b						
High	80%	64%	20%	87%	109%	105%
Low	na	0%	na	168%	74%	265%
Normal	1000%	23%	na	98%	105%	111%
Alt 3a						
High	18%	11%	20%	54%	52%	69%
Low	na	0%	na	31%	6%	85%
Normal	0%	0%	na	40%	30%	58%
Alt 3b						
High	103%	113%	140%	97%	132%	146%
Low	na	2%	na	176%	78%	416%
Normal	1600%	23%	na	108%	124%	156%
Alt 4						
High	70%	62%	70%	77%	100%	112%
Low	na	4%	na	132%	46%	235%
Normal	1100%	17%	na	85%	85%	113%
Alt 5						
High	93%	81%	140%	92%	114%	108%
Low	na	0%	na	149%	69%	236%

Normal	1750%	47%	na	106%	115%	148%

Notes: Colored cells indicates the Alternative differs by more than 5% from the No Action Alternative. Flows providing 80%, 90% and 100% of the MWUA are listed in Table. When there were zero days of occurrence under the NAA, a percentage could not be calculated and "na" was entered.

Survival

For Chinook adults (Chinook redds surviving until swim-up model), results were better compared to the NAA in all water years for Alternatives 1 and 2b, and worse in all water years for Alternative 3a. Results were mixed, depending on water year for the other alternatives, with Alternatives 2a and 4 performing better than the NAA in the dry year (2015).
For Chinook juveniles (Chinook salmon adult equivalents), results were similar or better for all alternatives compared to the NAA in the dry (2015) and moderate (2016) year modeled. Results were poorer in the wet (2011) year modeled for all alternatives compared to the NAA, except for Alternative 2a.

Table 5-21. Percent difference from the NAA in estimated survival of spring Chinook in the Middle Fork below Dexter Dam for three simulation years.

	Chinook redds surviving until swim-up	Chinook salmon adult equivalents
Alt1		
2011	43%	-25%
2015	140%	3%
2016	13%	8%
Alt2a		
2011	5%	6%
2015	134%	7%
2016	-9%	3%
Alt2b		
2011	13%	-11%
2015	53%	9%
2016	16%	7%
Alt3a		
2011	-23%	-22%
2015	-6%	-3%
2016	-46%	-1%
Alt3b		
2011	17%	-16%
2015	-25%	2%

2016	23%	4%
Alt4		
2011	-9%	-19%
2015	60%	6%
2016	-3%	0%

Table Notes: Colored cells indicate the Preferred Alternative is different by 5% or more from the No Action Alternative. Percentages calculated from results presented in WVS EIS Appendix E, Chapter 5, Tables 5-5, 5-6 and 5-7.

5.5.5 Mainstem Willamette RIVER Juvenile Habitat – Albany

Results for spring Chinook juvenile habitat in the mainstem Willamette in the Albany Reach (as defined by White et al. (2022) showed variation in habitat availability under the alternatives compared to the NAA. Generally, alternatives provided similar to somewhat lower habitat availability compared to the NAA in winter months, similar to higher habitat availability in spring months, and mixed results in summer and fall. In low water year types these same patterns occurred, but habitat in April and May was higher in all the alternatives compared to the NAA. Alternative 3a showed the most difference from the NAA, with lower habitat availability in spring and higher availability in summer compared to the NAA, likely due to delaying refill of some reservoirs associated with fish passage measures included in this alternative.

Table 5-22. Habitat available, as a percentage of the habitat available under the No Action Alternative (NAA), for juvenile spring Chinook in the Albany Reach (as defined in White et al. 2022) under each WVS EIS alternative and the near-term operational measures (NTOM).

	alt1	alt2a	alt2b	alt3a	alt4	alt5	NTOM
Water Year Type: High							
Jan	100.0	100.0	102.0	101.5	100.0	102.1	102.8
Feb	100.0	100.0	95.9	91.0	100.0	95.8	92.4
Mar	100.0	100.0	89.2	71.9	100.0	90.7	90.5
Apr	100.0	100.0	93.3	80.9	100.0	94.6	84.2
May	100.0	100.0	97.5	88.2	100.0	97.8	102.0
Jun	100.0	100.0	100.7	107.1	100.0	101.0	104.1
Jul	98.6	100.0	101.6	100.3	100.0	101.4	95.3
Aug	97.7	105.0	105.1	108.2	104.7	104.9	105.8
Sep	102.6	103.4	104.9	115.1	103.5	104.8	99.5
Oct	107.6	95.7	104.0	112.3	93.5	102.1	98.1
Nov	100.0	99.2	105.1	123.8	99.4	106.8	115.3
Dec	100.0	100.0	102.8	105.6	100.0	102.4	101.8
Water Year Type: Low							
Jan	100.0	100.0	102.6	103.8	100.0	102.6	106.4
Feb	100.0	100.0	96.1	92.1	100.0	95.8	92.1
Mar	100.0	100.0	86.2	63.6	100.0	90.1	88.6
Apr	132.6	131.0	117.1	105.8	131.1	109.8	107.2

May	131.9	121.1	117.0	108.2	121.5	112.1	113.2
Jun	107.5	97.5	100.4	103.7	97.6	100.2	100.5
Jul	93.0	99.0	99.4	100.1	99.1	99.3	99.4
Aug	93.5	100.1	100.4	106.2	99.9	100.3	101.7
Sep	93.5	99.9	100.0	103.5	100.0	100.2	102.1
Oct	100.6	94.0	97.4	103.5	94.7	99.3	95.2
Nov	95.2	96.6	98.8	100.1	94.7	99.5	93.2
Dec	100.2	100.6	103.8	107.4	100.7	103.7	103.8
Water Year Type: Normal							
Jan	100.0	100.0	101.7	100.8	100.0	102.1	103.2
Feb	100.0	100.0	95.6	90.1	100.0	95.6	91.4
Mar	100.0	100.0	86.1	63.4	100.0	88.5	88.1
Apr	108.4	108.6	95.5	77.9	107.8	97.5	85.1
May	106.4	102.2	100.0	91.3	102.5	100.4	109.6
Jun	101.6	98.2	100.7	107.8	98.2	101.3	104.3
Jul	94.6	100.1	100.6	100.4	100.0	100.8	99.3
Aug	97.0	103.8	103.9	108.7	103.8	104.3	105.1
Sep	99.5	103.2	103.6	109.8	103.4	102.4	102.8
Oct	104.8	92.4	100.8	110.1	92.8	96.8	93.8
Nov	98.6	96.4	103.8	121.0	93.2	107.6	109.8
Dec	100.0	100.0	103.5	109.6	100.1	103.9	104.8

Table notes: Highlighted cells indicate if percentage is less than or greater than 5% different from the NAA.

5.5.6 Mainstem Willamette RIVER Juvenile Habitat - Salem

Modeling results for spring Chinook juvenile habitat in the mainstem Willamette in the Salem Reach (as defined by White et al. (2022) showed that habitat availability was similar to higher during nearly all months and water year types under Alternatives 1, 2a, 2b and 5 compared to the NAA. In particular, generally more habitat was available in a majority of the months under Alternatives 2a and 2b compared to the NAA in all water year types. Under Alternative 3a and the NTOM, less habitat was available compared to the NAA during spring, likely due to delaying refill of some reservoirs associated with fish passage measures included in these alternatives.

Table 5-23. Habitat available, as a percentage of the habitat available under the No Action Alternative (NAA), for juvenile spring Chinook in the Salem Reach (as defined in White et al. 2022) under each WVS EIS alternative and the near-term operational measures (NTOM).

	alt1	alt2a	alt2b	alt3a	alt4	alt5	NTOM
Water Year Type: High							
Jan	100.0	362.7	365.3	110.3	100.0	106.9	107.8
Feb	100.0	306.3	296.1	91.0	100.0	97.7	91.3
Mar	100.1	349.5	315.9	66.7	100.4	94.1	92.7
Apr	101.5	376.7	347.7	76.4	100.6	96.8	89.1
May	100.0	273.2	264.8	88.9	100.0	98.2	101.1

Jun	100.0	182.4	186.0	101.9	100.0	99.9	101.3
Jul	100.0	99.4	99.3	99.3	98.9	99.2	97.9
Aug	100.0	98.4	98.3	100.0	99.8	100.0	100.0
Sep	102.1	103.5	103.6	102.8	101.8	99.3	95.0
Oct	100.0	122.1	123.2	103.4	99.7	91.6	91.7
Nov	99.9	246.0	257.5	121.5	100.2	106.7	110.0
Dec	100.0	324.4	340.6	116.8	100.0	104.5	107.5
Water Year Type: Low							
Jan	100.0	351.7	355.7	113.6	100.0	108.8	110.6
Feb	100.0	203.9	203.5	93.3	100.0	98.3	92.9
Mar	100.5	166.3	163.9	67.9	101.3	96.0	94.3
Apr	120.6	157.1	157.3	101.5	118.1	111.0	104.7
May	112.6	129.9	130.4	102.0	110.7	108.9	106.4
Jun	102.1	104.3	104.3	100.4	98.9	99.7	100.4
Jul	99.8	98.2	98.2	100.0	99.7	99.6	100.0
Aug	100.0	98.3	98.3	99.5	100.0	100.0	100.0
Sep	100.1	99.5	99.6	100.0	100.7	100.0	100.0
Oct	99.6	102.2	102.3	99.9	99.8	96.7	97.5
Nov	91.3	166.9	171.3	100.2	95.1	96.5	95.2
Dec	100.1	389.4	397.3	115.0	100.3	106.6	107.3
Water Year Type: Normal							
Jan	100.0	409.7	413.5	111.5	100.0	108.4	109.2
Feb	100.0	304.9	293.8	90.2	100.0	97.7	92.3
Mar	100.3	267.6	249.1	62.5	100.7	93.8	92.4
Apr	105.5	216.5	210.4	79.9	105.1	99.8	92.9
May	102.5	164.2	162.6	92.6	100.7	99.2	103.8
Jun	101.1	116.0	116.5	101.8	97.9	99.3	100.6
Jul	99.6	98.3	98.3	99.5	99.1	99.2	98.9
Aug	99.9	98.2	98.2	99.8	99.8	100.0	100.0
Sep	101.5	101.1	101.4	101.9	101.6	99.7	99.4
Oct	99.7	113.8	115.3	102.3	99.5	91.1	91.9
Nov	97.3	199.7	205.6	118.2	98.5	107.7	107.9
Dec	100.0	286.2	293.8	114.8	100.1	106.2	107.1

Table notes: Highlighted cells indicate if percentage is less than or greater than 5% different from the NAA.

5.5.7 Summary for Priority Lifestage and Water Year Type

Optimal flows for adult and juvenile salmon and steelhead habitat and survival differ. Where tradeoffs must be considered, both lifestage and water year type are aspects important to consider for prioritization.

There is a higher likelihood of adult upstream migrants' effectively reproducing compared to the likelihood of a younger life stage doing so. Upstream migrating adults are much closer in both time and space to contributing to population reproduction than younger life stages. Young life stages must migrate downstream and survive rearing in the ocean before returning as adults to reproduce, and as such subject to significant levels of mortality from factors which cannot be controlled by management actions. Therefore, management targeting adults is expected to have a much larger effect on population abundance.

In addition to lifestage priority considerations, performance in dry years is likely more important to consider compared to normal and wet year types. There is more storage available in normal and wet years providing real-time flexibility to achieve management objectives. Furthermore, the effects of hot air temperatures on water temperatures can be exacerbated in dry years when flows are lower, increasing effects of dry water years on salmon and steelhead. In the North Santiam in the dry years, the alternatives (with the exception of 3a) provided more days above the 80% and 90% MWUA spawning flow levels compared the NAA for Chinook, and the same number of days for steelhead. Fewer days were provided under Alternative 3a compared to the NAA. Chinook survival to egg swim up was similar to the NAA (within 5%) under Alternatives 2a, 2b and 4, and lower than the NAA under the other alternatives. A model of adult steelhead to egg swim up was not completed. Results for the smolt and juvenile steelhead models in the dry year showed similar to higher survival in all alternatives except 3a compared to the NAA.

In the South Santiam in the dry years, the alternatives (with the exception of 3b) provided more days above the 80% and 90% MWUA spawning flow levels compared the NAA for Chinook, and the same or higher number of days for steelhead spawning. Under Alternative 3b compared to the NAA fewer days were provided meeting MWUA Chinook spawning flows and results were mixed for steelhead spawning. Chinook survival to egg swim up was higher under all alternatives compared to the NAA with the exception of 3b. A model of adult steelhead to egg swim up was not completed. Results for the smolt and juvenile steelhead models in the dry year showed similar to higher survival in all alternatives compared to the NAA, except for Age-1 steelhead under Alternatives 1 and 3b.

In the McKenzie, the alternatives provided fewer days above the MWUA spawning flow levels compared the NAA. Conversely, Chinook survival to egg swim up was similar to higher under all alternatives compared to the NAA. This may be because although spawning habitat availability changes, it is adequate under the alternatives, and the combined effects on survival for upstream migrating adults into the McKenzie and survival of their eggs during incubation is better. Given these results, monitoring will be important during implementation to ensure spawning habitat availability is not limiting.

In the Middle Fork below Dexter Dam, the alternatives provided fewer days above the MWUA spawning flow levels compared the NAA. Chinook survival to egg swim up was higher under

Alternatives 1, 2a, 2b, and 4 compared to the NAA, and lower under Alternatives 3a and 3b. UWR steelhead are not present in the McKenzie.

When looking specifically at the draft preferred alternative (represented by alternative 2b in this assessment) with the priorities of effective adult spawning in dry years, similar to more days above the 80% and 90% MWUA flow spawning levels for Chinook and steelhead were provided compared to the NAA in the North and South Santiam below WVS dams, and fewer days for Chinook in the South Fork McKenzie and Middle Fork below WVS dams. Chinook survival to egg swim up was similar to higher under the draft preferred alternative compared to the NAA in all sub-basins, despite there being fewer days at flows above the MWUA spawning levels in the South Fork McKenzie and Middle Fork. Steelhead survival was not modeled for adults to egg swim up. Steelhead juvenile and smolt survival was similar to higher in the North Santiam and South Santiam under the draft preferred alternative compared to the NAA in all sub-basins.

Table 5-24. Summary of flows were greater than levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for Chinook salmon spawning during August 15 to November 1 (79 day period) below Big Cliff Dam in dry years for each alternative compared to the NAA.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1	=/+	=/+	-	=/+	=/+	-
Alt 2a	=/+	=/+	-	=/+	=/+	-
Alt 2b	=/+	=/+	-	=/+	=/+	-
Alt 3a	-	-	-	-	-	-
Alt 3b	=/+	=/+	=/+	=/+	=/+	=/+
Alt 4	=/+	=/+	-	=/+	=/+	-
Alt 5	=/+	=/+	-	=/+	=/+	-

Table Note: highlighted cells > or < 5% of NAA.

Table. Summary of flows were greater than levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for winter steelhead spawning during March 15 to June 1 (79 day period) below Big Cliff Dam in dry years for each alternative compared to the NAA.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1	=/+	=/+	-	=/+	=/+	-
Alt 2a	=/+	=/+	-	=/+	=/+	-
Alt 2b	=/+	=/+	-	=/+	=/+	-
Alt 3a	-	-	-	=/+	=/+	-

Alt 3b	=/+	=/+	-	=/+	=/+	-
Alt 4	=/+	=/+	-	=/+	=/+	-
Alt 5	=/+	=/+	-	=/+	=/+	-

Table Note: highlighted cells > or < 5% of NAA.

Table 5-25. Percent difference from the NAA in estimated survival for spring Chinook and winter steelhead in the Middle Fork below Big Cliff Dam in a hot and dry year, 2015.

	Chinook redds surviving until swim-up	Steelhead trout smolt survival	Steelhead trout Age-1
Alt1	-38%	-3%	20%
Alt2a	3%	-2%	16%
Alt2b	-4%	-2%	19%
Alt3a	-30%	-5%	-43%
Alt3b	-8%	0%	45%
Alt4	-2%	-2%	1%

Table 5-26. Summary of flows were greater than levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for Chinook salmon spawning during August 15 to November 1 (79 day period) below Foster Dam in dry years for each alternative compared to the NAA.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1	=/+	=/+	-	=/+	=/+	-
Alt 2a	=/+	=/+	-	=/+	=/+	=/+
Alt 2b	=/+	=/+	-	=/+	=/+	=/+
Alt 3a	=/+	=/+	-	=/+	=/+	=/+
Alt 3b	-	-	-	-	-	-
Alt 4	=/+	=/+	-	=/+	=/+	=/+
Alt 5	=/+	=/+	-	=/+	=/+	=/+

Table Note: highlighted cells > or < 5% of NAA.

Table 5-27. Summary of flows were greater than levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for winter steelhead spawning during March 15 to June 1 (79 day period) below Foster in dry years for each alternative compared to the NAA.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1	=/+	=/+	-	=/+	=/+	-
Alt 2a	=/+	=/+	-	=/+	=/+	-
Alt 2b	=/+	=/+	-	=/+	=/+	-
Alt 3a	=/+	=/+	-	=/+	=/+	-
Alt 3b	=/+	-	=/+	=/+	=/+	-
Alt 4	=/+	=/+	-	=/+	=/+	-
Alt 5	=/+	=/+	-	=/+	=/+	-

Table Note: highlighted cells > or < 5% of NAA.

Table 5-28. Percent difference from the NAA in estimated survival for spring Chinook and winter steelhead in the Middle Fork below Foster Dam in a hot and dry year, 2015.

	Chinook redds surviving until swim-up	Steelhead trout smolt survival	Steelhead trout Age-1
Alt1	37%	-4%	-11%
Alt2a	54%	-3%	3%
Alt2b	51%	-3%	12%
Alt3a	54%	-4%	84%
Alt3b	-100%	-4%	-9%
Alt4	37%	-3%	15%

Table 5-29. Summary of flows were greater than levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for Chinook salmon spawning during August 15 to November 1 (79 day period) below Cougar Dam in dry years for each alternative compared to the NAA.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1	-	-	-	=/+	=/+	=/+
Alt 2a	-	-	-	=/+	=/+	=/+
Alt 2b	-	-	-	-	-	-

Alt 3a	-	-	-	-	-	-
Alt 3b	-	-	-	-	-	-
Alt 4	-	-	-	=/+	=/+	=/+
Alt 5	-	-	-	-	-	-

Table Note: highlighted cells > or < 5% of NAA.

Table 5-30. Percent difference from the NAA in estimated survival for spring Chinook and winter steelhead in the Middle Fork below Cougar Dam in a hot and dry year, 2015.

	Chinook redds surviving until swim-up
Alt1	7%
Alt2a	9%
Alt2b	4%
Alt3a	0%
Alt3b	0%
Alt4	7%

Table 5-31. Summary of flows were greater than levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for Chinook salmon spawning during August 15 to November 1 (79 day period) below Dexter Dam in dry years for each alternative compared to the NAA.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1	-	-	-	=/+	-	=/+
Alt 2a	-	-	-	=/+	-	=/+
Alt 2b	-	-	-	=/+	-	=/+
Alt 3a	-	-	-	-	-	-
Alt 3b	-	-	-	=/+	-	=/+
Alt 4	-	-	-	=/+	-	=/+
Alt 5	-	-	-	=/+	-	=/+

Table Note: highlighted cells > or < 5% of NAA.

