US Army Corps
of Engineers®
Portland District

WILLAMETTE VALLEY SYSTEM OPERATIONS AND MAINTENANCE

APPENDIX E: FISH AND AQUATIC HABITAT ANALYSES

PART 1 – CHAPTER 1 THROUGH CHAPTER 4

TABLE OF CONTENTS

TABLES

FIGURES

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

Assumptions:

- 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 1-1, 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 Reservoir 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

Assumptions:

- 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 sub yearling 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 reservoir screw trapping. 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 (i.e., 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

<u>Assumptions</u>:

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	

Pool elevation	Previous DPE	DPE	Revised 9/23 DPE
1425	0.299	0.299	0.299
1400	0.5	0.5	0.5
1360	0.6	0.6	0.6
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 indicate 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

Assumptions:

- 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 life stages, 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%.

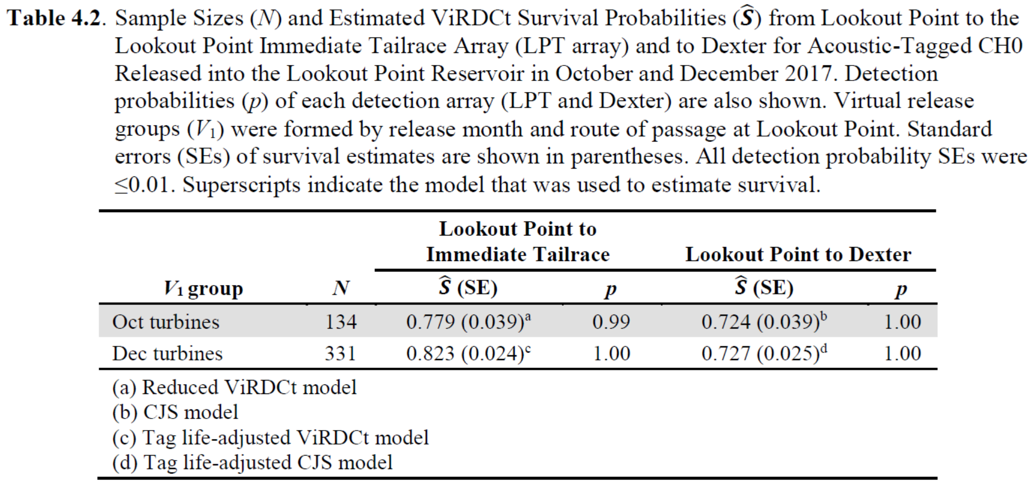


Table 4.2. Sample Sizes (N) and Estimated ViRDCt Survival Probabilities ($\widehat{S}$) from Lookout Point to the Lookout Point Immediate Tailrace Array (LPT array) and to Dexter for Acoustic-Tagged CH0 Released into the Lookout Point Reservoir in October and December 2017. Detection probabilities (p) 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	$\widehat{S}$ (SE)	p	$\widehat{S}$ (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

Figure 1-1. Table 4.2 of PNNL survival estimate summary from Fischer et al. 2019

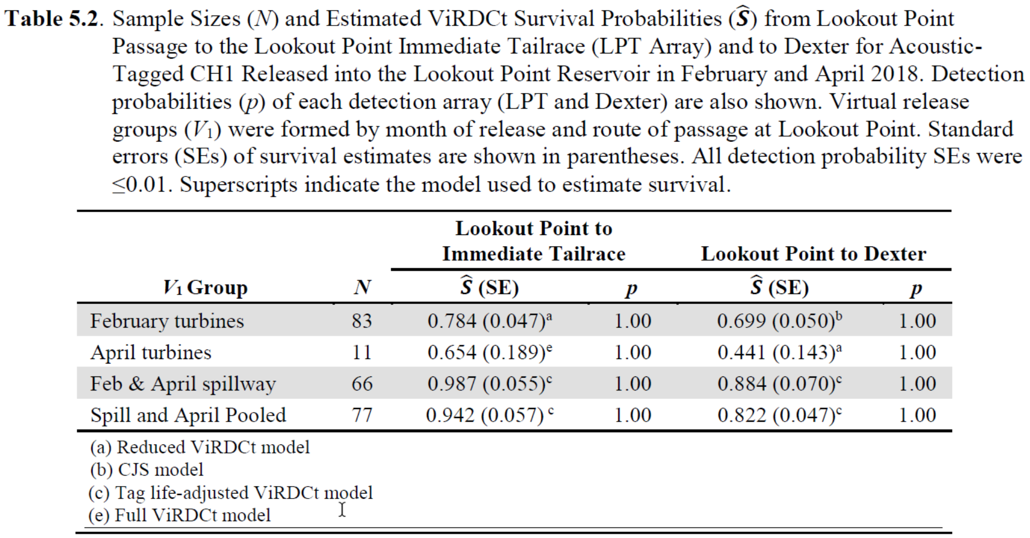


Table 5.2. Sample Sizes (N) and Estimated ViRDCt Survival Probabilities ($\hat{S}$) from Lookout Point Passage to the Lookout Point Immediate Tailrace (LPT Array) and to Dexter for Acoustic-Tagged CH1 Released into the Lookout Point Reservoir in February and April 2018. Detection probabilities (p) of 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

Figure 1-2. Table 5.2 of PNNL survival estimate summary from Fischer et al. 2019

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 1-3. 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, 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.