Table 5-32. Percent difference from the NAA in estimated survival for spring Chinook and winter steelhead in the Middle Fork below Dexter Dam in a hot and dry year, 2015.

	Chinook redds surviving until swim-up
Alt1	140%
Alt2a	134%
Alt2b	53%
Alt3a	-6%
Alt3b	-25%
Alt4	60%

5.6 REFERENCES

Hansen, G.S., Perry, R.W., Kock, T.J., White, J.S., Haner, P.V., Plumb, J.M., and Wallick, J.R., 2023. Assessment of habitat use by juvenile Chinook salmon (Oncorhynchus tshawytscha) in the Willamette River Basin, 2020–21: U.S. Geological Survey Open-File Report 2023–1001, 20 p., https://doi.org/10.3133/ofr20231001.

Peterson, J. T., J. E. Pease, L. Whitman, J. White, L. Stratton-Garvin, S. Rounds, and R. Wallick. 2022. Integrated tools for identifying optimal flow regimes and evaluating alternative minimum flows for recovering at-risk salmonids in a highly managed system. River Research and Applications 38: 293–308.

R2 (R2 Resource Consultants, Inc.). 2014. Evaluation of Habitat-Flow Relationships for Spring Chinook and Winter Steelhead in the North and South Santiam Rivers, Oregon. Prepared for the U.S. Army Corps of Engineers Portland District by Michael R. Gagner, Chiming Huang, Timothy J. Sullivan, Dudley W. Reiser, and Timothy L. Nightengale, R2 Resource Consultants, Inc., Redmond, Washington 98052.

RDG (River Design Group). 2015. Evaluation of the relationship between river flow and fish habitat availability in the Middle Fork of the Willamette and McKenzie Rivers. Prepared for the U.S. Army Corps of Engineers, Portland District. Prepared by River Design Group Inc and HDR Inc, Corvallis, Oregon.

Scheuerell, MD. 2021. Development and application of an integrated population model for Chinook salmon in the Willamette River basin. Prepared for the U.S. Army Corps of Engineers, Portland District by Mark D. Scheuerell, Fish Ecology Division, Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, WA

Sharpe C., B Cannon, B DeBow, T Friesen, D Hewlett, P Olmsted, and M Sinnott. 2015. Work Completed for Compliance with the 2008 Willamette Project Biological Opinion, USACE funding: 2013 hatchery baseline monitoring. Prepared by Oregon Department of Fish and Wildlife, Willamette Salmonid Research, Monitoring, and Evaluation, Corvallis Research Lab. Prepared for the U.S. Army Corps of Engineers, Portland District. Task Orders: W9127N-12-2-0004-1009. May 2015.

Sharpe C., B Cannon, B DeBow, T Friesen, D Hewlett, P Olmsted, and M Sinnott. 2016. Work Completed for Compliance with the 2008 Willamette Project Biological Opinion, USACE funding: 2014 hatchery baseline monitoring. Prepared by Oregon Department of Fish and Wildlife, Willamette Salmonid Research, Monitoring, and Evaluation, Corvallis Research Lab. Prepared for the U.S. Army Corps of Engineers, Portland District. Task Orders: W9127N-12-2-0004-1009 and W9127N-10-2-0008-0031. June 2016.

Sharpe C., R. Mapes, B. Cannon, P. Olmsted, M. Sinnott, B. DeBow, E. Bailey, T. Hoblit, and T. Friesen. 2018. Abundance, Distribution, Diversity and Survival of Adult Spring Chinook Salmon in the Upper Willamette River: 2015 and 2016. Prepared by Oregon Department of Fish and Wildlife, Willamette Salmonid Research, Monitoring, and Evaluation Program, Corvallis Research Lab. Prepared for the U.S. Army Corps of Engineers, Portland District. Task Orders: W9127N-12-2-0004-4009 and W9127N-10-2-0008-0036.

White, J.S., Peterson, J.T., Stratton Garvin, L.E., Kock, T.J., and Wallick, J.R., 2022, Assessment of habitat availability for juvenile Chinook salmon (Oncorhynchus tshawytscha) and steelhead (O. mykiss) in the Willamette River, Oregon: U.S. Geological Survey Scientific Investigations Report 2022–5034, 44 p., https://doi.org/10.3133/sir20225034.

CHAPTER 6 - ASSESSMENT OF THE EFFECT OF WILLAMETTE VALLEY SYSTEM OPERATIONS AND MANAGEMENT ALTERNATIVES ON RESIDENT FISHES SOUGHT BY ANGLERS IN WILLAMETTE VALLEY RESERVOIRS

6.1 INTRODUCTION

Under the NAA, many WVS reservoirs undergo a partial reservoir drawdown each fall for flood risk management. Exceptions include re-regulation projects (Big Cliff and Dexter) which fluctuate on a daily but not seasonable basis, and Fall Creek which is fully evacuated each fall and then refilled during the conservation season as other WVS reservoirs. Under the NAA, pool elevations are managed to maintain the minimum conservation pool elevations from mid-November or December 1 (depending on the reservoir) to February 1 annually, except during storm events when water is temporarily captured in reservoirs. Refill begins in February each year following pre-defined water management diagrams (i.e. rule curves). This operating regime has occurred since the dams were constructed several decades ago. Measures in the WVS EIS include 1) continuing with a similar reservoir operating regime, 2) deeper drawdowns in the fall (Measure 40) and 3) deeper drawdowns in the spring (Measure 720). Different combinations of these operating regimes are included in the WVS EIS alternatives.

Resident fish occurring in WVS reservoirs provide recreational fishing opportunity. Annual water level fluctuations have important effects on habitat availability and downstream passage rates, and therefore fish survival, productivity and abundance. Some fish species are annually stocked in larger WVS reservoirs, supplementing their availability regardless of contributions from natural reproduction or reductions in abundance from conditions within the reservoirs or downstream passage/entrainment rates.

This assessment was completed to estimate the potential effects for resident fish, particularly those targeted for sport fishing in the larger reservoirs. The assessment focused on the following fish species commonly targeted in local recreational fisheries:

- Kokanee (*Oncorhynchus nerka*)
- Smallmouth bass (*Micropterus dolomieu*)
- Crappie (*Pomoxis* spp.)
- Rainbow trout (*Oncorhynchus mykiss*)

The assessment focused on the following reservoirs which have relatively larger recreational fisheries than others in the WVS:

- Detroit
- Green Peter
- Lookout Point
- Hills Creek

6.2 ASSESSMENT APPROACH

To assess the effects of EIS alternatives on the abundance of resident fishes commonly targeted by sport anglers in WVS reservoirs, reservoir conditions were qualitatively related to effects on spawning, rearing, foraging, predation risk, and risk of entrainment downstream through the dams. To accomplish this, life history information for targeted fish species was summarized. Available reports and information shared by WVS EIS Cooperating Agencies was also reviewed to assess the effects of water level fluctuations on spawning, rearing, foraging, predation risk, and risk of entrainment. However very limited information was available to relate reservoir volume to these factors. After reviewing species life history information, distribution and passage data, assumptions were developed to relate changes in reservoir volume to these factors and develop effect criteria associated with changes in reservoir volume. Reservoir elevations were then summarized for each alternative based on modeling completed using RES-SIM (EIS Appendix B), and the effects of each alternative on fish availability in WVS reservoirs was assigned. Stocking practices were then considered, which help to mitigate the effects of changes in reservoir volume and maintain availability of fish for angling, before assigning effect categories for each reservoir by alternative.

6.3 REVIEW OF FISH LIFE HISTORY

6.3.1 Rainbow Trout

Life history and habitat use patterns – Rainbow trout occur in Detroit, Green Peter, Lookout Point and Hills Creek reservoirs. From USGS (2023):

> Rainbow trout are a deep-bodied, compressed species with a typical trout body shape, a moderately large head, and a mouth that extends back behind the eyes. Rainbow trout have highly variable coloration: those that live in lakes are silvery with a dark olive-green color on the back, though the dorsal coloration is sometimes a deep steely blue, mostly in fish that live offshore in deep lakes or in small fish that have not yet spawned. Numerous spots are present on the back and extend about two-thirds of the way to the lateral line down the sides. The sides are silvery and largely free of spots, the belly and ventral surface of the head are whitish, and sometimes a soft metallic-pink color is present along the sides of the body and the head (GISD, 2019). Their native range covers the Pacific Slope from Kuskokwim River, Alaska, to (at least) Rio Santa Domingo, Baja California; upper Mackenzie River drainage (Arctic basin), Alberta and British Columbia; and endorheic basins of southern Oregon (Page and Burr 1991).
> Lake fish usually spawn in lake tributaries, where the young trout feed and grow before migrating downstream after about a year. Growing to maturity in the lake takes between 2-4 years, at which time they migrate back to the tributaries to spawn. Most fish will return to the tributary in which they hatched (McDowall, 1990). Some lake populations may spawn in lake-shore gravels rather than travel into tributaries, however. Adult rainbow trout eat insects (both aquatic and terrestrial), crustaceans, molluscs, fish eggs, and small fish. Young trout feed predominantly on zooplankton (GISD, 2019).

Downstream Passage Patterns at WVS Dams – Passage of *Oncorhynchus mykiss* has been well studied at Detroit and Foster dams (e.g. Hansen et al. 2017). Several of these studies include both the anadromous form (steelhead) and resident form (rainbow trout). Steelhead would be expected to have higher passage rates than resident forms, however data are limited for quantifying this difference. Generally, passage rates increase as depths to outlets decreases and secondarily as discharge increases. Seasonally, many pass downstream when surface spill occurs in spring, and when reservoirs are drawn down in the fall. Survival depends on the size of the fish, route of passage utilized, hydraulic head over the outlet, and rate of discharge, and can range from very low to over 80% percent. Passage patterns for rainbow trout at other large WVS dams is assumed to be similar to Detroit Dam.

Stock practices in WVS reservoirs – Triploid (sterile) hatchery rainbow trout are released multiple times per year into WVS reservoirs to provide for sport fishing opportunities. These hatchery fish come from various facilities (Leaburg, Willamette, Roaring River, Wizard Falls, Marion Forks, and Desert Springs). According to the 2021 Hatchery Genetics Management Plan for rainbow trout (ODFW and USACE, 2021), up to 472,825 pounds of trout are stocked into Willamette Basin waterbodies (including WVS reservoirs and other waterbodies) annually (Table 1). For waterbodies without ESA-listed fish present, ODFW determines trout stocking levels. ODFW prepares annual reports providing the pounds and numbers of hatchery fish propagated and released (e.g. ODFW 2022, ODFW 2023). For example, in 2022, a total of 305,326 hatchery rainbow trout (totaling 44,928 pounds) were released into Detroit Reservoir. The range of annual release dates is between February and October. Releases are timed for maximum public harvest utilization and opportunities. Stocking schedules are reported online by ODFW: https://myodfw.com/fishing/species/trout/stocking-schedule. At the time of this assessment, ODFW reported that 40,400 legal sized rainbow trout would be stocked into Green Peter between April 3, 2023 and May 3, 2024, 40,000 trophy sized rainbow trout will be stocked between May 15 and June 30, 2023 into Detroit Reservoir, and 14,200 legal sized rainbow trout between February 20 and October 6, 2023 into Hills Creek Reservoir (ODFW, 2023b). Full annual stocking schedules were not available for Detroit and Hills Creek reservoirs. No trout are to be stocked into Lookout Point reservoir according to the ODFW trout stocking schedule. For this assessment, stocking of rainbow trout into Detroit, Green Peter, Hills Creek and other WVS reservoirs would continue at levels specified in the 2021 Hatchery Genetics Management Plan.

Table 6-1. Maximum pounds of trout to be released annually into ESA-listed fish waterbodies, effective beginning in 2020. Reproduced from Table 10.1-1 included in ODFW and USACE (2021)

Waterbody	Total pounds of trout
Alton Baker Canal	25,000
Bethany Pond	1,500
Billy Lake	20
Blue River Above Reservoir	3,000
Blue River Reservoir	8,000
Breitenbush River	6,700
Buck Lake	10
Canby Pond	800
Carmen Reservoir	8,000
Clear Lake	15,000
Commonwealth Lake	1,200
Cottage Grove Reservoir	30,000
Crabtree Lake	20
Crabtree Pond	5
Cronemiller Lake	200
Detroit Reservoir	59,000
Dexter Reservoir	15,000
Dorena Reservoir	30,000
Dorman Pond	2,000

EE Wilson Pond	7,300
Fall Creek above Reservoir	5,000
Fall Creek Reservoir	7,500
Foster Reservoir	16,000
Freeway Lake, East	1,800
Green Peter Reservoir	20,000
Henry Hagg Lake	27,000
Hills Creek Reservoir	30,000
Huddleston Pond	4,000
Junction City Pond	11,500
Lake Eleanor	20
Leaburg Lake	10,000
McKenzie R above Leaburg Dam	25,000
McKenzie R below Leaburg Dam	15,000
Progress Lake	1,300
Quartzville Creek	7,900
Roaring River Park	400
Row River Nature Park	5,000
Salmon Creek	7,000
Santiam R, N Fk, Above res	12,000
Sheridan Pond	3,500
Silver Cr Reservoir	6,500
Smith Reservoir	5,000
St Louis Pond	2,800
Sunnyside Pond	1,550
Timber Linn Pond	1,500
Trail Bridge Reservoir	10,000
Walling Pond	3,700
Walter Wirth Lake	10,600
Waverly Lake	2,500
Willamette R, Cst Fk	5,000
Yamhill River	1,000
Total	472,825

Table note: For waterbodies without ESA-listed fish present, ODFW determines trout stocking levels.

Stocking of hatchery rainbow trout can have detrimental effects on native fish. From USGS (2023):

> Stocking of hatchery rainbow trout in rivers has led to introduction of whirling disease into open waters in approximately 20 states including, most recently, the Madison River and its tributaries in Montana (B. Nehring and R. White, personal communication). In the Madison River, the disease has reduced the rainbow trout population by 90% (White, personal communication).

Rainbow trout have the potential to consume native fishes and compete with native salmonids (Page and Laird 1993). Introduced rainbow trout eat endangered humpback chub Gila cypha in the Little Colorado River, and may exert a major negative effect on the population there (Marsh and Douglas 1997). Fausch (1988), Clark and Rose (1997), and numerous papers cited in both, discussed several factors affecting competitive interactions between rainbow and brook trout. Rainbow trout drive nongame fishes such as suckers and squawfish from feeding territories (Li, personal communication to P. Moyle in Moyle 1976a). Introduced predatory fishes, including the rainbow trout, are likely at least partially responsible for the decline of the Chiricahua leopard frog *Rana chiricahuensis* in southeastern Arizona (Rosen et al. 1995).

6.3.2 Kokanee

Life history and habitat use patterns – Among reservoirs included in this assessment, kokanee occur in Detroit and Green Peter reservoirs. Kokanee are a non-anadromous form of the species *Oncorhynchus nerka*. Kokanee live their entire lives in freshwater. Their life span is typically 4 years long, and most die after spawning. Kokanee are native to many lakes in the Pacific Northwest, and have been introduced to many reservoirs.

Kokanee spawning occurs in September or October and can occur along lake shorelines or in tributary streams. This timing has been observed in the North Santiam above Detroit Reservoir (Wetherbee, 1965). Kokanee maturing in WVS reservoirs spawn in upstream tributaries due to the steep slopes of the nearshore areas and water level fluctuations (e.g. Wetherbee, 1965). After hatching, fry live in the gravel for about one month. As reviewed by Quinn (2005), fry emerge from stream gravels and immediately migrate to lakes. Fry generally feed on aquatic insects and zooplankton in nearshore areas. Once reaching about 50 mm in length, they move into open water where they feed on zooplankton. Growth rates are influenced by food availability and temperature. It is assumed kokanee rearing patterns are the same as those observed for sockeye.

Monzyk et al. 2012 reported that from August through October, most kokanee in Detroit Reservoir were caught in the 18-23 m (60-75 ft) depth range, with a seasonal shift towards the surface in November and December. This is consistent with other reports on vertical distribution. Distribution and diel migration of kokanee has been shown to vary in association with prey availability and fish density (Buktenica et al. 2007).

Kokanee can grow several inches in a year in Detroit Reservoir (Wetherbee, 1965). In recent years density may be affecting kokanee growth rates in Green Peter Reservoir. One fishing website reports "For the past several years, the Kokanee at Green Peter have been very abundant, but also very small, sometimes only averaging 7", which was too small to entice many anglers to go after them" and further that "Kokanee are still over populated and running very small, like 7-9" (KPO, 2023). Similar comments were posted on other fishing websites (Apalategui, E. 2023).

It is unlikely that kokanee which move downstream of WVS dams will adopt an anadromous life history. Anadromy at least in part is genetically determined, and research on sockeye and kokanee indicates a relatively sharp division between these two forms (Quinn, 2005). Few adult sockeye are observed at adult fish collection facilities downstream from WVS dams in the North or South Santiam rivers. ODFW avoids risks of disease transference by not transporting returning adult sockeye back upstream of WVS dams.

Downstream Passage Patterns at WVS Dams - Due to the deeper vertical distribution of kokanee in summer and early fall, kokanee moving within forebays of WVS reservoirs are exposed to entrainment downstream. Outlets at both Detroit and Green Peter dams are located at depths kokanee regularly occur at during summer and fall. Rotary screwtraps operated below Detroit Dam indicate kokanee pass downstream at Detroit Dam primarily in the fall (Romer et al. 2012). Only the turbine penstocks or regulating outlets were operated in fall. The spillway was operated in summer, and passage rates were lower compared to the fall through other routes (Khan et al. 2011; Romer et al. 2012). Observations by Khan et al. (2011) using hydroacoustics to assess fish vertical distribution and passage at Detroit Dam suggests kokanee will readily use the RO when it is operated in lieu of turbines to pass the dam. Direct capture numbers for kokanee peaked in early November during RO operations (Romer et al. 2012), and a similar peak was observed in the hydroacoustic data during the same period (Khan et al. 2011). Quantitative estimates of the number or proportion of kokanee moving downstream of WVS dams are not available. Entrainment rates under existing operations have not diminished the development of popular fisheries in both Detroit and Green Peter reservoirs.

Stock practices and fishing in WVS reservoirs – Kokanee were originally stocked into Detroit Reservoir in 1959 (Wetherbee, 1965). In 2011, the Detroit reservoir was stocked with 55, 125 kokanee for a sport fishery, which is less than half of the usual stocking amount due to low egg availability (personal communication with Doug Curtis, Wizard Falls Hatchery, Camp Sherman, Oregon as cited in Khan et al. 2011). Kokanee Stocking has remained constant at 25,000 annually in October since 2016 (KPO, 2023). Information on reservoir fish stocking plans by ODFW was requested from the USACE by email from R. Piaskowski to E. Kelley and J. Ziller on May 26, 2023. . Kelley emailed reply June 15, 2023 stated kokanee are not currently stocked in Green Peter Reservoir but have been in the recent past. For this assessment It was assumed stocking of kokanee into Detroit and Green Peter reservoirs would continue or resume as needed to maintain fishing opportunity.

Recent changes in stocking practices have apparently improved survival of hatchery kokanee released into Detroit Reservoir. Compared to previous practices, kokanee have been released at a larger size (6-7 inches) and later in the summer or early fall in recent years to reduce predation on kokanee by stocked hatchery rainbow trout (Gearing, 2023). Many kokanee are 11 to 12 inches when caught by anglers from Detroit Reservoir. Assuming similar growth rates as reported by Wetherbee (1965), then these fish were either stocked into the reservoir the prior year, or at most 2 years prior, before being caught.

Per ODFW Willamette Zone fishing regulations (ODFW 2023c), kokanee are included in trout limits for which there is an 8 inch minimum length. However, in Green Peter Reservoir, Lookout Point Reservoir there is no size limit for those which can be removed by angling.

According to one website covering fishing in WVS reservoirs, “Detroit Lake also has increasingly become one of the very best kokanee lakes around, and in some serious kokanee anglers’ opinions it has overtaken Green Peter Reservoir as the best kokanee fishing spot anywhere in Western Oregon” (Apalategui 2023b). Elise Kelly, ODFW fish biologist said “natural production at the lake accounts for 50 to 70% of the catch taken from the [Detroit] reservoir" (Gearing, 2023). Hatchery stocked kokanee would therefore account for the remaining 30-50% of the catch.

6.3.3 Smallmouth Bass

Life History and Habitat Use Patterns – Smallmouth bass occur in Green Peter, Lookout Point Reservoir and potentially Hills Creek Reservoir. The Smithsonian Environmental Research Center's National Estuarine and Marine Exotic Species Information System (Smithsonian ERC, 2023) summarized the following on smallmouth bass ecology

> The Smallmouth Bass (*Micropterus dolomieu*) is a freshwater predatory fish. Adults can mature at 2 years, or as late as 9 years, but more usually at age 3–4. Virginia and California populations at age 3 to 4 range from 190 to 410 mm at these ages (Jenkins and Burkhead 1994; Moyle 2002). Spawning takes place at 16–27 C, in freshwater, often moving upstream in tributaries. Adult male fish move into shallow water, ~1 m deep, near shore, and excavate a nest in sand, gravel, or rock (Hardy 1978; Wang 1986; Jenkins and Burkhead 1993; Moyle 2002). Males guard a nesting site against other males, and court females. Females may spawn with more than one male, and males may spawn with more than female. Females can carry ~2,000–21,000 eggs. Males vigorously guard the eggs through hatching and until the larvae reach 20–30 mm. Eggs take 2.5–9 days to develop at 15–26 C (Hardy 1978; Jenkins and Burkhead 1994; Moyle 2002).
> Smallmouth Bass inhabit clear gravel-bottom runs and flowing pools of small to large rivers, and the rocky shoals of lakes (Hardy 1978; Page and Burr 1991; Wang 1986). In the Chesapeake Bay region, it is common in the Piedmont and Fall Line, the bottoms are rocky, and currents are strong, but this fish is rare in the Coastal Plain region, where currents are slower, temperatures are higher, and oxygen is lower (Jenkins and Burkhead 1993; Murdy et al. 1997). Preferred temperatures are 20–28 C, but Smallmouth Bass have been collected at 4 °C and have an experimental upper lethal temperature of 35 °C (Hardy 1978). They are rare in brackish water, but have been collected at 7.4 PSU (Hildebrand and Schroeder 1928). Smallmouth Bass tolerates dissolved oxygen of 0.9-1.0 ppm at 21 °C, but is usually associated with well-oxygenated waters (Carlander 1977). Juveniles feed on microcrustaceans and insects, and switch to fish and crayfish as they grow. Other prey include amphibians, insects, and other Smallmouth Bass (Jenkins and Burkhead 1993; Moyle 2002). The Largemouth (M. salmoides) and Spotted Bass (M. punctulatus) are potential competitors. Humans are the primary predators of adult fish as the Smallmouth is an esteemed gamefish.

From the U.S. Forest Service (USFS 2023):

> Smallmouth bass prefer large clear-water lakes (greater than 100 acres, more than 30 feet deep) and cool streams with clear water and gravel substrate. In small streams a fish's activity may be limited to just one stream pool or extend into several. Spawning occurs in the spring. Smallmouth bass are carnivorous and feed on a variety of animals such as other fish, crayfish, reptiles, amphibians, small mammals.
> When water temperatures approach 60°F males move into spawning areas. Nests are usually located near shore in lakes; downstream from boulders or some other obstruction that offers protection against strong current in streams. Mature females may contain 2000-15,000 golden yellow eggs. Males may spawn with several females on a single nest. On average each nest

contains about 2,500 eggs, but nests may contain as many as 10,000 eggs. Eggs hatch in about 10 days if water temperatures are in the mid 50's (°F), but can hatch in 2-3 days if temperatures are in the mid-70's (°F). Males guard the nest from the time eggs are laid until fry begin to disperse, a period of up to a month.

Because of its excellent sporting reputation, smallmouth bass have been stocked throughout the United States and Arizona. Minnows, crayfish, and alderfly larvae (hellgrammites) are among the most successful live baits used. Smallmouth bass now rank among the top 15 most preferred species. Life Span – Smallmouth live on average 6 – 14 years. Some specimens have been determined to be 20 years old.

ODFW describes smallmouth bass as adapted to flowing waters and do well in warm streams with deep holes and rocky ledges (ODFW 2023d). They also prefer lakes and reservoirs with rocky shorelines and limited vegetation. Adult smallmouth feed mostly on fish and crayfish. Although not native to the western U.S., they have been transplanted into several WVS reservoirs.

Downstream Passage Patterns at WVS Dams – Sampling within WVS reservoirs included in this assessment documents smallmouth bass occurrence in Lookout Point and Hills Creek reservoirs, but not Detroit Reservoir (Monzyk and others, 2011, 2014 and 2015). Email from E. Kelley dated 6.616.23) to R. Piaskowski stated smallmouth bass also occur in Green Peter Reservoir. Although smallmouth bass occur in Lookout Point and Hills Creek reservoirs, few are observed in traps below these dams (Romer and others, 2012, 2013, 2014, 2015 and 2016). Assuming trapping provides a reasonable indication of relative passage rates, it appears downstream passage under NAA operations does not result in many of these fish passaging downstream of the reservoir. However, under deep reservoir drawdowns, passage rates would be expected to increase. At Fall Creek, where the reservoir is drawdown to river bed in the fall, large numbers of resident fishes have been collected having passed downstream during the annual drawdown. If a reservoir is drawn down however with a pool remaining upstream, it is not clear how many will exit downstream. Foster Reservoir is smaller than the reservoirs included in this assessment. Although present, few crappie are observed passing downstream of Foster Reservoir. However, this may not be a good indicator of other resident fishes downstream passage rates if a reservoir pool is drawn down substantially lower than elevations occurring under the NAA, which could result in higher densities of these fish in the forebay and increase passage rates downstream. Given they are typically distributed in nearshore areas of reservoirs in vegetated areas, it is unclear how much passage rates for smallmouth bass may change except under drawdown to riverbed.

Stock practices in WVS reservoirs – No records on stocking of smallmouth bass were found. It was assumed for this assessment no stocking occurs of smallmouth bass into WVS reservoirs or tributaries flowing into WVS reservoirs.

6.3.4 Crappie

Life History and Habitat Use Patterns – White and Black Crappie occur in Lookout Point and Hills Creek reservoirs. The Smithsonian (Smithsonian ERC, 2023b) summarized the following on the ecology of crappie:

The White Crappie (*Pomoxis annularis*) is a freshwater predatory fish. Adults can mature at 1 year, but more usually 2–3 years, depending on latitude, at sizes of 142–200 mm (Hardy 1978; Jenkins and Burkhead 1994; Moyle 2002). Spawning takes place at 14–23°C, in freshwater. Adult male fish move into shallow water, ~0.1–06 m deep, near shore, and nest in colonies. Eggs may be deposited on algae, leaves, or tree roots, or in an excavation in the substrate (Hardy 1978; Wang 1986; Jenkins and Burkhead 1993; Moyle 2002). Males guard a nesting site against other males, and court females. Females may spawn with more than one male, and males may spawn with more than female. Females can carry 970–326,000 eggs. Males vigorously guard the eggs through hatching to the postlarval stage. Eggs take 1–4 days to develop at 14-24°C. The postlarvae swim in schools in shallow, weedy waters (Hardy 1978; Wang 1986; Jenkins and Burkhead 1993; Moyle 2002). Adults in Virginia typically live up to 7 years, but one specimen lived for 9 years (Jenkins and Burkhead 1993).
White Crappies inhabit sand and mud-bottomed pools and backwaters of creeks and small to large rivers, and lakes and ponds, often associated with vegetation, and often with turbid conditions. (Hardy 1978; Page and Burr 1991; Wang 1986). They appear to be tolerant of alkaline conditions and sensitive to low pH ((Jenkins and Burkhead 1993; Moyle 2002). Based on their distribution, they tolerate ice-covered waters, and temperatures at least as high as 29°C (Hardy 1978; Page and Burr 1991). White Crappies appear to be rare in brackish water, but they have been collect at 6 PSU in Delaware Bay tributaries (Hardy 1978). They tend to school and often remain near logs or other cover. Adults have long, fine gill-rakers, and are capable of feeding on zooplankton, but are also predators on aquatic insects and fishes, including Threadfin Shad (*Dorosoma petenense*) and Mississippi Silversides (*Menidia audens*) (Moyle 2002). Predators include other fishes, birds, and humans.

Black Crappies tolerate a temperature range from 4 to 32.5 °C, and survive under ice-cover in much of their range (Hardy 1978). Most estuarine records are from tidal fresh water, but specimens have been collected at a salinity of 5.9 PSU (Smith 1971). This fish is tolerant of somewhat acidic water, and is common in the Dismal Swamp of Virginia (Jenkins and Burkhead 1993). Black Crappies inhabit lakes, reservoirs, sloughs, ponds, swamps, and backwaters and pools of streams. They are often associated with vegetation and coarse woody debris (Hardy 1978; Wang 1986; Jenkins and Burkhead 1993). Young Black Crappie feed on zooplankton, and in the Delta, mysids and amphipods, while adult fish feed smaller fishes, including juveniles of Threadfin Shad (*Dorosoma petenense*) and Striped Bass (*Morone saxatilis*). Predators include other fishes, birds, and humans.

Downstream Passage Patterns at WVS Dams – Among reservoirs included in this assessment, crappie occur in Lookout Point and Hills Creek reservoirs. Sampling within WVS reservoirs included in this assessment documents crappie occurrence in Lookout Point and Hills Creek reservoirs, but not Detroit Reservoir (Monzyk and others, 2011, 2014 and 2015). No data was available for Green Peter Reservoir. Although crappie occur in Lookout Point and Hills Creek reservoirs, few are observed in traps below these dams (Romer and others, 2012, 2013, 2014, 2015 and 2016). Assuming trapping provides a reasonable indication of relative passage rates, it appears downstream passage under NAA operations does not result in many of these fishes passaging downstream of the reservoir. However, under deep reservoir drawdowns, passage rates would be expected to increase.

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Stock practices in WVS reservoirs – No records on stocking of crappie into WVS reservoirs were found. It was assumed for this assessment no stocking of crappie occurs into WVS reservoirs or tributaries flowing into WVS reservoirs.

6.4 REVIEW OF RESERVOIR FLUCTUATIONS ON AQUATIC HABITAT, PRODUCTIVITY AND FOOD WEBS

WVS dams were constructed in the western side of the Cascade Mountains and foothills. Reservoirs inundate primarily steeply sloped valleys. Reservoir water levels fluctuate significantly each year, and can undergo significant fluctuations on a daily or seasonal timeframe as well (see WVS EIS Appendix B).

Local populations of several resident fish species have been able to naturally maintain without stocking under the current operating regime (i.e. NAA) as evidenced by their presence for several years and observations of multiple size classes collected using a variety of methods (e.g. Monzyk et al. 2014; Romer et al. 2016). Changing the operation regime to fully draining reservoirs annually to riverbed (as included as a measure for Cougar Reservoir in Alternative 3b) would significantly impact the abundance of resident fish residing in the reservoir (e.g. Murphy et al. 2019), where most fish will be flushed downstream annually. This in turn will affect predation and competition between fishes in the reservoir at other times of year. Data on the effects partial annual drawdowns deeper than occurs under the NAA, as proposed under Measures 720 and 40, are not available, however would not be expected to have the same effects as a full drawdown to riverbed. Effects of deeper partial drawdowns likely depend on each species life history and distribution, diet and food availability, presence of competitors and predators, among other factors.

There is evidence that biomass and community composition of zooplankton would not be different between current partial drawdowns depicted under the NAA and deeper drawdowns as included in the alternatives. Zooplankton, biomass and community composition in Fall Creek Reservoir, which was drawn down to the streambed for a week each fall, were not different from the other WVS reservoirs sampled that were partially drawn down each fall (Murphy et al. 2020. Peak abundance occurred in June within the WVS reservoirs sampled, similar to seasonal patterns in other oligo-mesotrophic lakes.

Deeper reservoir drawdowns will temporarily change habitat available, affect the density and distribution of fish and their primary forage items (macroinvertebrates, zooplankton, prey fish). Temporary draining of a reservoir each year to riverbed could cause normally piscivorous fish (largemouth bass and rainbow trout) to switch to feeding on invertebrates and zooplankton instead of fish, but not partial drawdowns (Murphy et al. 2019b). Partial drawdowns likely do not result in the same reduction in smaller prey fish availability compared to fully draining a reservoirs.

6.5 EFFECTS CRITERIA DETERMINATION

Information to quantify the effects of different reservoir volumes on rainbow trout, kokanee, crappie or smallmouth bass growth, survival, abundance or downstream passage rates were not available. Assumptions were developed based on review of each species life history, and available information on reservoir usage patterns, stocking practices, and downstream passage information. Assessment criteria were developed based on the conservative assumption that habitat and food availability decreases, and predation risk increases, as pool volume decreases (Table 2). These effects in turn were assumed to reduce seasonal and annual growth and survival rates leading to decreased abundance (i.e. availability for anglers). There is considerable uncertainty in this assumption. Population response to significant but partial reservoir drawdowns is complex and expected to be variable. All drawdowns influence habitat availability, densities of competitors, predators and prey. As reservoir volumes decline, compulsory movements and shifts in distribution could expose individuals to increased predation or reduce foraging opportunity, especially for littoral species or life stages. Longer duration drawdowns could allow some fishes to re-establish in preferred habitat or switch food sources, however reduced volumes could reduce carrying capacity. Responses would be expected to differ with habitat available under the drawdown, duration, season, life history patterns, reservoir aquatic community composition and trophic structure, and differences in environmental conditions.

As summarized above, data indicate downstream passage rates at WVS dams are higher for rainbow trout and kokanee compared to crappie and smallmouth bass. Data also indicate that nearly all resident fishes will move downstream when a reservoir is fully evacuated to river bed (Murphy et al. 2020. However, data were not adequate to understand how passage rates would change with a partial deeper drawdowns (i.e. when a reservoir pool remains), as occurs under all alternatives for the reservoirs being assessed here. Previous summaries of fish downstream passage generally support that passage rates increase as depths to operating outlets decrease (e.g. Hansen et al. 2017; Keefer et al. 2012). It was therefore assumed that downstream passage rates of all fish species assessed would increase as reservoir elevations decreased, particularly when pool surface elevations are close to (within 25 ft) the top of available outlets at each dam (Table 3).

Final effect determinations accounted for fish stocking (Table 4). No stocking was assumed for crappie and smallmouth, and therefore the effect determinations based on reservoir volumes was applied. Where stocking has occurred in recent years for rainbow trout (Detroit, Green Peter, and Hills Creek reservoirs) and kokanee (Detroit and Green Peter reservoirs), it was assumed it would occur in the future, and thereby mitigate for the effects of reservoir volume reductions. Effects from the reservoir volume analysis were adjusted from major to moderate where average reservoir elevations were estimated to be > 50% lower than the NAA for more than 3 months per year, and from major to minor where average reservoir elevations were estimated to be > 50% lower than the NAA for 3 months or less per year. If reservoir elevation > 50% lower than the NAA for 6 or more months, then a major effect was not adjusted even when stocking was considered. This approach accounts for the positive effects of stocking to provide fish for angling while accounting for the assumed negative effects of smaller reservoir volumes on the growth and survival of stocked fish and/or naturally produced fish.

Table 6-2. Assumptions on the availability of fish targeted by anglers at different reservoir elevations and the associated effects levels assigned.

Monthly reservoir volume difference from NAA	Effect level	Assumptions
Within <10%	None/ negligible	Habitat and food availability decreases, and predation risk increases, as pool volume (elevation) decreases. These effects in turn reduce seasonal
Between 10% and 24% lower for 2 or more months/yr	Minor	
Between 25% and 50% lower for 2 or more months/yr	Moderate	

Greater than 50% lower for 2 or more months/yr	Major	and annual growth and survival rates leading to decreased fishing opportunity.

Table 6-3. Assumptions on the downstream passage effects availability of fish targeted by anglers at different reservoir elevations and the associated effects levels assigned.

Monthly reservoir volume difference from NAA	Effect level	Assumptions
Between 0% and 10% lower	None/ negligible	Downstream passage/entrainment increases as reservoir elevation decreases
Between 10% and 25% lower for 2 or more months/yr	Minor	
Between 25% and 50% lower for 2 or more months/yr	Moderate	
Greater than 50% lower for 2 or more months/yr	Major	

Table 6-4. Adjustment in effect category when accounting for stocking

Effect level based on reservoir volume	Adjustment in effect level with annual stocking	Assumption
None/ negligible	None/ negligible	NA
Minor	None/ negligible	Stocking mitigates effects of reservoir reductions on fish abundance
Moderate	Minor	Stocking substantially mitigates effects of reservoir reductions on fish abundance
Major	Moderate, unless reservoir elevation > 50% lower than the NAA for 6 or more months	Stocking partially mitigates effects of reservoir reductions on fish abundance

6.6 EFFECTS ANALYSIS

6.6.1 Detroit

Reservoir operational changes on the availability of resident fish for angling in Detroit Reservoir were estimated to result in non/negligible effects from Alternatives 1, 2a, 2b and 4 for both the availability of kokanee and rainbow trout, when considering ongoing stocking practices. Conversely Alternatives 3a and 3b were assessed to have a major and moderate effect, respectively, on the availability of kokanee and rainbow trout. Effects of Alternatives 3a and 3b reflect the assumed effects from delayed reservoir refill and/or deep reservoir drawdowns on habitat availability, food, competition, predation and downstream passage/entrainment rates. Ongoing stocking of kokanee and rainbow trout are expected to partially mitigate for these effects helping to maintain availability of these fishes for sport angling.

Table 6-5. Percent difference in average reservoir pool volume at Detroit Reservoir for each WVS EIS Alternative compared to the NAA by month.

Average Pool Volume - Percent Difference from NAA						
	Alt 1	**Alt 2a**	**Alt 2b**	**Alt 3a**	**Alt 3b**	**Alt 4**
Jan	1%	0%	0%	-16%	-16%	1%
Feb	0%	0%	0%	-22%	-5%	0%
Mar	1%	1%	1%	-65%	-3%	1%
Apr	5%	5%	5%	-82%	3%	5%
May	5%	4%	4%	-86%	3%	4%
Jun	4%	3%	3%	-85%	2%	3%
Jul	6%	1%	1%	-82%	-2%	1%
Aug	6%	-2%	-2%	-82%	-7%	-2%
Sep	9%	-2%	-2%	-81%	-14%	-2%
Oct	6%	3%	3%	-76%	-34%	3%
Nov	2%	1%	1%	-69%	-66%	1%
Dec	0%	-1%	-1%	-51%	-51%	-1%

Table 6-6. The number of months average pool elevation categories for Detroit Reservoir occur for each WVS Alternative and the associated effect category.