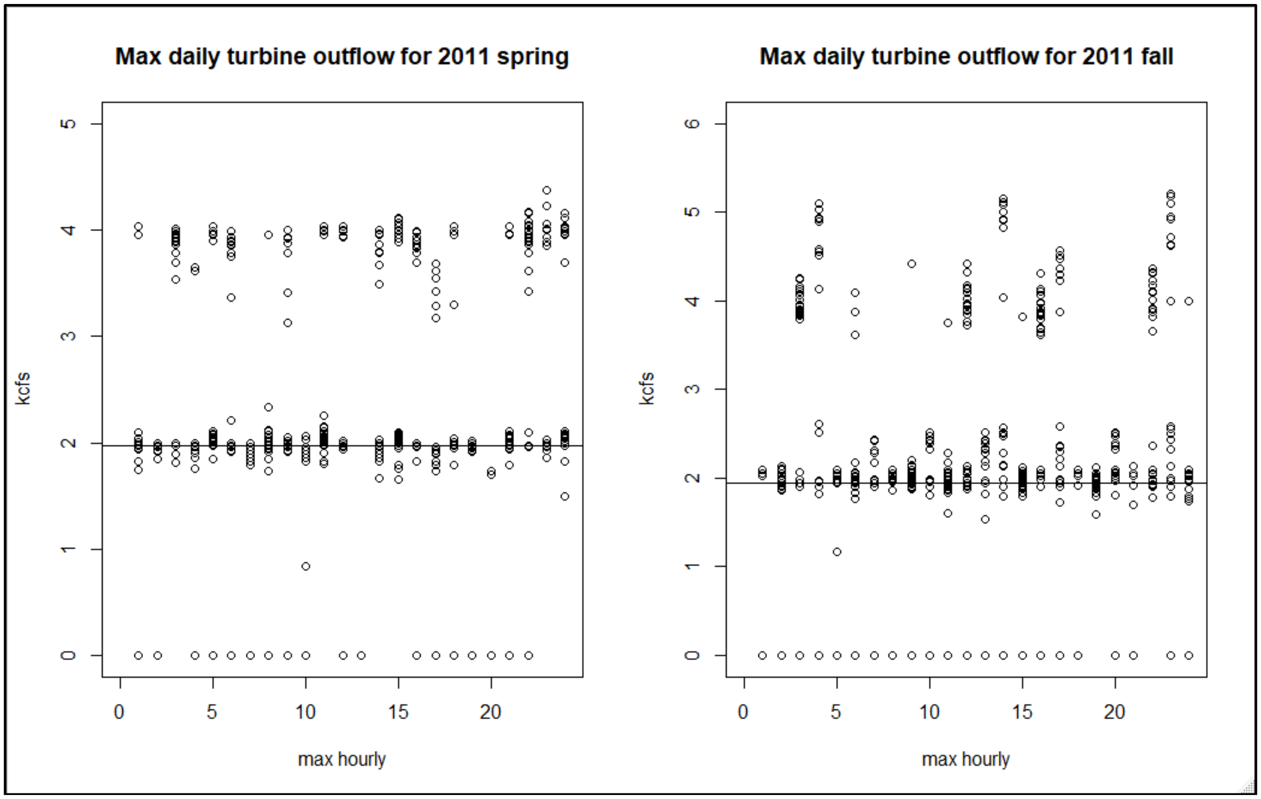


Figure 1-4. Detroit Spring and Fall Median Abundant Water Year Hourly Outflows. *Detroit Spring (Left) and Fall (Right) Median Abundant Water Year Hourly Outflows. The open dots represent the median hourly outflow. The solid line represents the median outflow for all data points.*

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 life stages
  - 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:

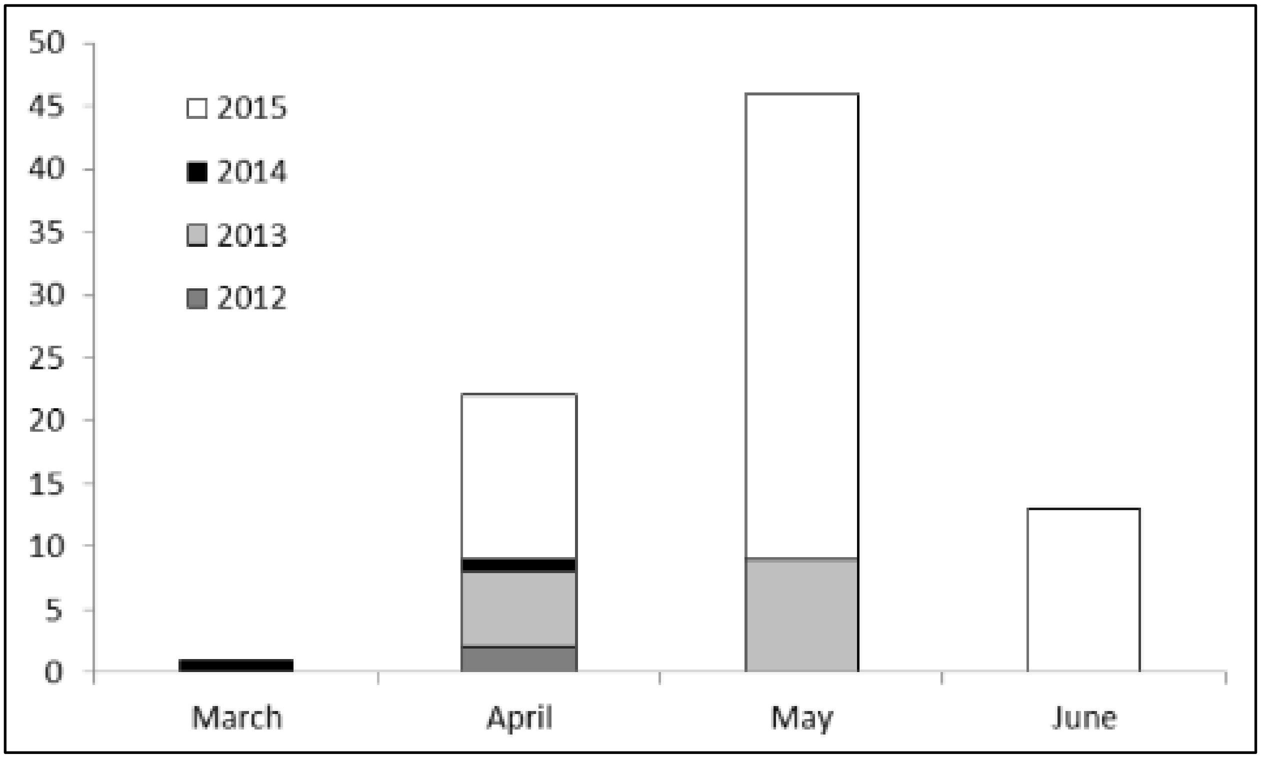


Figure 1-5. Monthly Steelhead smolt detections at Willamette Falls or the Columbia Estuary. *Steelhead smolt detections by month (N-82) at Willamette Falls or the Columbia Estuary during*

seaward migration. Year corresponds to the year of migration (or detection), not to year tagged (Romer et al. 2016; Figure 15).

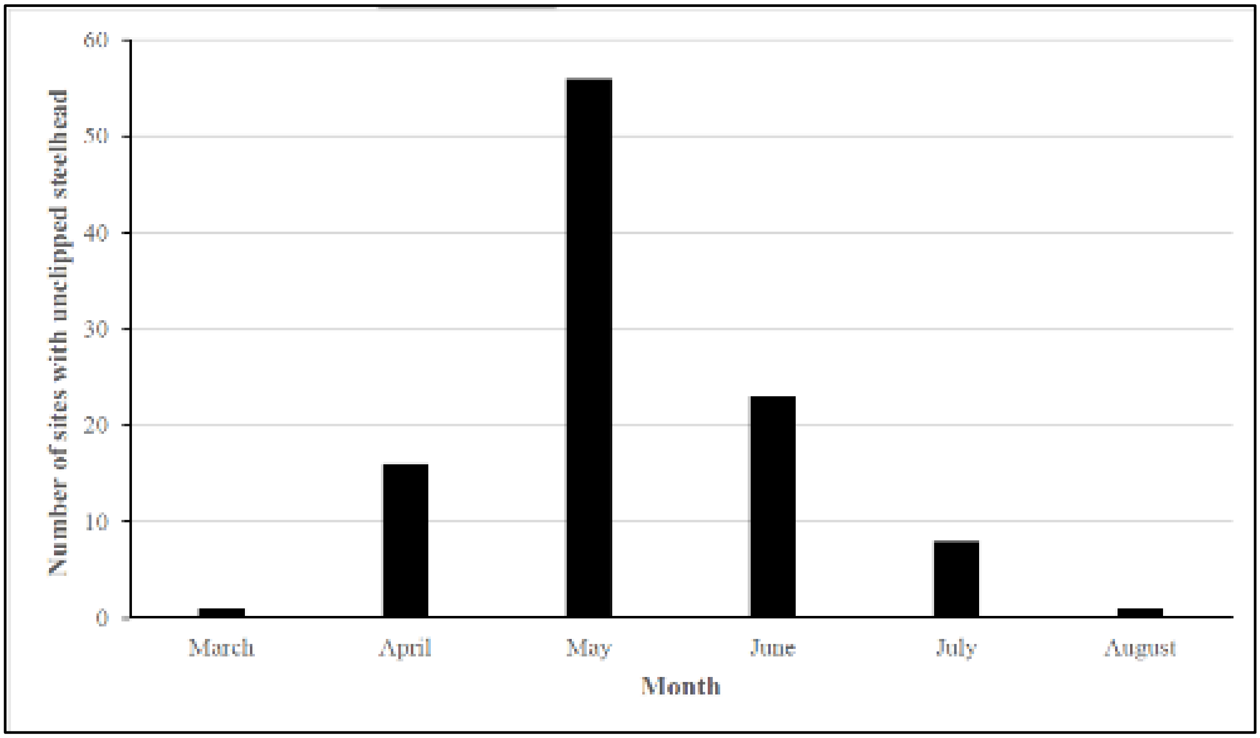


Figure 1-6. Scinc sites where unclipped juvenile steelhead were present, by Month. *Figure 5 from Monzyk et al. (2017)*