	Number of months average pool elevation categories occur					
Pool volume category	**Alt 1**	**Alt 2a**	**Alt 2b**	**Alt 3a**	**Alt 3b**	**Alt 4**
10-24% lower	0	0	0	2	2	0
25-50% lower	0	0	0	0	1	0
>50% lower	0	0	0	10	2	0
Effect category	None/ negligible	None/ negligible	None/ negligible	Major	Major	None/ negligible

Table 6-7. Effect determination for the availability of resident fish for sport angling in Detroit Reservoir by alternative, accounting for differences in reservoir volumes and stocking.

	Alt 1	**Alt 2a**	**Alt 2b**	**Alt 3a**	**Alt 3b**	**Alt 4**
Kokanee (w/stocking)	None/ negligible	None/ negligible	None/ negligible	Major	Moderate	None/ negligible

Rainbow trout (w/stocking)	None/ negligible	None/ negligible	None/ negligible	Major	Moderate	None/ negligible

6.6.2 Green Peter

Effects of changes in reservoir operations on the availability of resident fish for angling in Green Peter Reservoir were estimated to result in non/negligible effects from Alternative 1, minor effects from Alternative 4, and moderate to major effects from the remaining alternatives, when considering ongoing stocking practices. Moderate and major effects for 2a, 2b, 3a and 3b reflect the assumed effects from delayed reservoir refill and/or deep reservoir drawdowns on habitat availability, food, competition, predation and downstream passage/entrainment rates. Ongoing stocking of kokanee and rainbow trout are expected to partially mitigate for these effects helping to maintain availability of these fishes for sport angling.

Table 6-8. Percent difference in average reservoir pool volume at Green Peter Reservoir for each WVS EIS Alternative compared to the NAA by month.

Average Pool Volume - Percent Difference from NAA						
	Alt1	**Alt4**	**Alt2a**	**Alt2b**	**Alt3a**	**Alt3b**
Jan	-1%	-1%	-24%	-24%	-24%	-20%
Feb	0%	0%	-5%	-3%	-3%	-24%
Mar	1%	1%	0%	0%	0%	-72%
Apr	2%	2%	1%	1%	1%	-96%
May	3%	2%	2%	2%	2%	-97%
Jun	4%	0%	0%	0%	0%	-89%
Jul	6%	-5%	-5%	-5%	-5%	-91%
Aug	8%	-14%	-14%	-14%	-14%	-95%
Sep	19%	-18%	-26%	-26%	-26%	-96%
Oct	23%	-15%	-67%	-67%	-67%	-95%
Nov	4%	-7%	-92%	-92%	-92%	-94%
Dec	0%	-1%	-79%	-79%	-79%	-77%

Table 6-9. The number of months average pool elevation categories at Green Peter Reservoir occur for each WVS Alternative and the associated effect category.

	Number of months average pool elevation categories occur					
Pool volume category	**Alt 1**	**Alt 4**	**Alt 2a**	**Alt 2b**	**Alt 3a**	**Alt 3b**
10-24% lower	0	3	2	2	2	2
25-50% lower	0	0	1	1	1	0

>50% lower	0	0	3	3	3	10
Effect category	None/negligible	Minor	Major	Major	Major	Major

Table 6-10. Effect determination for the availability of resident fish for sport angling in Green Peter Reservoir by alternative, accounting for differences in reservoir volumes and stocking.

	Alt 1	**Alt 4**	**Alt 2a**	**Alt 2b**	**Alt 3a**	**Alt 3b**
Smallmouth (no stocking)	None/negligible	Minor	Major	Major	Major	Major
Kokanee (w/stocking)	None/negligible	Minor	Minor	Moderate	Moderate	Major
Rainbow trout (w/stocking)	None/negligible	Minor	Minor	Moderate	Moderate	Major

6.6.3 Lookout Point

Effects of changes in reservoir operations on the availability of resident fish for angling in Lookout Point Reservoir were estimated to result in non/negligible effects from Alternatives 1, 2a, 2b and 4, and major effects from Alternatives 3a and 3b. Major effects for 3a and 3b reflect the assumed effects from delayed reservoir refill and/or deep reservoir drawdowns on habitat availability, food, competition, predation and downstream passage/entrainment rates. Stocking does not occur for species assessed in this reservoir and therefore not assumed to offset the effects of reservoir operations.

Table 6-11. Percent difference in average reservoir pool volume in Lookout Point Reservoir for each WVS EIS Alternative compared to the NAA by month.

Average Pool Volume - Percent Difference from NAA						
	Alt 1	**Alt 2a**	**Alt 2b**	**Alt 3a**	**Alt 3b**	**Alt 4**
Jan	-2%	-2%	-3%	-16%	-19%	-2%
Feb	-4%	-4%	-4%	-17%	-1%	-4%
Mar	-6%	-6%	-5%	-66%	4%	-6%
Apr	-3%	-3%	-3%	-85%	6%	-3%
May	-1%	-1%	-1%	-89%	5%	-1%
Jun	1%	1%	1%	-88%	2%	1%
Jul	3%	2%	1%	-76%	-5%	2%
Aug	1%	3%	2%	-65%	-14%	3%
Sep	-2%	9%	5%	-53%	-27%	9%
Oct	0%	10%	3%	-58%	-56%	10%
Nov	2%	2%	0%	-77%	-80%	2%
Dec	-2%	-2%	-2%	-55%	-63%	-2%

Table 6-12. The number of months average pool elevation categories in Lookout Point Reservoir occur for each WVS Alternative and the associated effect category.

	Number of months average pool elevation categories occur					
Pool elevation category	**Alt 1**	**Alt 2a**	**Alt 2b**	**Alt 3a**	**Alt 3b**	**Alt 4**
10-24% lower	0	0	0	2	2	0
25-50% lower	0	0	0	0	1	0
>50% lower	0	0	0	10	3	0
Effect category	None/ negligible	None/ negligible	None/ negligible	Major	Major	None/ negligible

Table 6-13. Effect determination for the availability of resident fish for sport angling in Lookout Point Reservoir by alternative, accounting for differences in reservoir volumes and stocking.

	Alt 1	**Alt 2a**	**Alt 2b**	**Alt 3a**	**Alt 3b**	**Alt 4**
Crappie (no stocking)	None/ negligible	None/ negligible	None/ negligible	Major	Major	None/ negligible
Smallmouth (no stocking)	None/ negligible	None/ negligible	None/ negligible	Major	Major	None/ negligible

6.6.4 Hills Creek

Effects of changes in reservoir operations on the availability of resident fish for angling in Hills Creek Reservoir were estimated to result in non/negligible effects from Alternatives 1, 2a, 2b, and 4, when considering ongoing stocking practices. Minor to moderate effects were assessed for Alternatives 3a and 3b and reflect the assumed effects from delayed reservoir refill and/or deep reservoir drawdowns on habitat availability, food, competition, predation and downstream passage/entrainment rates. Ongoing stocking of rainbow trout are expected to partially mitigate for these effects helping to maintain availability of this fish species for sport angling.

Table 6-14. Percent difference in average reservoir pool volume in Hills Creek Reservoir for each WVS EIS Alternative compared to the NAA by month.

Average Pool Volume - Percent Difference from NAA						
	Alt 1	**Alt 2a**	**Alt 2b**	**Alt 3a**	**Alt 3b**	**Alt 4**
Jan	0%	-2%	-2%	-3%	-3%	-2%
Feb	0%	-1%	-2%	4%	-17%	-1%
Mar	0%	-1%	-1%	3%	-37%	-1%

Apr	5%	4%	4%	5%	-45%	4%
May	13%	12%	11%	13%	-48%	12%
Jun	18%	12%	12%	13%	-46%	12%
Jul	12%	7%	6%	-1%	-41%	7%
Aug	4%	7%	3%	-15%	-36%	8%
Sep	0%	7%	1%	-27%	-30%	7%
Oct	1%	2%	-4%	-26%	-23%	2%
Nov	-2%	-7%	-7%	-19%	-18%	-6%
Dec	-1%	-6%	-5%	-8%	-6%	-5%

Table 6-15. The number of months average pool elevation categories in Hills Creek Reservoir occur for each WVS Alternative and the associated effect category.

	Number of months average pool elevation categories occur					
Pool volume category	**Alt 1**	**Alt 2a**	**Alt 2b**	**Alt 3a**	**Alt 3b**	**Alt 4**
10-24% lower	0	0	0	2	3	0
25-50% lower	0	0	0	2	7	0
>50% lower	0	0	0	0	0	0
Effect category	None/ negligible	None/ negligible	None/ negligible	Moderate	Moderate	None/ negligible

Table 6-16. Effect determination for the availability of resident fish for sport angling in Hills Creek Reservoir by alternative, accounting for differences in reservoir volumes and stocking.

	Alt 1	**Alt 2a**	**Alt 2b**	**Alt 3a**	**Alt 3b**	**Alt 4**
Crappie (no stocking)	None/ negligible	None/ negligible	None/ negligible	Moderate	Moderate	None/ negligible
Smallmouth (no stocking)	None/ negligible	None/ negligible	None/ negligible	Moderate	Moderate	None/ negligible
Rainbow trout (w/stocking)	None/ negligible	None/ negligible	None/ negligible	Minor	Minor	None/ negligible

6.7 REFERENCES

Apalategui, E. 2023. Green Peter Reservoir Kokanee Fishing – Tips from a Resident Expert by Eric Apalategui. Accessed online June 7, 2023 at https://www.bestfishinginamerica.com/or-green-peter-reservoir-kokanee.html.

Apalategui, E. 2023b. Detroit Lake Fishing: How to Limit on Trout & Kokanee (2023 Update). Accessed online June 7, 2023 at https://www.bestfishinginamerica.com/or-detroit-lake-fishing-rainbow-trout-kokanee-oregon.html.

Buktenica, M.W., Girdner, S.F., Larson, G.L. et al. Variability of kokanee and rainbow trout food habits, distribution, and population dynamics, in an ultraoligotrophic lake with no manipulative management. Hydrobiologia 574, 235–264 (2007). https://doi.org/10.1007/s10750-006-0355-1

Gearing, C. 2023. These landlocked mini-salmon are delicious and fun to catch at Detroit Lake in Oregon. Salem Statesman Journal, May 27, 2023. https://www.statesmanjournal.com/story/travel/outdoors/2023/05/27/oregon-fishing-detroit-lake-regulations-permits-licenses-report-boating-salmon/70208827007/.

Hansen, A.C., Kock, T.J., and Hansen, G.S., 2017, Synthesis of downstream fish passage information at projects owned by the U.S. Army Corps of Engineers in the Willamette River Basin, Oregon: U.S. Geological Survey Open File Report 2017-1101, 118 p., https://doi.org/10.3333/ofr20171101.

Keefer, M.L., Taylor, G.A., Garletts, D.F., Helms, C.K., Gauthier, G.A., Pierce, T.M. and Caudill, C.C., 2012, Reservoir entrapment and dam passage mortality of juvenile Chinook salmon in the Middle Fork Willamette River: Ecology of Freshwater Fish, v. 21, no. 2, p. 222–234.

KPO (Kokanee Power of Oregon). 2021. 2021 Mid Willamette ODFW Annual Meeting. Dated April 12, 2021. Accessed online June 7, 2023 at https://kokaneepoweroregon.com/club-blog-3/.

KPO (Kokanee Power of Oregon). 2022. 2022 End of Year KPO Report. Dated January 10, 2023. Accessed online June 7, 2023 at https://kokaneepoweroregon.com/club-blog-3/.

Monzyk, F.R., J.D. Romer, R. Emig, and T.A. Friesen. 2011. Pilot head-of-reservoir juvenile salmonid monitoring. 2010 Annual report to U.S. Army Corps of Engineers, Portland, Oregon. Task Order W9127N-10-2-0008-0001. Oregon Department of Fish and Wildlife, Corvallis, OR.

Monzyk, F.R., J.D. Romer, R. Emig, and T.A. Friesen. 2014. Life-history characteristics of juvenile spring Chinook salmon rearing in Willamette Valley reservoirs. Annual Report to U.S. Army Corps of Engineers, Portland, Oregon. Task Order W9127N-10-2-00080007. Oregon Department of Fish and Wildlife, Corvallis, OR.

Monzyk, F.R., J.D. Romer, R. Emig, and T.A. Friesen. 2015. Life-history characteristics of juvenile spring Chinook salmon rearing in Willamette Valley reservoirs. Annual Report to U.S. Army Corps of Engineers, Portland, Oregon. Task Order W9127N-10-2-00080007. Oregon Department of Fish and Wildlife, Corvallis, OR.

Murphy, CA, Taylor, G, Pierce, T, Arismendi, I, Johnson, SL. Short-term reservoir draining to streambed for juvenile salmon passage and non-native fish removal. Ecohydrology. 2019; 12:e2096. https://doi.org/10.1002/eco.2096

Murphy CA, I Arismendi, GA Taylor, SL Johnson. 2019b. Evidence for lasting alterations to aquatic food webs with short-duration reservoir draining. PLoS ONE 14(2): e0211870. https://doi.org/10.1371/journal.pone.0211870

Murphy, CA, A Evans, B Coffin, I Arismendi & SL Johnson. 2020. Resilience of zooplankton communities in temperate reservoirs with extreme water level fluctuations, Inland Waters, 10:2, 256-266, DOI: 10.1080/20442041.2019.1657349

ODFW (Oregon Department of Fish and Wildlife) and USACE (U.S. Army Corps of Engineers). 2021. Hatchery Genetics Management Plan, Upper Willamette Hatchery Rainbow Trout Program. Date last updated February 24, 2021. Accessed online at www.dfw.state.or.us/fish/hgmp/docs/2021/Upper%20Willamette%20Rainbow%20Trout%20HGMP%20Modified_Release_Table%20approved%20Febuary%202021.pdf.

ODFW (Oregon Department of Fish and Wildlife). 2022. Fish Propagation Annual Report For 2021. Fish Division Oregon Department of Fish and Wildlife 4034 Fairview Industrial Drive SE Salem, OR 97302. Edited by Trevor R. Clark. June 2022.

ODFW (Oregon Department of Fish and Wildlife). 2023. Fish Propagation Annual Report For 2022. Fish Division Oregon Department of Fish and Wildlife 4034 Fairview Industrial Drive SE Salem, OR 97302. Edited by Logan Kent. May 2023.

ODFW (Oregon Department of Fish and Wildlife). 2023b. Weekly trout stocking schedule. Accessed online June 8, 2023 at https://myodfw.com/fishing/species/trout/stocking-schedule.

ODFW (Oregon Department of Fish and Wildlife). 2023c. eRegulations, Willamette Zone. Accessed online June 9, 2023 at https://www.eregulations.com/oregon/fishing/willamette-zone.

ODFW (Oregon Department of Fish and Wildlife). 2023d. Bass. Accessed August 11, 2023 at https://myodfw.com/fishing/species/bass.

USGS (U.S. Geological Survey). 2023. Nonindigenous Aquatic Species Database. Gainesville, Florida. Accessed 8/16/2023. https://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=910.

Romer, J.D., F.R. Monzyk, R. Emig, and T.A. Friesen. 2012. Juvenile salmonid outmigration monitoring at Willamette Valley Project reservoirs. 2011 Annual Report to U.S. Army Corps of Engineers, Portland, Oregon. Task Order W9127N-10-2-0008-0006. Oregon Department of Fish and Wildlife, Corvallis, OR.

Romer, J.D., F.R. Monzyk, R. Emig, and T.A. Friesen. 2013. Juvenile salmonid outmigration monitoring at Willamette Valley Project reservoirs. 2012 Annual Report to U.S. Army Corps of Engineers, Portland, Oregon. Task Order W9127N-10-2-0008-0010. Oregon Department of Fish and Wildlife, Corvallis, OR.

Romer, J.D., F.R. Monzyk, R. Emig, and T.A. Friesen. 2015. Juvenile salmonid outmigration monitoring at Willamette Valley Project reservoirs. 2014 Annual Report to U.S. Army Corps of Engineers, Portland, Oregon. Task Order W9127N-10-2-0008-0026. Oregon Department of Fish and Wildlife, Corvallis, OR.

Romer, J.D., F.R. Monzyk, R. Emig, and T.A. Friesen. 2016. Juvenile salmonid outmigration monitoring at Willamette Valley Project reservoirs. 2015 Annual Report to U.S. Army Corps of Engineers, Portland, Oregon. Task Order W9127N-10-2-0008-0035. Oregon Department of Fish and Wildlife, Corvallis, OR.

Smithsonian ERC (Environmental Research Center). 2023. National Estuarine and Marine Exotic Species Information System, Micropterus dolomieu. Accessed online August 15, 2023 at https://invasions.si.edu/nemesis/species_summary/550562#:~:text=The%20Smallmouth%20Bass%20(Micropterus%20dolomieu,dorsal%20fin%2C%20which%20are%20fused.

Smithsonian ERC (Environmental Research Center). 2023b. National Estuarine and Marine Exotic Species Information System, Micropterus dolomieu. Accessed online August 14, 2023 at https://invasions.si.edu/nemesis/species_summary/550562#:~:text=The%20Smallmouth%20Bass%20(Micropterus%20dolomieu,dorsal%20fin%2C%20which%20are%20fused.

Quinn, T. P. (2005). The Behavior and Ecology of Pacific Salmon and Trout, Seattle, Washington, USA: University of Washington Press.

USFS (U.S. Forest Service). 2023. Smallmouth Bass - *Micropterus dolomieui*. Accessed online June 7, 2023 at extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev3_018493.pdf.

Wetherbee, JJ. 1965. A History of the Kokanee in Detroit Reservoir. Prepared by JJ. Wetherbee, District Fish Biologist, Oregon Department of Fish and Wildlife. 26pp.

CHAPTER 7 - ALTERNATIVE 5 MODELING ASSUMPTIONS

Incorporation of Alternative 5 is functionally similar Alternative 2B except that there is slightly more water released from the Santiam in the spring of dry years. Non-exceedance plots were compared for alternatives 2B and 5 (see Appendix B). Based on this assessment, it was determined that the flow management differences between alternatives 2B and 5 would be insignificant with respect to fish performance. However, to confirm this hypothesis, quantitative analysis of fish population dynamics was completed for Alternative 5.

As the DEIS was being updated to a FEIS, additional quantitative modeling was implemented to include the effects of the Near-term Operations Measures as described in Alternative 2a, and an additional implementation plan. The implementation plan describes the order and timeline for EIS actions. Since the Implementation Plan is specific to the Draft Preferred Alternative, the analyses for Chinook and steelhead up to this point in the document have assumed that EIS measures are implemented at the time of the Record of Decision. This allowed for appropriate comparisons among alternatives such that they could be evaluated according to rank of relative performance. Therefore, Alternative 5 required a more detailed description of methodology. This analysis varies from the methodology approach used for the previous alternatives in two fundamental ways: 1. It included quantitative analysis of the effects of the NTOM's and LTOM's (see Section 3.1.4.12) and 2. The NTOM's and LTOM's were considered together. Described another way, the fish performance under the NTOM's could directly influence the starting point and performance of the LTOM's.