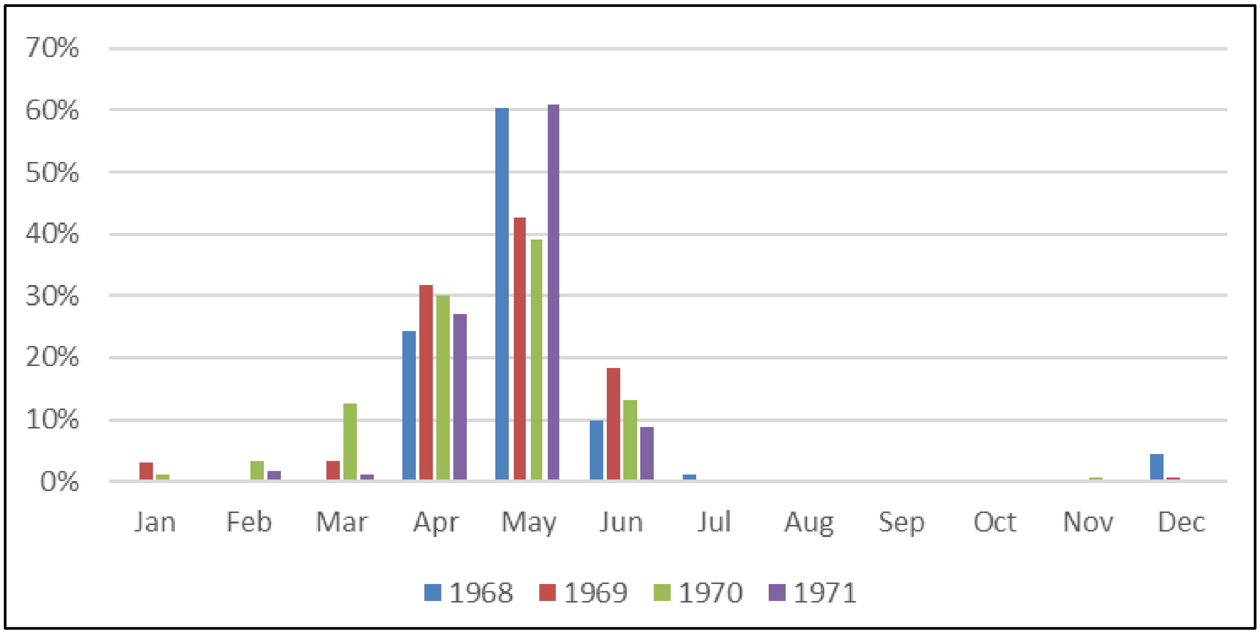


Figure 1-7. Juvenile Winter Steelhead Downstream Passage at Green Peter Dam. *Figure reproduced from data in Table 9, Wagner and Ingram (1973).*

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 life stages 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.

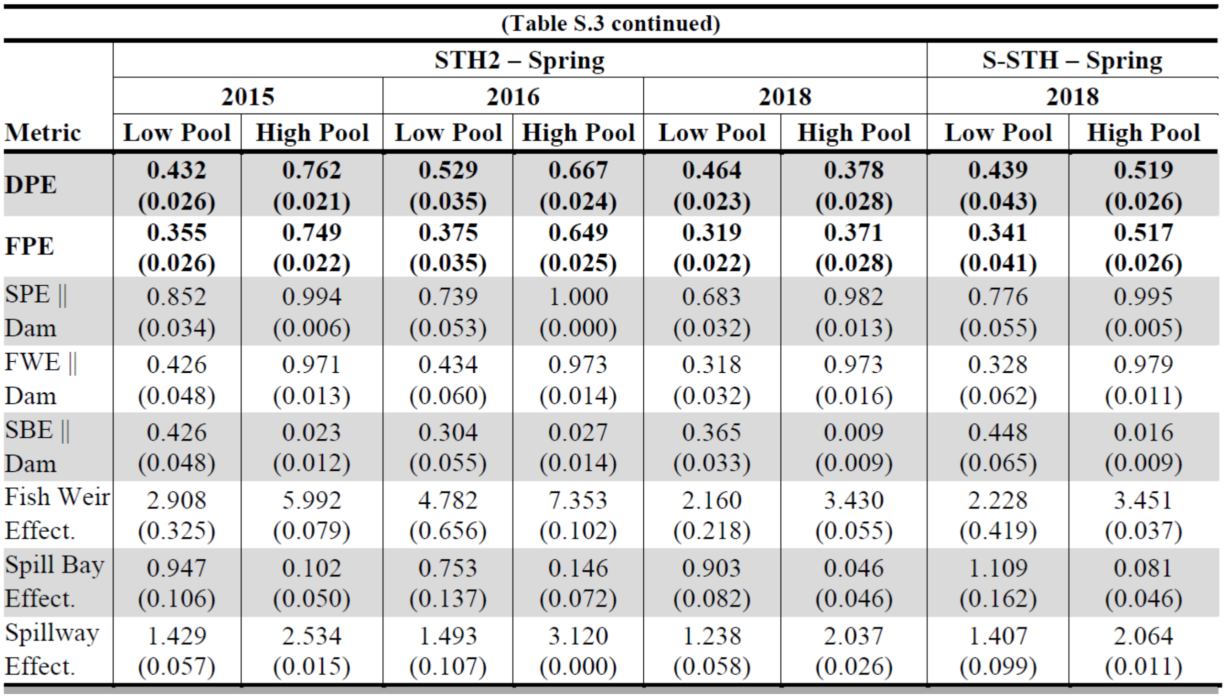
Table 1-33. Foster Baseline Measure Dam Passage Efficiency

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.

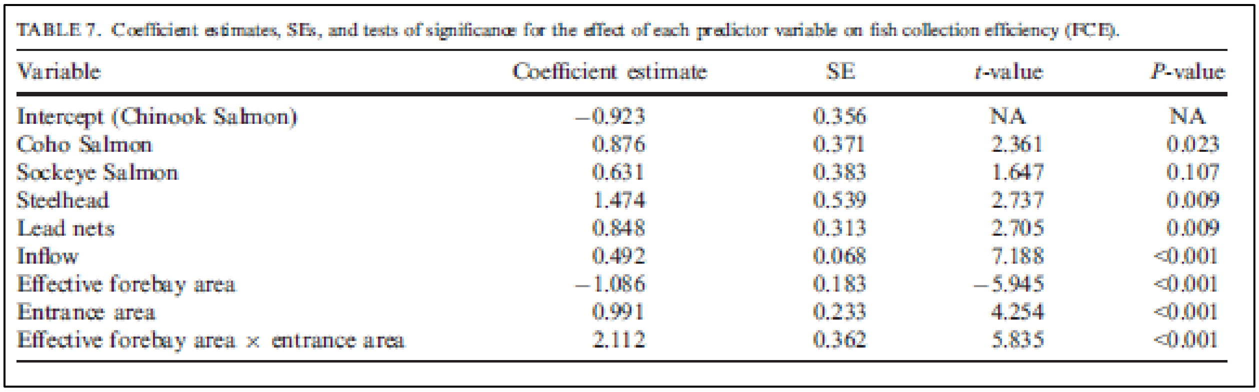


TABLE 7. Coefficient estimates, SEs, and tests of significance for the effect of each predictor variable on fish collection efficiency (FCE).

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, when dam 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

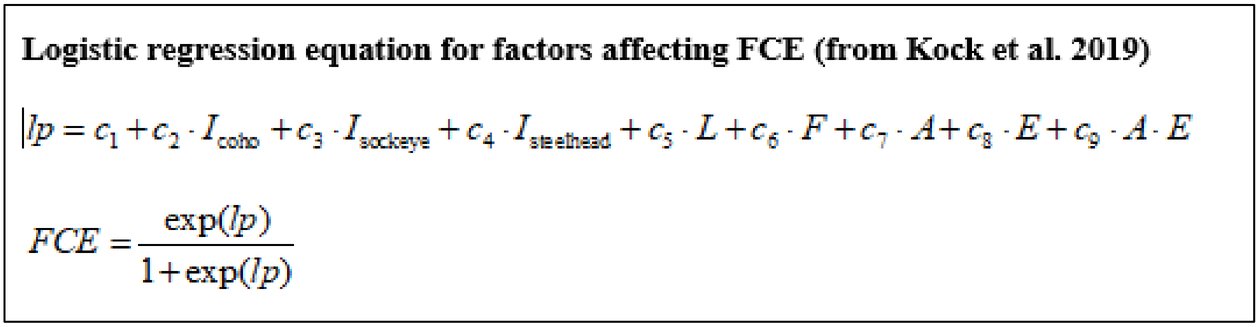
Notes: 1. Estimated dimensions for FSS entrances, minimum, and maximum outflow capacities based on turbine capacities and the relationship between entrance size and inflows.

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 1-8. 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.