The IPA is unique in that it accommodates implementation timing of NTOM's in conjunction with LTOM's. Because different action "start dates" must necessarily be staggered, the IPA was refined to accommodate different timelines. Individual populations might be expected to perform better or worse depending on the timeline of an implemented action. Some actions may be conditioned on one another. For example, the Cougar Dam diversion tunnel construction cannot be implemented unless hydropower is deauthorized. The deauthorization process cannot occur until a disposition study is completed to determine feasibility. Ultimately, this impacts the model timeline for evaluating listed species. Since the timing of implementation is important to understand potential effects to the species, the analysis included modeling that reflected the assumed timing described in the implementation plan for the Draft Preferred Alternative. Evaluation of the implementation plan is critical to accurately capture the effects of the proposed action. Therefore, the IPA is used to present quantitative model predictions of Alternative 5, including near- and long-term actions.

The requested additional projection runs of the IPA Life Cycle Model include UWR spring Chinook salmon and winter steelhead populations. These additional runs used the same parameter specifications, performance metrics, and years of implementation of long-term effective and safe downstream passage for juvenile Chinook salmon and winter steelhead as described in the Methodology (Section 3.1.2.1) and in the Biological Assessment (BA) report (McAllister et al. 2022). Additional runs were required to calculate performance metrics for all four sub-basins for the evaluation of NTOM's and LTOM's relative to the No Action Alternative To address the need for reasonable comparisons, three additional runs were developed and compared to the NAA:

1. NTOM-Alt2B. Apply NTOM until implementation year, then Alt2B for the 30-year management horizon.
2. NAA-Alt5. Apply NAA until implementation year, then Alt5 for the 30-year management horizon.
3. NTOM-Alt5. Apply NTOM until implementation year, then Alt5 for the 30-year management horizon.

This approach allowed us to explicitly test the following hypotheses:

1. Alternative 2B is not functionally different than Alternative 5
2. Alternative 5 performs better than the NAA

The Fish Benefits Workbook (FBW) was applied by the Corps to generate estimates of Dam Passage Efficiency (DPE) and Dam Passage Survival (DPS) under the NTOMs; DPE and DPS for each alternative were made available for use in the IPA. Alternative 5 is the same as Alternative 2B but includes different minimum flows through Green Peter specifically, so it was assumed that fish passage parameters (DPE and DPS) would be the same as under Alternative 2B. Outputs from FBW for the NTOMs were provided by the Corps to the IPA team. CE-QUAL-W2 temperature outputs were also made available for the reaches downstream of dam projects for both NTOMs and Alternative 5, as different flows may affect temperature experienced by adults and thus pre-spawn mortality (PSM). This is an important assumption as it describes how, if differences between Alternative 2B and Alternative 5 existed, the differences are manifested through downstream PSM which is related to downstream flows (i.e., it accounts for the slightly different outflows at Green Peter). Outplanting assumptions in each sub-basin under NTOMs and Alternative 5 were the same as under NAA and Alternative 2B, respectively. All derived parameter values applied in life cycle models were retained (see McAllister et al. 2022). See Appendix E, Alternative 5 Modeling Memo for additional details.

The Implementation Plan, which is part of the Adaptive Management Plan (AM Plan), identifies a prioritization of measures for implementation, a timeline for their implementation, and implementation performance criteria that must be met. It describes the sequencing of the measures in the proposed action, and links immediate operations to improve fish passage and water quality (i.e., Near-term Operations measure; NTOM's) to the longer-term (i.e., Long-term Operations/Construction measure; LTOM's) operational or structural measures, such as the downstream fish passage construction projects [The plan identifies check-ins, or points along the implementation timeline where course correction (i.e., “on-ramps/off-ramps”) may be necessary based on research, monitoring, and evaluation (RM&E). The Implementation Plan is considered a roadmap that lays out a strategy and plan for implementation of the proposed action. Considerations such as basin-wide priorities including costs, risk and uncertainty, and RM&E of data gaps, have been used to shape the Implementation Plan and to develop a schedule that is both reasonable and implementable given the information available to USACE at present.

Timing of decisions for implementing management measures and/or adjustments is influenced by the operational planning for the conservation release season, which begins with the January water supply forecast and continues through October. The conservation season is approximately from March through October, including the filling season (spring) and the release season (summer). A document titled “Willamette Basin Project Conservation Release Season Operating Plan” (Conservation Plan) is prepared annually to provide flow requirements based on the basin water supply for that year. The Conservation Plan identifies flow and storage needs for each tributary and USACE reservoir in the WVS and mainstem Willamette control points based on the anticipated total system storage in mid-May, from the April forecast.

It was also necessary to make additional assumptions regarding fish translocation. The Chinook mitigation hatchery program provides conservation benefits for UWR Chinook salmon (NMFS 2019b) with demonstrated benefits to help maintain spawners below dams and for supplementing adults outplanted above WVS dams to spawn. Use of hatchery Chinook is a fundamental component included in the reintroduction strategy for spring Chinook above WVS dams (NMFS 2019b). Preparation of formal reintroduction plans for Chinook are included as a term and conditions in NMFS (2019a). Use of hatchery Chinook for supporting reintroduction is to be continued as described in HGMPs and NMFS Biological Opinion, with future reductions in hatchery production after measured improvements in fish passage at WVS dams are achieved as described in this proposed action.

Given the length of time required to implement some long-term passage actions, it was considered that steelhead may only persist at critically low abundances rendering an evaluation of long-term actions impossible. This is not the case for Chinook since a hatchery program exists for reintroduction. To address this, it was necessary to make some assumptions about steelhead during the period of the NTOM’s such that steelhead were allowed to persist even if they fell below the minimum abundance before the implementation of the long-term action. NMFS and ODFW do not currently outplant natural origin returns of UWR steelhead above Detroit or Green Peter dams and have not permitted research activities involving release of natural origin steelhead eggs, juveniles, or adults above these dams due to several concerns, including reduced productivity below dams through the transport of adults above dams, poor downstream passage conditions at these dams, and concerns with transference of disease to upstream Chinook hatcheries. There are no plans to prepare formal reintroduction plans for steelhead, at the time of this writing.

For modeling the effects of Alternative 5 using the IPA it assumes future reintroduction of UWR steelhead will require an unspecified augmentation to maintain populations at least to minimum abundance thresholds until the long-term action comes online. This modeling approach is not intended to add an undescribed action under the proposed action. These assumptions are meant for exploratory purposes only to demonstrate the value of an action, should intervention for steelhead be required prior to the implementation of a long-term action. Modeling also assumes continued outplanting of hatchery Chinook above WVS dams except when natural origin adult returns to traps achieve thresholds defined in the HGMPs. For this reason, steelhead results are presented with and without translocation assumptions.

There are several key modeling assumptions for steelhead that must be made using this approach:

- The model considers only above dam populations, i.e., those populations directly impacted by blocked passage.
- Productivity is measured as the max number of recruits per spawner in the years immediately following implementation. Note, this is as opposed to reporting the long-term average productivity.
- The model only considers the length of the proposed management action (30 years into the future).
- Egg-fry survival rate as a function of eggs deposited and follows a Beverton-Holt function.
- There are six juvenile migrant types above dams within three main groups (fry, fall subyearlings, yearlings). Life history types are further broken down based on peer reviewed literature and are presented in (Appendix J).
- Reservoir survival rate of juveniles is invariant to the downstream dam passage measure applied.
- Splits for juvenile migration groups above dams are invariant to downstream dam passage measure applied.
- In two-dam models juveniles originating above and passing down through Hills Creek and Green Peter will try to pass directly through downstream dams without stopping.

- Dam passage survival and dam passage efficiency were bootstrapped from fish benefits workbook.
- Future marine survival reflects historical variation in early age marine survival.
- At sea fishing mortality rates and incidental mortality rates in terminal fisheries from CTC mortality rate assessment approximate long-term average mortality rates.
- Upstream passage has 100% survival once an adult volunteers to be translocated above a barrier. In other words, mortality processes due to prespawn mortality, temperature, handling, etc, are assumed to occur prior to volunteering to a trap.
- Spawning success of hatchery origin fish is less than natural origin fish.
- Juvenile reservoir survival does not change under different management scenarios.
- The telemetry data used to predict downstream survival is representative of long-term averages.
- The proportion of adults in each age class remains the same in the ocean phase of the life history.
- Previously measured harvest rates are representative of the long-term average.
- Juveniles can depth compensate during periods of high TDG.

The implementation plan time for the long-term measures affects the predicted performance of a species but the near-term measures do not.

In the North Santiam, measures being implemented for Alternative 5 are the same as those as for Alternative 2B. For downstream fish passage, construction of structural downstream fish passage (#392) would be implemented at Detroit Dam. For upstream passage, fish would be collected at the existing Minto adult fish facility and trucked upstream. The structural fish passage improvements allow Chinook and steelhead to access habitat above Detroit Dam, and support increased abundance and productivity compared to the NAA. Passage improvements would also support passage of a re-introduced bull trout population above Detroit Dam to access habitat below the dam and return back upstream to re-enter the spawning population, but there are a greater number of limiting factors downstream increasing potential for mortality for individuals that move downstream. Since there is not any spawning habitat available downstream of the dam, individuals must survival and migrate back upstream, be collected and trucked above Detroit Dam, in order to re-enter the spawning population.

In the South Santiam, measures being implemented for Alternative 5 are the same as those as for Alternative 2B. For downstream fish passage at Foster Dam, construction of structural downstream fish passage (#392) would be implemented. At Green Peter Dam, a deeper fall reservoir drawdowns for fish passage (#40) and spring spill would be implemented to provide downstream fish passage. An adult fish facility would also be constructed at the base of Green Peter Dam. These fish passage improvements allow Chinook and steelhead to access habitat above both Foster and Green Peter dams, supporting the potential for increased abundance and productivity compared to the NAA. Compared to above other WVS dams, the relatively lower elevation habitat above these dams may constrain productivity and survival.

The diversion tunnel at Cougar would be used for downstream passage. The reservoir will be drafted to 25 feet over the diversion tunnel during both spring and fall. This will results in a very small residual reservoir pool during these season, and limited opportunity to refill the reservoir to supplement downstream flows during spring to fall seasons. Most Chinook would be expected to pass downstream as fry in spring. It is uncertain how bull trout may respond, however some would be expected to move upstream of the reservoir while others downstream. Forage opportunity will change over time for bull trout with repeated reservoir deep drawdowns, with the potential for less prey food availability in the reservoir potentially requiring bull trout to move downstream.

Fish passage conditions are the same as under Alternative 2B. The existing adult facility at Fall Creek Dam in combination with the operational downstream passage by way of a fall reservoir deep drawdown will support maintaining the re-established Chinook sub-population above Fall Creek Dam. Construction of structural downstream fish passage (#392) would be implemented at Lookout Point Dam but not Hills Creek Dam. Upstream passage would occur using the existing adult fish facility at the base of Dexter Dam. The structural fish passage improvements allow Chinook to access habitat above Lookout Point Dam, supporting increased abundance and productivity compared to the NAA. The existing adult facility at Fall Creek Dam in combination with the operational downstream passage by way of a fall reservoir deep drawdown will support maintaining the re-established Chinook sub-population above Fall Creek Dam. At Hills Creek Dam, downstream passage occurs through existing outlets where on average downstream fish passage survival is low under the NAA dam operational regime. The existing bull trout population above Hills Creek Dam would be expected to perform the same as under the NAA.

CHAPTER 8 - LAMPREY SPECIES EFFECTS ASSESSMENT

8.1 INTRODUCTION

Three species of lamprey occur in the area of analysis: Western River Lamprey (*Lampetra ayresii*), Western Brook Lamprey (*Lampetra richardsoni*), and Pacific Lamprey (*Entosphenus tridentatus).* There is concern that both adult and juvenile life stages could be impacted by dam operations by affecting habitat access and quality. Knowledge of the abundance, distribution, and run timing of these species in the area of analysis is limited. Pacific Lamprey are the most studied and a culturally important food for local tribes. This assessment therefore focused on Pacific Lamprey. Results are assumed to generally be representative of effects on the other lamprey species occurring in the Willamette River Basin.

8.2 SUMMARY OF LIFE HISTORY AND HABITAT NEEDS

Timing and general habitat needs for Pacific lamprey are summarized in Table 1. Pacific lamprey are anadromous and adults use the Willamette River Basin for overwintering and spawning, and juveniles use it for a period of freshwater rearing that can last up to ten years (Hess et al. 2021). Maturation to the adult stage occurs after migrating to the ocean. After emerging from redds, ammocoetes rear in freshwater as eyeless filter feeders. Their distribution is constrained by the availability of fine substrates mixed with organic material and can be additionally constrained by warm water (Goertler et al. 2020). Ammocoetes burrow into soft substrates tail first. They are commonly found in tributary streams and in higher densities at the deltas of these streams as they enter the mainstem (Harris & Jolley 2011, Jolley et al. 2012). Several authors have researched water temperature effects on adult lamprey highlighting the negative impacts of warm water (Clemens 2022; Meeuwig, Bayer, and Seelye 2005).

Adult Pacific lamprey begin their spawning run by moving from the ocean into the Columbia estuary with numbers peaking in January and February then trailing into May (Weitkamp et al., 2015). They either overwinter (in some cases multiple years) in large rivers or migrate directly to smaller spawning tributaries and spawn. They spawn in gravel-bottomed tributary streams at the upstream end of riffle habitat during the summer (Beamish 1980; Clemens and Schreck 2021). Mayfield et al. (2014) conducted redd surveys for Pacific Lamprey in the Willamette Valley finding they were associated with gravel dominated pool tail outs, similar to salmonid spawning habitat. At larger scales, they found spawning lamprey selected tributaries with gravel dominated streambeds such as the Calapooia River, lower Clear Creek, and Thomas Creek (Mayfield et al. 2014). Pacific lamprey die after spawning releasing important marine derived nutrients into the streams, primarily nitrogen and phosphorus. As Figure 1 shows, run timing at Bennett Dam on the Santiam River peaks in June and July of most year (ODFW 2023).

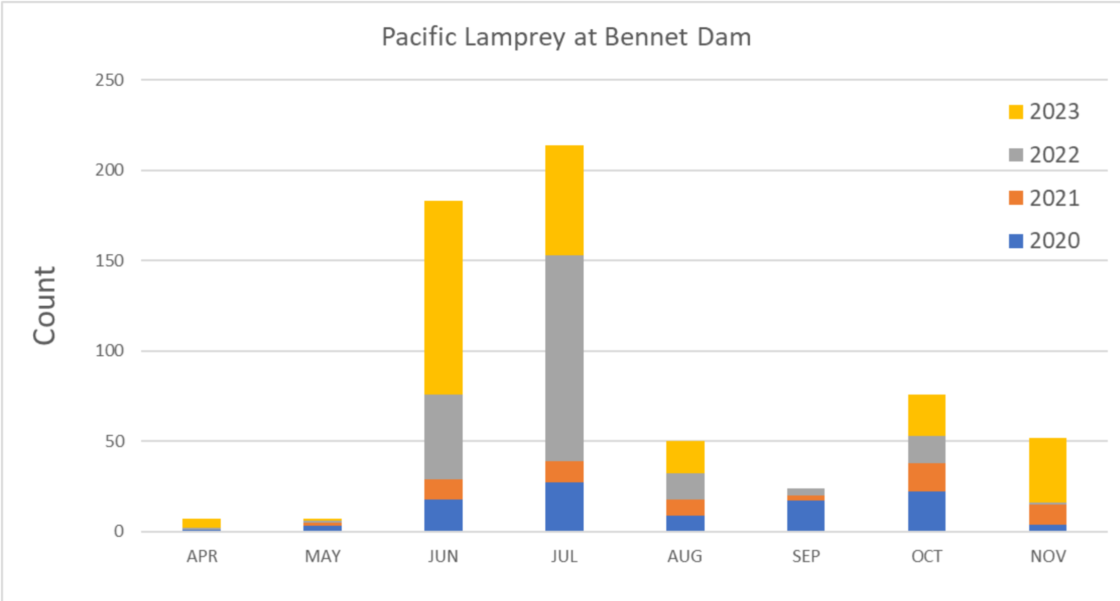

Figure 8-1. Returning adult Pacific Lamprey counts show run timing past Bennett Dam peaking in June and July on the Santiam River. Bennett Dam is downstream of Big Cliff and Detroit Dams that do not have fish passage (ODFW 2023).

Table 8-1. General freshwater timing hand habitat preferences of Pacific lamprey by life stage .

Lifestage	Timing	Habitat preferences
Spawning	March to July	See Table 2
Egg	Three to four weeks to hatch.	Gravel lamprey nest.
Larvae (ammocoetes)	Three to ten years	Soft sediment with organic matter. Burrow in tail first.
Juvenile (macrophthalmia)	February, March, and April	Mainstem migrating to ocean.
Adult – Ocean	Three to five years	Pacific Ocean – Mexico to Alaska to Kamchatka Russia
Adult - Freshwater	One to three years	Mainstem overwintering, tributaries for spawning

After hatching, the larvae (also called ammocoetes) drift downstream and burrow into silt or mud where suitable habitat occurs such as backwater areas, and stream confluences where there are lower water velocities. Here they live as eyeless, toothless filter feeders, and rear on the bottom for three to ten years (Hess et al. 2022). Larval lamprey have a patchy distribution related to environmental variables such as water velocity (low), substrate (silt), and proximity to upstream nests. Larger sized larvae are occasionally collected at Corps juvenile passage facilities at dams on the lower Columbia and Snake Rivers. The timing of their collection indicates that they may move downstream from rearing grounds after high flow events as the hydrograph declines (Mesa et al., 2015). Sheoships (2014) investigated lamprey larval use of rearing habitat in six Willamette River tributaries and found they were greater abundance in areas with mostly medium fine sand (0.25 – 0.50 mm). Larval Pacific Lamprey, one positively identified Western Brook Lamprey (144 mm TL), and several unidentified *Lampretra spp*. have been collected rearing in soft sediments in the mainstem Willamette River near Portland, OR at water depths up to 52.5 feet (16 meters) (Jolley, Silver, and Whitesel 2012).

Tribal harvest of Pacific lamprey for subsistence and ceremonial use indicates the basin wide population is in decline. At Willamette Falls, harvest has decreased from over 500,000 fish in 1946 to less than 6,000 lamprey per year in 2000 and 2001 (Clemens et al. 2023). Although not listed under the Endangered Species Act, the State of Oregon categorizes them as a Sensitive Species (Clements et al. 2020) and cited five key limiting factors: access (passage and screening at artificial obstructions), water quantity (reduced flows, flow management), water quality (high water temperature, sedimentation), physical habitat (stream and floodplain degradation), and predation by other species (particularly nonnative fishes). A tribal lead translocation program collected 240 adult Pacific Lamprey at Willamette Falls and released them upstream of the Fall Creek Reservoir in 2016 (Le et al. 2017). USACE biologists continue to collect adults that return at Fall Creek Adult Fish Facility and release them upstream of Fall Creek Reservoir.