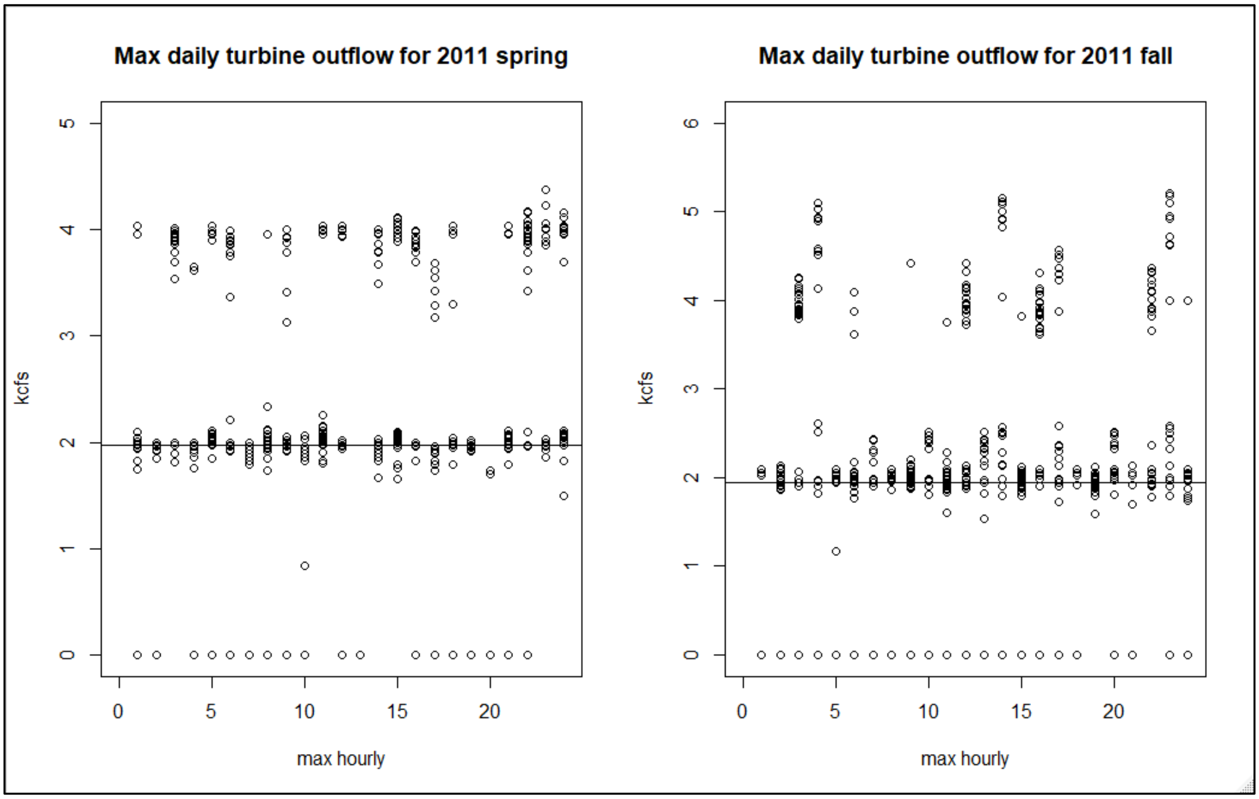


Figure 1-9. Detroit Median Hourly Spring and Fall Outflows in Abundant Water Years. *Median hourly outflows from Detroit for an abundant water year type (2011) in spring (left) and fall (right). The open dots represent the median hourly outflow. The solid line represents the median outflow for all data 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

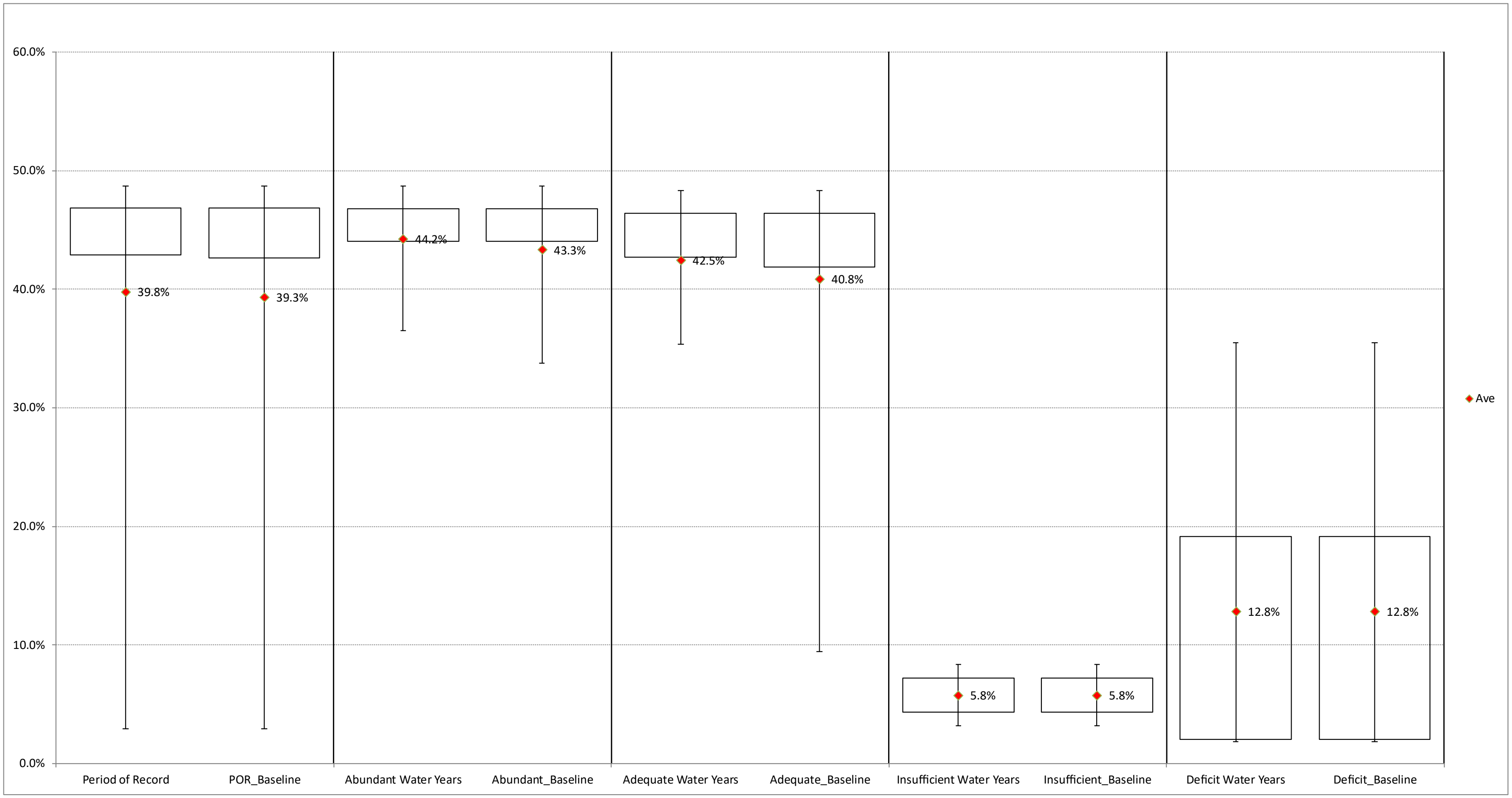


Figure 2-1. Detroit Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Detroit for juvenile spring Chinook fry under the No Action Alternative. The mean is given by the point*