Western River Lamprey and Western Brook Lamprey are genetically similar but have divergent life histories. Western River lamprey are anadromous moving downstream through the area of WVS EIS analysis to the ocean. Western Brook are not anadromous and stay in freshwater. It has recently been suggested the two should share the same scientific name (*L. ayresii*), but retain their common names which would emphasize the differing life histories (Carim et al. 2023). In this analysis, it is assumed that the effects to Pacific lamprey would be similar to the effect to Western River and Western Brook lamprey.

8.3 METHODS

Passage for lamprey was not included at WVS dams when they were constructed and therefore access to and from habitat upstream of most WVS dams has been blocked since their construction. The current distribution of Pacific lamprey is constrained downstream of WVS dams in the Willamette River Basin with the exception of Fall Creek Dam.

For this assessment, it was assumed that Pacific lamprey passage would occur at Fall Creek Dam in the Middle Fork Willamette Subbasin under all alternatives and would also occur at Monroe, Stroda, and Cox drop structures in the Long Tom River Subbasin under Alternatives 1 and 4 over the 30-year implementation timeframe. No passage would occur at other WVS dams under any alternative.

Efforts to reintroduce Pacific lamprey above Fall Creek Dam by the Confederated Tribes of the Grand Ronde occurred recently, and any adults returning to Fall Creek Dam would be collected at the Fall Creek Adult Fish Facility and released upstream of Fall Creek Reservoir. Downstream passage would be provided via the annual reservoir drawdown to streambed each fall which is proposed to continue under all of the WVS EIS alternatives.

In the Long Tom River Subbasin, upstream passage of salmon and Pacific lamprey at the Monroe, Stroda, and Cox drop structures would be provided by structural modifications for fish passage under Alternatives 1 and 4. Effective downstream fish passage would be available because water flows freely over these structures. The drop structures are considered "run of river" dams, which means there is no water storage function for the dams. As water enters the ponded area behind the dams from upstream, it exits over the dams at the same rate and has no effect on flows downstream. The primary function of the dam is to dissipate energy of the river and reduce scour as it falls over these low head dams. There are no unscreened water diversions occurring in association with water pooled behind the drop structures. Detailed designs have not been developed for drop structure passage improvements, and future NEPA compliance will be completed once available.

Pacific lamprey passage features would be integrated into the new Green Peter, Hills Creek, and Blue River Adult Fish Facilities that would be constructed under various action alternatives. However, it was assumed that these facilities would remain inaccessible to Pacific Lamprey during the 30-year implementation timeframe due to other impassable downstream dams (i.e., WVS Foster and Lookout Point Dams, and non-federal Leaburg Dam) because there are no known plans to reintroduce Pacific lamprey above these dams by any State, Tribal, or Federal resource agencies, or any other entities.

This assessment was designed to account for differences in the WVS EIS alternatives among the following factors previously identified in other assessments by state and federal lamprey biologists (Clemens et al. 2020; Poirier, Gray, and Clemens 2023):

1. Regulated flow effects on spawning and incubation habitat availability

2. Regulated flow down-ramping effects on rearing habitat dewatering

2. Frequency of water temperatures above 20^{o}C discharged from dams

4. Sediment transport effects from operation of reservoirs and dams on larval rearing habitat availability

5. Habitat access

Sediment and substrate availability, channelization, streamside vegetation, are present and recruitment of large wood into streams are some of the primary attributes relating to physical habitat. An assessment of sediment transport is provided in Appendix C.

Total dissolved gas (TDG) can be above Oregon Department of Environmental Quality standards of 110% (Oregon Secretary of State 2023) as modeled in Appendix D, [Water Temperature and

Total Dissolved Gas Methodology]). Recent work documents lamprey's vulnerability to gas bubble trauma from high TDG, but the effects are generally sublethal (Liedtke et al. 2023). Total dissolved gas (TDG) levels were assessed separately in the WVS EIS.

Other identified factors for the decline of lamprey are chemical pollution and presence of exotic fish (ODFW 2005). These factors were not included in the assessment because either these were not expected to change between the NAA and alternatives (chemical pollution), or no data were available to assess their effects (competition or predation risks for lamprey by exotic fish).

8.3.1 Spawning and Incubation

Quantified relationships between habitat availability for Pacific lamprey and stream flows in the Willamette River Basin are not available. Relationships have been developed for spring Chinook salmon and winter steelhead. Spawning habitat needs for Pacific lamprey are similar to Chinook salmon and steelhead (Bjornn and Reiser 1991; Mayfield et al. 2014; Geist and Dauble 1998; Gunckel et al. 2009). Although the range of substrate sizes used by steelhead and Chinook salmon for spawning can be higher, those reported for use by spawning lamprey are general within the range of those used by steelhead and Chinook salmon (Table 2.[Comparison of spawning habitat attributes]). Therefore, spawning habitat availability assessed for winter steelhead and spring Chinook salmon for Pacific lamprey (Appendix E [NewChapter_fish_flow_effects_summary] was considered representative of Pacific lamprey with adjustments for lamprey spawning periods.

Table 8-2. Comparison of spawning habitat attributes for Pacific Lamprey reported by Gunkel et al. (2009) to those applied as preferred criteria for assessing winter steelhead and spring Chinook reported in Appendix E, Chapter [flow effects analysis summary].

		Pacific Lamprey		Winter Steelhead		Spring Chinook	
	UNITS	RANGE	MEDIAN	RANGE	~MID-POINT	RANGE	~MID-POINT
Redd water depth	ft	0.5-3.4	1.4	1.0-3.0	2	1.0-8	4
Velocity	ft/s	0.6-3.3	2	1.5-3.5	2.5	1.5-3.5	2.5
Substrate	in	1.0-3.5	1.9	0.3-6	4.5	0.3-6	5

Flows below WVS dams where Upper Willamette River winter steelhead and spring Chinook salmon spawning occurs were assessed based on development of weighted usable area relationships reported by R2 Resources (2013) and RDG (2014). Winter steelhead were assessed in the North Santiam River and South Santiam River Subbasins, and spring Chinook salmon in those subbasins and in the McKenzie River and Middle Fork Willamette River Subbasins. Based on the comparison of spawning habitat attributes discussed above, spawning attributes for winter steelhead were applied for the North Santiam River and South Santiam River Subbasins.

Lacking information for steelhead in the other two reaches, Chinook attributes were applied for the McKenzie and Middle Fork (Table 3 [Comparison of flows developed by R2 and RDG providing 80%, 90% and 100%]).

Table 8-3. Comparison of flows providing 80%, 90% and 100% weighted usable area habitat for spring Chinook and winter steelhead spawning (R2 Resources 2013 and RDG 2014) and those applied for assessment of Pacific lamprey spawning habitat.

	Chinook spawning				Winter steelhead spawning		Pacific Lamprey spawning			
	Big Cliff	Foster	Cougar	Dexter	Big Cliff	Foster	Big Cliff	Foster	Cougar	Dexter
WUA	Flow	Flow	Flow	Flow	Flow	Flow	Flow	Flow	Flow	Flow
80%	889	449	242	1800	867	533	867	533	242	1800
90%	1011	567	319	2176	1000	685	1000	685	319	2176
100%	1286	1140	472	2800	1286	1140	1286	1140	472	2800

Flows for the 80% and 90% levels were taken from the lower end of the flow-habitat curve relationship for spring Chinook and winter steelhead.

To assess changes in spawning habitat availability, the number of days flow levels during the spawning season were above 80%, 90% and 100% weighted usable area levels for lamprey spawning were summarized. Pacific lamprey spawn timing was assessed as March 15 to August 1, covering both the active spawning season and egg incubation. Spawn timing was cited by Mayfield et al. (2014) as occurring primarily in spring months. USFWS (2023) reports that spawning occurs between March and July depending upon location within their range. Gunckel et al. (2009) reported spawning in the Umpqua River, Oregon between April and early June. Egg incubation is reported to last for 3 to 4 weeks (WDFW 2024).

8.3.2 Rearing

Although stream flows naturally fluctuate, regulated streams can have greater and more frequent stage changes. Dewatering has been found to substantially affect spatial distribution and abundance of larval lampreys in freshwater ecosystems (Harris et al. 2020). The WVS dams are operated to maintain down ramping rates at or below 0.1 ft/hour (3 cm/hr) during nighttime hours and 0.2 ft/hour (6 cm/hr) during daytime hours during non-flood control operations. NMFS (2008) biological opinion stated it was their goal for down ramping rates not to exceed these rates to minimize stranding of juvenile fish and aquatic invertebrates and desiccation of redds. Liedtke et al. (2020) evaluated larval Pacific lamprey emergence under different dewatering rates in the laboratory and found the mean movement rates for study groups ranged from 19.0 to 44.4 centimeters per minute [cm/min]). Therefore, it was assumed that the current ramping rates are adequate to allow larval lamprey to emerge and avoid stranding. Models used to estimate river flow below dam operate on a daily time step. The frequency at which stream flow declines 1 ft or more over two or more days was used to assess effects of flow management on larval Pacific Lamprey under the alternatives.

8.3.3 Water Temperature

Water Temperatures at or above 20℃ were found to increase stress in Pacific lamprey resulting in habitat loss and above 26.6℃ pre-spawn mortalities have been documented (Clemens 2022). In addition, lab studies investigating egg development at several temperatures found that temperatures above 20℃ led to an increased number of developmental abnormalities in both Pacific and Western Brook lamprey (Meeuwig, Bayer, and Seelye 2005). To assess the effects of the NAA and WVS EIS alternatives on lamprey, the percent of days water temperatures in each subbasin below WVS dams was above 20℃ were summarized.

8.3.4 Sediment Transport

WVS dams block transport of both fine and coarse sediment downstream, affecting habitat formation and maintenance for larval lamprey and other aquatic species. Sheoships (2014) surveyed six Willamette Valley tributary streams and found larval Pacific lamprey were most abundant in areas with mostly medium sand (0.25 – 0.50 mm).

Sediment transport is expected to increase when reservoirs are drawn down lower under measures included in the WVS EIS alternatives compared to NAA conditions (Schenk and Bragg 2021). Reservoir drawdowns to streambed would result in higher levels of sediment releases than partial drawdowns. Fall Creek and Cougar Dam are two locations where measures in the WVS EIS alternatives include drawdowns to streambed. Sediment materials passing downstream would include sands and possible coarser grain sizes, as well as finer silts and clay materials.

Substantial sediment releases would be expected below Cougar Dam in the first few years of drawdowns to streambed since this reservoir has not been drawn down repeatedly to streambed for several years, then reductions in discharged sediment would occur as sediment currently stored in the reservoir is depleted. In the long term, sediment passing Cougar Dam is expected to be higher than NAA levels because the drawn down reservoir would not trap as much incoming sediment from the watershed.

At other locations, there are no measures for reservoir drawdowns to streambeds (i.e. reservoir pools would remain under all alternatives). Residual pools would continue to reduce the transport of sand and larger sized materials downstream of the dams. Sediment materials released at these locations are expected to be finer grain than sand, primarily silts and clays when reservoirs are drawn down. Finer grained sediments would be expected to deposit in connected backwaters and within channels in the first few years after deeper drawdowns are implemented.

Sediments transported downstream during reservoir drawdowns to streambed would provide positive and negative effects for lamprey. Increased sediment transport should increase habitat for larval lamprey over a multi-year timeframe. The magnitude and durations of these habitat changes are uncertain, and therefore our assessment only considered if there is a positive change in habitat formation potential below WVS dams. Silt transported during drawdowns could negatively affect spawning/incubation habitat and rearing habitat for ammoecetes. Where deeper drawdowns are implemented, silt stored in the reservoirs would be transported downstream and is expected to deposit primarily in lower gradient areas, and to a lesser extent in main channels. These deposits would be expected to substantially impact areas used for lamprey rearing by partially or fully covering sand and organic areas with silt. Gravel areas in main channels used for spawning could also be impacted, either seasonally or in certain years when larger releases of silt occur. Higher flows however are expected flush gravel areas in future years.

Daily reservoir elevations estimated for the NAA and each action alternative are included in Appendix B; see [Appendix A Chapter 5] for non-exceedance plots. For ease of reference, Table 4 [Summary of major reservoir operational differences] summarizes key reservoir operational differences among alternatives, driven by downstream fish passage operational measures, which affect sediment discharge downstream of WVS dams.

Table 8-4. Summary of major reservoir operational differences among EIS alternatives with potential to change sediment delivery downstream.

Alt	LOP	HCR	FCR	CGR	BLU	GPR	DET
1			fall deep drawdown				
2A			fall deep drawdown			spring spill fall deep drawdown	
2B			fall deep drawdown	spring & fall deep drawdown		spring spill fall deep drawdown	
3A	spring & fall deep drawdown	spring spill fall deep drawdown	fall deep drawdown	spring & fall deep drawdown (RO)	fall deep drawdown	spring spill fall deep drawdown	**spring & fall deep drawdown**
3B	spring spill fall deep drawdown	spring & fall deep drawdown	fall deep drawdown	spring & fall deep drawdown (DT)	fall deep drawdown	**spring & fall deep drawdown**	spring spill fall deep drawdown

4			fall deep drawdown				
5			fall deep drawdown	spring & fall deep drawdown (DT)		spring spill fall deep drawdown	

Analysis of sediment supply changes is included in Appendix C. Qualitative summaries on sediment supply are included in the Appendix C tables 2-12 to 2-19:

- Table 2-12. Alternative 1- Qualitative Sediment Supply Metric
- Table 2-13. Alternative 2A - Qualitative Sediment Supply
- Table 2-14. Alternative 2B - Qualitative Sediment Supply
- Table 2-15. Alternative 3A - Qualitative Sediment Supply
- Table 2-16. Alternative 3B - Qualitative Sediment Supply
- Table 2-17. Alternative 4 - Qualitative Sediment Supply
- Table 2-18. Alternative 5 - Qualitative Sediment Supply
- Table 2-19. NTOM - Qualitative Sediment Supply

We used the information on sediment delivery from Appendix C and accounted for the major reservoir operational differences among the alternatives to qualitatively characterize the effects on lamprey spawning/incubation and larval-stage rearing habitat.

8.3.5 Habitat Access

Historically, Pacific lamprey were found throughout the Willamette River Basin. Currently, the upstream extent of their range is truncated by dams (Poirier, Gray, and Clemens 2023). Clemens et al. (2023) estimates that 32% of available stream habitat basin wide is blocked by major federal and non-federal dams. Where there are no barriers to upstream migration, Pacific lamprey are capable of spawning in a wide diversity of stream sizes and underlying geologic types (Mayfield et la. 2014). Information on the spawning distribution of Pacific lamprey across the action area for this EIS is lacking. However, habitats used for spawning are similar to those for salmonids (*Oncorhynchus* spp.) (Stone 2006; Bjornn and Reiser 1991). Therefore, spawning information for steelhead and Chinook salmon reported by Bond et al. (2017) was used to represent Pacific lamprey spawning distribution.

For this assessment, it was assumed that Pacific lamprey passage would continue to be provided at Fall Creek Dam under the NAA and all action alternatives. Additionally, Pacific lamprey passage would be provided at the Monroe, Stroda, and Cox drop structures under

Alternatives 1 and 4 through integrated Pacific lamprey features included in passage improvements for ESA-listed species at these structures.

To assess the effects of WVS EIS operations, access to habitat and passage survival was considered when qualitatively assessing changes to population attributes.

8.4 RESULTS

8.4.1 Spawning and Incubation

Flows from 1936 to 2019 were categorized as high, normal, or low water years based on the 25th and 75th percentiles of Willamette-at-Salem unregulated flow estimated for the Mar 15-Oct 15 timeframe in each year. For years in each water year category (high, low, normal), the minimum number of days flow levels during the spawning and incubation season (March 15 to August 1) under the NAA were above 80%, 90% and 100% weighted usable area levels are summarized in Table 5 [Minimum number of days across years flows under the NAA]. The percent difference in the number of days under each alternative from the NAA is also included in the Table.

Under the NAA, below Big Cliff, Foster and Cougar dams, flows remain above the 80% and 90% WUA levels during the 140-day spawning and incubation period in normal and high water years. Flows were below the 80% and 90% WUA levels for a portion of the period in dry years below Big Cliff and Foster. Downstream of Dexter Dam flows were below the 80% and 90% WUA levels a majority of the time in all water year types. Few. days at these WUA levels occurred below Dexter compared to the other locations.

Under Alternatives 1, 2A and 4, the number of days at or above the 80% and 90% WUA areas during the spawning and incubation period was similar or greater than the NAA downstream of Big Cliff, Foster, and Cougar Dams. There were fewer days when flows were > 100% WUA levels downstream of these dams compared to the NAA. Under Alternative 2B, patters were similar except below Cougar, were fewer days at or above WUA flow levels occurred due to the deep reservoir drawdown. Fewer days at each WUA levels occurred below Dexter compared to the other locations for these Alternatives.

Alternatives 3a and 3b include deep reservoir drawdowns at multiple reservoirs, which effect downstream flows. The number of days at or above the 80% and 90% WUA areas during the spawning and incubation period was lower than the NAA downstream of Big Cliff and Cougar dams under Alternative 3a and below Foster and Cougar dams in Alternative 3b. However, there were more days above WUA levels below Dexter Dam compared to the NAA under these Alternatives.

Table 8-5. Minimum number of days across years flows under the NAA were at or above maximum weighted usable area (MWUA) levels for spawning during March 15 to August 1 (140 day period) below WVS dams under three water year categories, and amount of time flows were at or above each category under each EIS action alternative as a percentage of the NAA.

	Big Cliff			Foster			Cougar			Dexter		
Alternative	>80 %	>90%	>100%	>80%	>90%	>100%	>80%	>90%	>100%	>80%	>90%	>100%
NAA												
High	140	140	89	140	140	105	140	140	45	38	27	15
Low	117	117	68	140	113	38	140	140	37	15	5	0
Normal	140	140	75	140	140	72	140	140	58	52	40	0
1												
High	100 %	100%	45%	100%	100%	63%	100%	100%	91%	103%	100%	127%
Low	120 %	120%	0%	100%	124%	0%	100%	100%	111%	40%	40%	(0 days)
Normal	100 %	100%	0%	100%	100%	44%	100%	100%	64%	33%	28%	(3 days)
4												
High	100 %	100%	88%	100%	100%	120%	100%	100%	82%	61%	78%	133%
Low	120 %	120%	24%	100%	124%	42%	100%	100%	70%	13%	40%	(0 days)
Normal	100 %	100%	83%	100%	100%	106%	100%	100%	43%	21%	15%	(0 days)
2A												
High	100 %	100%	88%	100%	100%	120%	100%	100%	84%	61%	78%	133%
Low	120 %	120%	24%	100%	121%	42%	100%	100%	78%	13%	20%	(0 days)
Normal	100 %	100%	83%	100%	99%	106%	100%	100%	41%	21%	15%	(0 days)
2B												
High	100 %	100%	88%	100%	100%	120%	99%	66%	200%	61%	81%	133%
Low	120 %	120%	24%	100%	121%	42%	70%	51%	81%	47%	120%	(0 days)
Normal	100 %	100%	83%	100%	99%	106%	74%	61%	122%	27%	20%	(0 days)
3A												
High	79 %	74%	98%	100%	100%	120%	100%	93%	200%	232%	300%	313%

Low	54 %	41%	54%	100%	118%	42%	70%	51%	81%	207%	200%	(5 days)
Normal	62 %	57%	84%	100%	96%	108%	76%	64%	122%	131%	120%	(20 days)
3B												
High	100 %	100%	88%	100%	89%	66%	99%	66%	200%	179%	167%	247%
Low	120 %	120%	24%	84%	53%	105%	70%	51%	141%	180%	280%	(0 days)
Normal	99 %	97%	21%	94%	51%	71%	77%	64%	122%	129%	105%	(4 days)

Table Notes: Texted colored with yellow indicate the alternative percentage is within 5% of the NAA.

Text colored with green indicate the alternative percentage is more than 5% higher than the NAA. Non-filled cells indicate the alternative percentage are 5% lower than the NAA. When there were zero days within a MWUA flow category under the NAA, a percentage was not calculated for the alternatives, and the number of days meeting the flow category is reported instead.

8.4.2 Rearing

Ammocoetes are present year-round, and so effects assumed can occur in all days of the year. Flows from 1936 to 2019 were categorized as high, normal or low water years based on the 25th and 75th percentiles of Willamette-at-Salem unregulated flow estimated for the Mar 15-Oct 15 timeframe in each year. There were very few days (5 or less) down-ramping below each dam exceeded 1 ft/day for more than 1 day (Table 6 [The median number of days annually, by water year type, that down-ramping]). This was the case for all alternatives, locations and under each water year type. In most cases, there were zero to 1 days. The criteria was exceeded more below Fall Creek Dam than other locations under all the alternatives.

Table 8-6. The median number of days annually, by water year type, that down-ramping below each dam exceeded 1 ft/day for more than 1 day.

Location	Type	Alt_1	Alt_2a	Alt_2b	Alt_3a	Alt_3b	Alt_4	Alt_ LTM	Alt_ NAA	Alt_ Interim
Big Cliff Dam	High	0	0	0	1	2	0	0	0	0
	Low	0	0	0	1	1	0	0	0	0
	Normal	1	1	1	1	2	1	1	1	0
Cougar Dam	High	0	0	0	0	0	0	0	0	0
	Low	0	0	0	0	0	0	0	0	0
	Normal	0	0	0	0	0	0	0	0	0
Dexter Dam	High	1	1	1	1	2	1	0	3	0
	Low	0	0	0	0	0	0	0	1	0

	Normal	1	1.5	1.5	0	1	1.5	1	2.5	0
Fall Creek Dam	High	5	4	4	4	4	5	4	4	2
	Low	3	3	3	3	2	3	3	2	3
	Normal	4	4	4	4	5	4	4	5	4
Foster Dam	High	3	3	3	3	1	2	2	3	2
	Low	0	1	1	1	1	0	1	0	1
	Normal	1.5	2	2.5	2	1	1	2	1	2

Table Notes: Alt_LTM = long term measures under Alternative 5. Alt_Interim = Interim measures under Alternative 5.

8.4.3 Water Temperature

Monthly maximum water temperatures in three different years were modeled under each alternative (2011 = cool/wet, 2015 = hot/dry, 2016 = moderate/dry) following methods reported in Appendix D [Water Temperatures and Total Dissolved Gas Methodology]. Results are reported in Table 7 [Monthly maximum water temperatures].

For 2011 conditions, monthly maximum water temperatures only exceeded 68 degrees (20 degrees Celsius) in August at mainstem locations (Salem and Albany). This occurred under all alternatives. Differences between months at each location were generally the same among the alternatives.

In 2015, monthly maximum water temperatures exceeded 68 degrees (20 degrees Celsius) in June, July and August at mainstem locations under all alternatives. This was also the case below Dexter Dam in July and August. Below Hills Creek Dam, monthly maximum water temperatures exceeded 68 degrees in July and/or August under Alternatives 2a, 2b, 3b, and 5.

In 2016, patterns were very similar to 2011.

Table 8-7. Monthly maximum water temperatures (Fahrenheit) for three water years by location and WVS EIS alternative.

Year and Location	Alt1	Alt2a	Alt2b	Alt3a	Alt3b	Alt4	Alt5	NAA
2011								
ALBO								
Apr	49.6	49.6	49.4	49.5	49.7	49.7	49.4	49.5
May	53.3	53	52.8	53.4	53.5	53.3	52.8	53.1
Jun	59.4	58.8	58.8	60.5	60.1	59.4	58.8	58.8
Jul	67.7	66.8	66.9	67.9	68	67.8	66.9	66.8
Aug	69.2	68.8	68.5	69.7	70	70.1	68.6	68
Sep	63.3	62.4	62.8	64.2	62.5	63.7	63	62.8
Oct	55.1	56.7	57.1	56.9	55.3	55	56.8	56.7

Year and Location	Alt1	Alt2a	Alt2b	Alt3a	Alt3b	Alt4	Alt5	NAA
BCLO								
Apr	42.3	42.2	42.3	42.3	42.5	42.3	42.2	42.4
May	45.6	45.6	45.6	45.2	46.6	45.6	45.6	45.4
Jun	50.3	50.2	50.2	48.9	50.9	50.3	50.2	48.8
Jul	56.9	56.7	56.7	54.2	58	56.7	56.7	53.9
Aug	60.3	59.8	59.8	59.1	56	59.8	59.8	56.4
Sep	56.9	56.9	56.9	60.5	45.3	56.9	56.9	53.7
Oct	51.1	51.1	51.1	53.8	50.1	51.1	51.1	49.5
CGRO								
Apr	42.5	42.5	41.5	42.2	41.5	42.5	41.6	42.5
May	45.6	44.8	43.8	44.5	43.8	44.8	43.7	45.6
Jun	49.4	48.2	46.4	47.1	46.3	48.2	46.4	49.4
Jul	55.7	54.3	52.4	50.4	52.3	54.4	53	55.7
Aug	58.8	58	58.2	54	58.3	57.9	64.4	58.7
Sep	56.4	56.5	56.8	56.9	56.8	56.5	61.9	56.4
Oct	49.6	49.9	53.5	55.8	53.4	49.9	51.6	49.6
DEXO								
Apr	46.6	46	46.1	46.7	46.6	46.7	46.2	45.9
May	49.6	48.3	48.3	49.5	50.1	49.8	48.3	48.3
Jun	53.7	51.5	51.5	54.7	54.7	54.1	51.5	51.5
Jul	61	56.5	56.5	61.9	61.5	61.9	56.4	56.5
Aug	64.7	59.8	59.5	65.6	66.9	66.9	59.4	59.2
Sep	62.6	60.1	60.3	64.4	57.7	64.1	60.4	60.4
Oct	52.6	59.2	59.2	58.1	54.3	52.6	59.1	58.9
HCRO								
Apr	44.4	44.3	44.3	45.9	45.8	45.3	44.4	44.3
May	45.9	45.8	45.8	47.9	48.5	47.7	45.9	45.8
Jun	47.9	47.9	47.9	51	51	49.9	47.9	47.9
Jul	49.3	49.3	49.3	57.7	53.8	59	49.3	49.3
Aug	51.3	50.6	50.9	62.5	55.7	62.6	50.9	51.1
Sep	54.6	55.5	55.2	51.1	57.7	56.2	55.2	54.7
Oct	57.6	58.6	58.7	52.1	59.6	53.1	58.5	58.3
SLMO								
Apr	49.1	49.1	49	48.9	49.2	49.1	49	49.1
May	52.9	52.7	52.7	52.9	53.2	52.9	52.7	52.6
Jun	58.8	58.4	58.4	59.5	59.3	58.7	58.4	58.1
Jul	67.6	66.5	66.7	67.4	67.2	67	66.7	66.8
Aug	70.4	69.9	69.8	70.5	70.1	70.3	69.8	69.2
Sep	64.2	62.4	62.7	63.7	61.9	64.2	62.7	62.7
Oct	54.6	55.5	55.6	55.9	54.6	54.6	55.5	55.5

Year and Location	Alt1	Alt2a	Alt2b	Alt3a	Alt3b	Alt4	Alt5	NAA
SSFO								
Apr	44.8	44.8	44.7	44.6	44.4	44.8	44.7	44.5
May	48.5	48.3	48.3	47.6	46.9	48	48.3	46.6
Jun	53.2	52.7	52.7	51.5	51.6	52	52.6	49.9
Jul	58.7	56.2	56.2	57.3	55.1	54.6	56.2	56.8
Aug	65	64.1	64.1	64.2	58	60.9	64	56.2
Sep	62.1	54.6	54.6	54.8	64.7	57.3	54.8	52.4
Oct	52.6	52.9	52.9	52.9	59.6	51.8	52.6	51.6
2015								
ALBO								
Apr	55.3	55.1	54.7	54.9	54.7	55.3	54.7	54.5
May	62.8	61.8	61.9	62.4	61.9	62.2	61.5	60.9
Jun	70.9	69.6	69.8	71.1	70.1	70	69.9	70.5
Jul	73.9	74.1	74.2	74.9	75.4	74.4	74.4	75.3
Aug	71.8	72.9	72.9	73.1	73.4	72.4	73	73.3
Sep	65.1	64.8	64.8	65	65	64.8	64.8	64.9
Oct	58.9	59.2	59.1	59.2	60	59	59	59.1
BCLO								
Apr	46.9	46.9	46.9	47.3	46.4	46.9	46.9	46.5
May	52.4	52.4	52.4	53.6	49.2	52.4	52.4	50.5
Jun	57.9	57.7	57.7	62.2	52.9	57.7	57.7	55.5
Jul	61.8	61.4	61.4	69	58	61.4	61.4	58.6
Aug	61.5	61.5	61.5	68.5	61.4	61.5	61.5	60.5
Sep	57.3	57.4	57.4	63.8	56.6	57.4	57.4	60.8
Oct	53.2	53.6	53.6	58.8	55	53.6	53.6	60.1
CGRO								
Apr	46.5	46.5	46.1	46.6	46.1	46.5	46.3	46.3
May	50	50.4	50.2	50.8	49.4	50.4	50.4	50.2
Jun	56.9	56.3	56.2	56	54.9	56.6	56	57
Jul	60.8	59	57.3	60.1	56.4	59	57.2	62.1
Aug	59.5	57.8	55.4	61.7	54.9	57.8	55.5	61
Sep	56.2	56.7	51.1	59.1	50.6	56.6	50.9	56.8
Oct	52.5	53.9	48.2	55.4	48	53.8	48.2	54.9
DEXO								
Apr	53.8	52.7	52.5	53.3	52.5	53.9	52.7	52.1
May	59.4	57.1	56.7	59.4	56.4	59.1	56.5	55.9
Jun	65.4	62.5	62.1	66.1	62.1	63.9	62.2	63.5
Jul	69.8	69.1	68.5	71.1	69.7	70.2	68.7	70.3
Aug	68.9	70.8	70.4	72.7	72.1	69.8	70.2	73.1
Sep	65.7	67.2	68	68.3	68.2	66.5	68.6	69

Year and Location	Alt1	Alt2a	Alt2b	Alt3a	Alt3b	Alt4	Alt5	NAA
Oct	60.9	63.8	64	63.1	63.6	61.5	64.2	63.6
HCRO								
Apr	47.9	47.9	48.1	51.2	50.9	51.2	48.3	48.6
May	49.1	50.7	51.1	56.4	55.6	54.2	52.4	52.1
Jun	54.4	58.2	59	57	60.4	58.6	62.2	55.4
Jul	63	67.1	69.2	65.4	68.8	65.5	74	59.9
Aug	67.5	72.1	72.1	64.8	70.6	66.4	72.5	64.1
Sep	65.2	66.5	66.6	65.1	68	65.1	66.8	64.6
Oct	61.2	61.6	61.8	62.6	64	61.2	62	63.9
SLMO								
Apr	55.1	55.1	54.9	54.8	54.5	55.2	54.8	54.2
May	62.8	62.1	62.1	62.6	62	62.2	61.8	60.5
Jun	72	70.5	70.9	72.4	71.1	70.6	70.9	71
Jul	75.1	74.4	74.5	75.6	75.7	74.5	74.4	76.3
Aug	72.5	72.9	72.9	73.6	74.6	72.5	72.6	75
Sep	65.1	64.6	64.6	65.3	65.3	64.7	64.7	65.9
Oct	59.1	59.6	59.5	59.7	60.5	59.4	59.8	59.9
SSFO								
Apr	49.2	49.2	49.2	48.9	49.3	49.2	49.2	48.3
May	54.1	54.6	54.6	54	54.4	54.1	54.2	51
Jun	62	62.6	62.6	60.8	62.7	61.4	61.3	56.7
Jul	66.4	56.5	56.6	57	71.5	55.7	55.3	61.2
Aug	67.7	56.2	56.2	56.5	72.5	56.4	55.9	69.5
Sep	62.6	56.8	56.8	57.1	66.7	58	59.4	66
Oct	56.5	60.3	60.2	60.9	61.1	60.2	61.3	61
2016								
ALBO								
Apr	56	55.7	55.8	55.6	56	55.9	55.6	55.1
May	61.5	60.4	60.3	61	61	61.1	59.7	59.4
Jun	69	66.8	67.1	68.9	68.5	68.1	66.5	66.7
Jul	71.2	71	71	72.5	73.1	72.3	71	71.1
Aug	71.9	71.7	71.6	72.9	71.2	72.6	71.7	71.9
Sep	64.4	65.8	65.8	65.6	63.9	64.7	65.8	65.8
Oct	56.5	57.5	57.5	57	56.7	56.5	57.5	57.5
BCLO								
Apr	46.9	46.7	46.7	47	46.8	46.7	46.7	46.9
May	52.2	52.1	52.1	52.1	52.1	52.1	52.1	50.7
Jun	57.4	57	57	58.4	57.1	57	57	55.3
Jul	61.5	61.1	61.1	63.7	48.9	61.1	61.1	50
Aug	61.7	61.4	61.4	67.3	52.1	61.4	61.4	51.8

Year and Location	Alt1	Alt2a	Alt2b	Alt3a	Alt3b	Alt4	Alt5	NAA
Sep	57.2	57	57	63.1	52.8	57	57	54.5
Oct	51.1	51.2	51.2	53.9	53.5	51.2	51.2	53.2
CGRO								
Apr	45.6	45.8	45.5	46.3	45.5	45.6	46.1	45.7
May	49.8	49.7	48.5	50.4	49.1	49.6	50.1	49.6
Jun	56.5	55.3	52.9	54.3	53.5	55.7	53.5	56
Jul	60.1	59.2	55.7	57.4	55.8	59.3	55.2	60.9
Aug	60.7	58.5	55.7	60.3	55.7	60.5	55.1	58.6
Sep	56.4	53.2	50.6	58.6	50.6	55.9	50.2	51.9
Oct	49.7	49.1	47.6	52.8	47.6	49.6	47.7	49.1
DEXO								
Apr	52.6	50.5	50.5	52.2	52.2	52.7	50.5	50.2
May	57.2	52.8	52.8	56.5	56	57.2	52.5	52.5
Jun	62.9	57.1	57.2	63.3	61.7	62.3	57.3	57.3
Jul	65.3	61.6	61.5	67.9	68	67	61.5	61.7
Aug	67.5	64.8	64.9	69.4	61.3	68.9	65.3	65.7
Sep	62.1	65.6	65.8	66.4	59.5	63.1	66.1	66.3
Oct	54.6	60.5	60.6	59.1	57.6	54.5	60.9	60.4
HCRO								
Apr	46.7	46.7	46.7	50.1	49.9	50.2	46.7	46.9
May	48	48.1	48.1	53.6	54	53.8	48.7	49.9
Jun	49.4	50.5	50.4	60.1	59	58	52.7	54.3
Jul	52.5	52.3	52.2	62.4	64.4	65.8	54.4	56.4
Aug	59	59	60.1	56.3	69.2	62.9	64.6	61.9
Sep	61.7	61.7	64.3	57.6	67.7	56.4	65	63
Oct	58.8	59.4	59	55.4	59.5	52.5	56.4	59.8
SLMO								
Apr	56	55.8	55.6	55.4	55.6	55.9	55.6	55.5
May	62	60.9	60.8	61.2	61.4	61.3	60.4	60
Jun	69.5	67.3	67.6	69.5	68.6	68	67.3	67.1
Jul	71.9	71.6	71.6	73.1	72.1	72	71.6	71.1
Aug	73	72.4	72.3	73.8	72	72.8	72	72.3
Sep	64.8	64.1	64.3	64.3	63.7	64.3	64.4	64.4
Oct	55.4	55.9	55.9	55.7	55.7	55.6	56	56.2
SSFO								
Apr	49.4	49.7	49.7	48.9	49.3	49.7	49.7	48.6
May	54.2	54.3	54.3	53.7	54.1	53.7	54	50.9
Jun	60.8	60.9	60.9	60.3	60.7	59.5	60.8	54.7
Jul	64.8	64.6	64.6	65.3	65.8	61	64.8	58.6
Aug	67.2	60.3	60.3	60.3	71.2	58.8	57.2	57

Year and Location	Alt1	Alt2a	Alt2b	Alt3a	Alt3b	Alt4	Alt5	NAA
Sep	62.8	54.6	54.6	54.8	66.4	55.2	53.8	55.4
Oct	54	54	54	54.1	54.8	53.1	54.5	55.3

Cells highlighted in red indicate when maximum water temperatures were greater than 68 degrees (20 degrees Celsius) in the mainstem Willamette River at Salem and Albany.

8.4.4 Sediment Transport

NAA - WVS reservoirs are only partially drawdown under the NAA, with the exception of Fall Creek Dam, to the existing minimum conservation pool elevations. Although there are sediments entering the reservoir from upstream each year, the vast majority of these settle out within each reservoir. Sediment processes due to annual operations within the reservoir are limited with only the finest grained sediments able to resuspend during drawdowns and pass the reservoir (including those accumulating each year from annual upstream inputs). Downstream of these dams, lack of sediment delivery would affect habitat availability for lamprey over time.

Assuming no other major changes in the watershed downstream of WVS dams occur altering the ambient levels of sediment inputs in the watershed area downstream of each WVS dam, the availability of larval rearing habitat would be expected to slowly decline due to the lack of inputs of sediment and coarse organic matter from upstream of WVS dams. Similarly for spawning areas, the lack of gravel-sized and larger materials being transported below WVS dams would be expected to negatively affect areas with suitable gravel sized substrates for building redds. However, due to the high abundance of gravel areas currently existing (R2 Resources 2009), the availability of areas with suitable gravel conditions is not expected to become substantially limiting during the period of this analysis.

Reservoir elevations under the NAA would continue to be managed under the existing rule curves and therefore existing, low levels of sediment discharge would continue below WVS dams.

Sediment discharges from Fall Creek Dam are expected to contribute to maintenance of lamprey spawning and rearing habitat downstream of the dam. Fall Creek Reservoir would continue to be drawn down to streambed annually, as has occurred since 2011. Substantial quantities of fine sediments were released below the dam within the first few years following 2011, and then sediment releases have declined. Similar to those occurring in more recent years, lower levels of sediment releases are expected under the NAA, owing to contributions entering into the reservoir zone from upstream annually which are then resuspended and transported downstream during drawdowns to streambed each fall.

Operations of Big Cliff, Foster and Dexter Reservoirs under the action alternatives remain the same as under the NAA. These reservoirs provide for re-regulation of water discharged from upstream WVS dams. Therefore, they would not be further considered in the action alternatives except regarding their effects on sediment delivery in the system from upstream WVS dams.

Alternatives 2A, 2B, 4 and 5 – Under these alternatives, reservoir operations would occur similar to the NAA at Lookout Point, Hills Creek, Fall Creek, Blue River, Green Peter, and Detroit Dams, and therefore effects on lamprey would be as described for these dams under the NAA. In addition, gravel augmentation is included as a measure in all action alternatives below WVS dams in the North Santiam, South Santiam, and McKenzie Rivers. Gravel augmentation would help maintain and improve spawning and incubation habitat availability for lamprey below these dams.

At Cougar Dam under Alternative 2B, a deeper drawn to the diversion tunnel would result in significant delivery of sediments in the first few years after implementation of this measure. The drawdown would occur down to 25 feet over the top of the diversion tunnel. In this case, there would still be a small residual reservoir pool present which would initially affect coarse grained sediment delivery from reservoir erosion and upstream watershed sources from passing the dam. The. all residual pool would likely fill with sediment eroded from the reservoir and increase the ability of the dam to pass coarser grained sediments. Reductions in quantity would then likely occur, similar to that which occurred below Fall Creek Dam after initiation of drawdowns to streambed in 2011.

During the first few years below Cougar Dam, it is likely that finer sediments would negatively impact areas used by larval lamprey for rearing, covering these areas with finer silt and clay sediments. Areas used for spawning and incubation in the South Fork McKenzie and mainstem McKenzie Rivers also would be negatively affected by finer sediments filling interstitial spaces in gravel substrate, reducing the value of the habitat for spawning and incubation. These effects are however expected to be temporary and finer sediments, particularly in the spawning gravel areas within main channels would be flushed out with subsequent winter high flows and as declines in sediment delivery occur after the first few years (e.g. see Zymonas et al. 2010). Deposition of fines in low energy and backwater areas is expected to be persistent.

Below Green Peter Dam under alternatives 2A and 2B, deeper reservoir drawdowns to the regulating outlets would result in silts and clay sediments being discharged below the dam. Some of this sediment would settle in downstream Foster Reservoir, and some would be transported downstream of Foster Reservoir. It is highly uncertain if the levels passing downstream of Foster Reservoir would result in impacts to rearing or spawning/incubation areas. Conservatively, it is assumed these effects would be similar but lesser to those described above for Alternative 2B below Cougar Dam, and that repeated deeper drawdowns would lead to decreases in these effects over a few years following initiation of this measure.

Alternatives 3A and 3B – Deeper drawdowns are included in these alternatives at Lookout Point, Hills Creek, Fall Creek, Cougar, Blue River, Green Peter and Detroit reservoirs. With the exception of Cougar under Alternative 3B, large residual pools would remain. Effects downstream for lamprey are expected to be the same as described for Green Peter Reservoir for Alternatives 2A and 2B. For Cougar Reservoir under Alternative 3B, the deep drawdown is down to 25 feet over the top of the diversion tunnel. In this case, there would still be a small residual reservoir pool present which would affect sediment delivery from upstream in the watershed, however large releases of sediment are possible in the first few years, with effects as described for lamprey under Cougar Alternative 2B for Cougar Dam.

Under Alternative 3A, deeper drawdowns occur twice per year (in spring and fall) at Lookout Point and at Detroit reservoirs. Total annual sediment delivery is expected to be higher in the first couple of years, but also decline in magnitude to lower levels within fewer years, than in cases where deep drawdowns occur only once per year.

8.4.5 Habitat Access

Due to the lack of Pacific Lamprey spawning habitat information available, habitat for spring Chinook spawning was applied, as reported by Bond et al. (2017), to assess the availability of Pacific lamprey spawning habitat (Table 8 [Spawning redd capacity estimates]). We assumed habitat was available if effective fish passage to the reach exists. As previously described, we assumed Pacific lamprey passage at WVS dams would only occur at Fall Creek Dam under the NAA and under each action alternatives. Therefore, accessibility of habitat above WVS dams only occurs above Fall Creek under the NAA and under all action alternatives.

Based on the redd capacity information for spring Chinook salmon applied as a surrogate for lamprey, 43% of the existing spawning habitat in tributaries affected by WVS dams is accessible for Pacific lamprey under the NAA and under each action alternative. At the basin wide scale, Clemens et al. (2023) estimates there is 68% accessible Pacific lamprey habitat downstream of federal and non-federal dams.

Table 8-8. Spawning redd capacity estimates for spring Chinook salmon in the Upper Willamette River Basin applied for assessing Pacific lamprey habitat availability reproduced from Bond et al. (2017).

Basin and Range	Redd Capacity Estimates*	Accessible**
North Santiam Below Detroit	22,693	Y
North Santiam Above Detroit	15,602	
North Santiam Total	38,295	
South Santiam Below Foster	8,787	Y
South Santiam Above Foster	4,504	Y
South Santiam Above Green Peter	1,508	
South Santiam Total	14,799	
McKenzie Below Cougar and Trail Bridge dams	44,480	Y
McKenzie Above Cougar Dam	5,423	
McKenzie Total	49,903	

Middle Fork Below Fall Cr/Dexter/Lookout Point dams	8,813	Y
Middle Fork Above Fall Creek Dam	3,419	Y
Middle Fork Above Dexter/Lookout Point dams	72,937	
Middle Fork Above Hills Creek Dam	27,532	
Middle Fork Total	112,701	
Total available	215,698	
Total accessible	92,696	
Percent of total accessible	43%	
* under 1993-2011 avg temperatures		
**Fish Passage provided under NAA or Action Alternatives		

Y= yes

8.5 SUMMARY

NAA – Habitat access for Pacific lamprey spawning would be constrained to approximately 40% of that existing in tributaries where WVS dams are located, due to the lack of effective fish passage conditions at these dams. At Fall Creek Dam, an adult fish collection facility allows for collection of upstream migrating adults and trucking above the dam, and downstream passage is provided annually via a drawdown of the reservoir to streambed. Due to constrained habitat access above most WVS dams, abundance and production of lamprey would also be substantially constrained to existing levels. WVS water management would support spawning and rearing below WVS dams, with temperatures nearly always below stressful levels within tributaries. WVS reservoir releases during spring to fall would increase (supplement) river flows downstream, helping to reduce mainstem water temperature maximums, water temperatures in the mainstem, particularly in dry hot years would rise above stressful levels in summer. Flood management in winter however would reduce peak flows and associated river channel forming processes to that help maintain and create habitat. Sediment transport from upper watershed areas to areas below WVS dams would continue to be reduced by operation and maintenance of dams, which would reduce habitat quality and quantity for rearing and spawning slowly over time in these areas.

Alternative 1 and 2A – Spawning habitat access (constrained to approximately 40% of available), and effects of water management on habitat below WVS dams is similar to the NAA for Pacific lamprey with the following notable exceptions. Spawning habitat available at the 90% MWUA flow levels below WVS dams are provided nearly throughout the spawning and incubation season, except for below Dexter Dam. Alternative 1 also includes gravel augmentation which would improve spawning habitat quality and availability below WVS dams in major Willamette River tributaries affected by the WVS. Fish passage improvements at the Monroe Drop structure would provide access upstream in the Long Tom River, providing a minor increase in potential spawning and rearing habitat availability.

Alternative 2B and 5 – Habitat access, and effects of water management on habitat below WVS dams would be similar to Alternative 1, except below Cougar Dam. A deep drawdown of Cougar Reservoir to 25 feet over the diversion tunnel would reduce water storage for summer flow supplementation downstream annually, and change sediment discharge rates. Spawning habitat availability below Cougar Dam at the 90% MWUA flow level would range from approximately 51% to 66% annually depending on water year type. Substantial sediment releases in the first few years after deep reservoir drawdowns commence would reduce the quality and quantity of spawning and rearing habitat downstream in this timeframe. The levels of sediment are then expected to decline to natural levels of sediment transport similar to that entering Cougar Reservoir from the upstream watershed.

Alternative 3A– Deep drawdown of Detroit, Green Peter, Cougar, Hills Creek, Lookout and Fall Creek Reservoirs occur under this alternative. Under Alternative 3A, combined spring and fall drawdowns at Detroit and Cougar reservoirs would reduce water storage for summer flow supplementation annually downstream, reducing spawning habitat availability. Conversely, a deep reservoir drawdown in fall at Green Peter and Hills Creek Reservoir would increase flows below Foster and Dexter dams, respectively, increasing incubation habitat available in this reach. Sediment releases below Detroit, Green Peter and Lookout Point dams as a result of the deeper reservoir drawdowns to the regulating outlets would result in silts and clay sediments being discharged below the dams. Some of this sediment would settle in downstream reservoirs (Big Cliff Reservoir, Foster and Dexter), and some would be transported further downstream, impacting rearing and spawning/incubation areas. The highest levels of silt and clay releases would be temporary, occurring in the first few years of operations, and then sediment release levels would decline to approximately ambient levels delivered from upstream of Detroit Dam. Sediment releases from Hills Creek Dam are not expected to affect conditions downstream of Dexter Dam due to the presence of two downstream reservoirs (Lookout Point and Dexter Reservoirs) which would cause much or all of the suspended sediment to settle. Aside from the effect of deeper reservoir drawdowns at Detroit, Cougar and Lookout Point dams, effects are as described for Alternative 1.

Alternative 3B - Deep reservoir drawdowns also occur at the dams listed for Alternative 3A, however combined spring and fall drawdowns shift to occur at Green Peter, Cougar (to the diversion tunnel) and Hills Creek Reservoirs. The combined spring and fall drawdowns at Green Peter Reservoir would reduce water storage for summer flow supplementation annually downstream, reducing spawning habitat availability. Conversely, deep reservoir drawdowns in fall at Lookout Point would increase flows below Dexter dams, respectively, increasing incubation habitat available in this reach. Deep drawdown of Cougar Reservoir to the diversion tunnel would reduce water storage for summer flow supplementation downstream annually, and change sediment discharge rates, with effects are described for Alternative 2b. Other effects would occur as described for Alternative 1.

Alternative 4 – Structural improvements for downstream fish passage are included at Detroit, Cougar, Lookout Point and Hills Creek Dams. Although minimum flow targets are different, reservoir operations and the flow releases estimated to occur below each dam are similar to those occurring under Alternative 1. Therefore, effects are the same as those described for Alternative 1.

8.6 REFERENCES

Beamish, Richard J. 1980. "Adult Biology of the River Lamprey (*Lampetra Ayresi*) and the Pacific Lamprey (*Lampetra Tridentate*) from the Pacific Coast of Canada." *Canadian Journal of Fisheries and Aquatic Sciences* 37 (11): 1906–23. https://doi.org/10.1139/f80-232.

Carim, K. J., D. C. Larson, J. M. Helstab, M. K. Young, and M. F. Docker. 2023. "A Revised Taxonomy and Estimate of Species Diversity for Western North American Lampetra." *Environmental Biology of Fishes* 106 (5): 817–36. https://doi.org/10.1007/s10641-023-01397-y.

Clemens, Benjamin J. 2022. "Warmwater Temperatures (≥ 20°C) as a Threat to Pacific Lamprey: Implications of Climate Change." *Journal of Fish and Wildlife Management* 13 (2): 591–98. https://doi.org/10.3996/JFWM-21-087.

Clemens, Benjamin J., Kara Anlauf-Dunn, Matt Weeber, and Thomas Stahl. 2020. "FINAL Coastal, Columbia, and Snake Conservation Plan for Lampreys in Oregon." ODFW. https://www.dfw.state.or.us/fish/CRP/docs/coastal_columbia_snake_lamprey/CPL%20-%20Final%202-14-20.pdf.

Clemens, Benjamin J., Thomas A. Friesen, Stanley V. Gregory, and Courtney L. Zambory. 2023. "The Case for Basinwide Passage and Habitat Restoration for Pacific Lamprey in the Willamette River Basin (Oregon, USA)." *North American Journal of Fisheries Management*, March, 1–17. https://doi.org/10.1002/nafm.10891.

Clemens, Benjamin J., and Carl B. Schreck. 2021. "Microhabitat Use by Pre-spawning Pacific Lamprey Entosphenus Tridentatus in a Large, Regulated River Differs by Year, River Segment, and Availability." *Environmental Biology of Fishes* 104 (3): 325–40. https://doi.org/10.1007/s10641-021-01079-7.

Clements, Shaun, Kara Anlauf-Dunn, Matt Weeber, and Thomas Stahl. 2020. "Coastal, Columbia, and Snake Conservation Plan for Lampreys in Oregon." ODFW. Nathan's Zotero library. https://www.dfw.state.or.us/fish/CRP/coastal_columbia_snake_lamprey_plan.asp.

Goertler, Pascale A. L., Anjali W. Shakya, Alicia M. Seesholtz, Brian M. Schreier, S. Zoltan Matica, and K. Sheena Holley. 2020. "Lamprey (Entosphenus Sp. and Lampetra Sp.) Estuarine Occupancy Is Regionally Variable and Constrained by Temperature." *Journal of Fish Biology* 96 (2): 527–32. https://doi.org/10.1111/jfb.14143.

Gunckel, Stephanie L, Kim K Jones, and Steven E Jacobs. 2009. "Spawning Distribution and Habitat Use of Adult Pacific and Western Brook Lampreys in Smith River, Oregon." *American Fisheries Society Symposium*, no. 72: 173–89.

Harris, Julianne E., and Jeffrey C. Jolley. 2017. "Estimation of Occupancy, Density, and Abundance of Larval Lampreys in Tributary River Mouths Upstream of Dams on the Columbia River, Washington and Oregon." *Canadian Journal of Fisheries and Aquatic Sciences* 74 (6): 843–52. https://doi.org/10.1139/cjfas-2016-0212.

Harris, Julianne E., Joseph J. Skalicky, Theresa L. Liedtke, Lisa K. Weiland, Benjamin J. Clemens, and Ann E. Gray. 2020. "Effects of Dewatering on Behavior, Distribution, and Abundance of Larval Lampreys." *River Research and Applications* 36 (10): 2001–12. https://doi.org/10.1002/rra.3730.

Hess, Jon E., Thomas A. Delomas, Aaron D. Jackson, Michael J. Kosinski, Mary L. Moser, Laurie L. Porter, Greg Silver, Tod Sween, Laurie A. Weitkamp, and Shawn R. Narum. 2022. "Pacific Lamprey Translocations to the Snake River Boost Abundance of All Life Stages." *Transactions of the American Fisheries Society* 151 (3): 263–96. https://doi.org/10.1002/tafs.10359.

Hess, Jon E., Rebecca L. Paradis, Mary L. Moser, Laurie A. Weitkamp, Thomas A. Delomas, and Shawn R. Narum. 2021. "Robust Recolonization of Pacific Lamprey Following Dam Removals." *Transactions of the American Fisheries Society* 150 (1): 56–74. https://doi.org/10.1002/tafs.10273.

Jolley, Jeffrey C., Gregory S. Silver, and Timothy A. Whitesel. 2012. "Occupancy and Detection of Larval Pacific Lampreys and Lampetra Spp. in a Large River: The Lower Willamette River." *Transactions of the American Fisheries Society* 141 (2): 305–12. https://doi.org/10.1080/00028487.2012.662201.

Le, Bao, Sara Twitchell, Rod O'Connor, and Mike Clement. 2017. 2016 Pacific Lamprey Management Plan (PLMP) Comprehensive Annual Report 2017. https://www.grantpud.org/templates/galaxy/images/images/Downloads/ResourceCommittees/OtherDocuments/2017_03_29_2016_Pacific_Lamprey_Management_Plan_Report.pdf

Liedtke, Theresa L., Lisa K. Weiland, Joseph J. Skalicky, and Ann E. Gray. 2020. "Evaluating Dewatering Approaches to Protect Larval Pacific Lamprey." 2020–1026. *Open-File Report*. U.S. Geological Survey. https://doi.org/10.3133/ofr20201026.

Mayfield, M. P., L. D. Schultz, L. A. Wyss, B. J. Clemens, and C. B. Schreck. 2014. "Spawning Patterns of Pacific Lamprey in Tributaries to the Willamette River, Oregon." *Transactions of the American Fisheries Society* 143 (6): 1544–54. https://doi.org/10.1080/00028487.2014.949013.

Meeuwig, Michael H., Jennifer M. Bayer, and James G. Seelye. 2005. "Effects of Temperature on Survival and Development of Early Life Stage Pacific and Western Brook Lampreys." *Transactions of the American Fisheries Society* 134 (1): 19–27. https://doi.org/10.1577/FT03-206.1.

Mesa, Matthew G., Lisa K. Weiland, Helena E. Christiansen, and Christopher A Peery. 2015. "SYNTHESIS OF JUVENILE LAMPREY MIGRATION AND PASSAGE RESEARCH AND MONITORING AT COLUMBIA AND SNAKE RIVER DAMS." Study Codes: LMP-P-12-2, LMP-W-13-2. Columbia River and Snake River: USGS and USFWS.

ODFW. 2005. "2005 Oregon Native Fish Status Report." ODFW. https://www.dfw.state.or.us/fish/ONFSR/docs/volume-2-final.pdf.

———. 2023. "Upper and Lower Bennett Dams Fish Counts." 2023. https://myodfw.com/upper-and-lower-bennett-dams-fish-counts.

Oregon Secretary of State. 2023. "Division 41 WATER QUALITY STANDARDS: BENEFICIAL USES, POLICIES, AND CRITERIA FOR OREGON." Legislative. Department of Environmetnal Quality. December 19, 2023. https://secure.sos.state.or.us/oard/viewSingleRule.action?ruleVrsnRsn=68743.

Poirier, Jennifer M., Ann Gray, and Benjamin J. Clemens. 2023. "Pacific Lamprey 2022/2023 Regional Implementation Plan for the Willamette Sub-Unit of the Lower Columbia/Willamette Regional Management Unit." USFWS. https://www.pacificlamprey.org/wp-content/uploads/2023/08/2022-PLCI-Willamette-RMU-RIP.pdf.

Schenk, Liam, and Heather Bragg. 2021. "Sediment Transport, Turbidity, and Dissolved Oxygen Responses to Annual Streambed Drawdowns for Downstream Fish Passage in a Flood Control Reservoir." *Journal of Environmental Management* 295 (October): 113068. https://doi.org/10.1016/j.jenvman.2021.113068.

Sheoships, Gabe. 2014. "Pacific Lamprey Entosphenus Tridentatus: Integrating Traditional Ecological Knowledge and Contemporary Values into Conservation Planning, and Stream Substrate Associations with Larval Abundance in the Willamette River Basin, Oregon, U.S.A." Willamette Valley, OR: Oregon State University. https://ir.library.oregonstate.edu/concern/graduate_thesis_or_dissertations/08612r67k

USFWS. 2023. "Pacific Lamprey (Entosphenus Tridentatus) | U.S. Fish & Wildlife Service." May 31, 2023. https://www.fws.gov/species/pacific-lamprey-entosphenus-tridentatus.

WDFW. 2024. "Pacific Lamprey | Washington Department of Fish & Wildlife." Species & Habitats. 2024. https://wdfw.wa.gov/species-habitats/species/entosphenus-tridentatus.

Weitkamp, Laurie A., Susan A. Hinton, and Paul J. Bentley. 2015. "Seasonal Abundance, Size, and Host Selection of Western River (Lampetra Ayresii) and Pacific (Entosphenus Tridentatus) Lampreys in the Columbia River Estuary." *Fishery Bulletin* 113 (2): 213–26. https://doi.org/10.7755/FB.113.2.9.