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

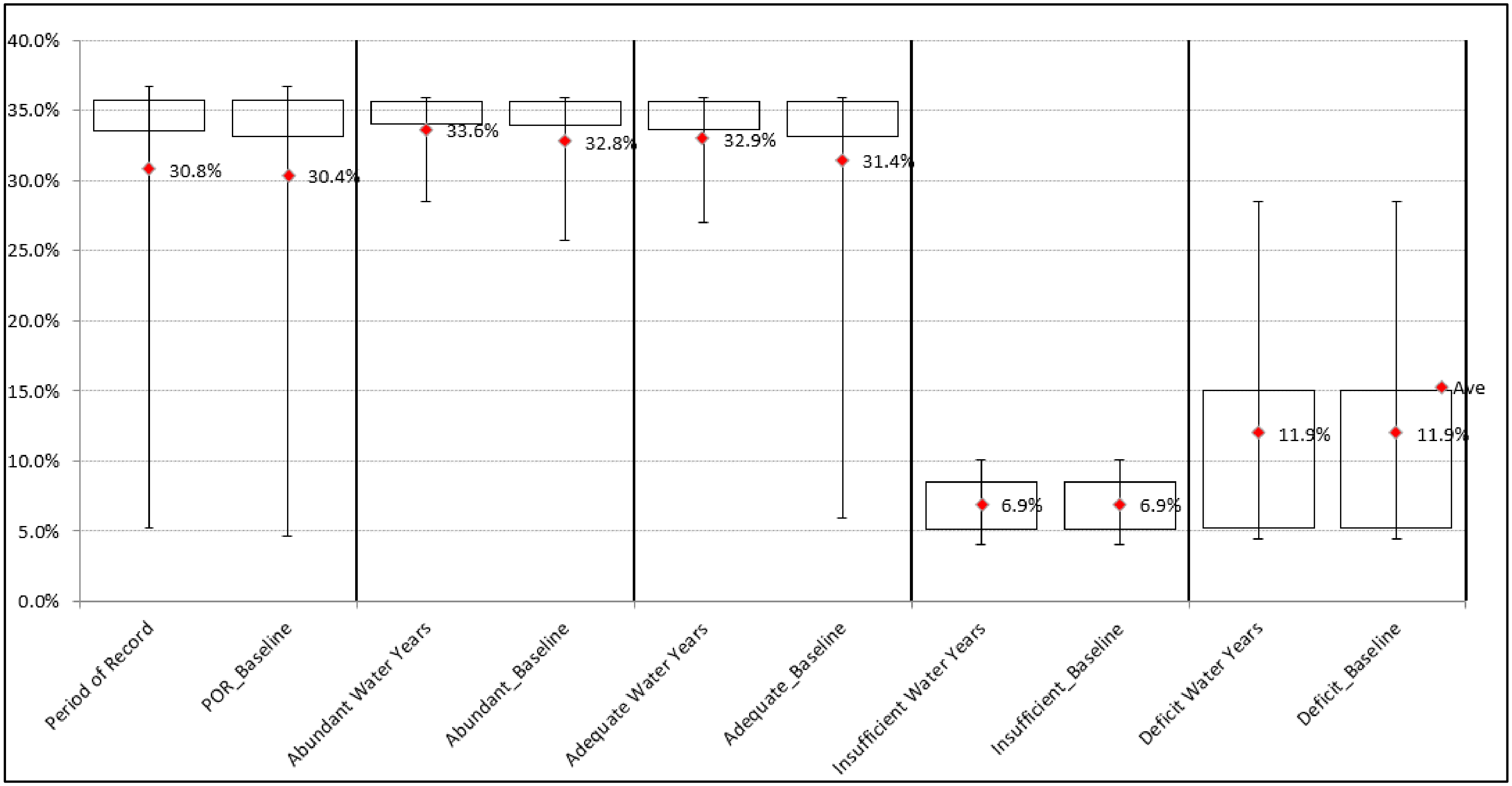


Figure 2-2. Detroit Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Detroit for juvenile spring Chinook sub-yearlings under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival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

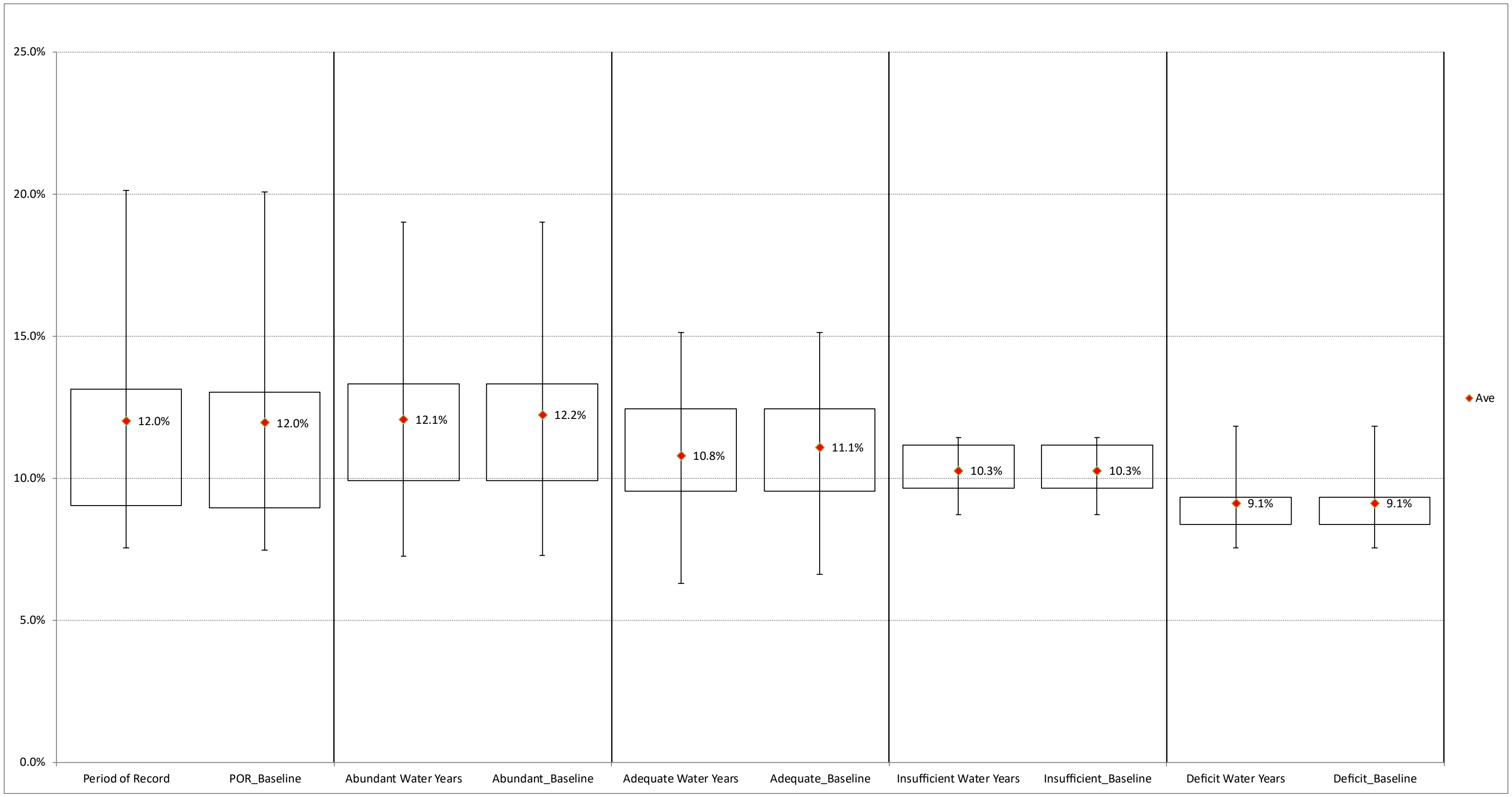


Figure 2-3. Detroit Juvenile Spring Chinook Yearlings Downstream Dam Passage Survival Under the No Action Alternative*.* *Downstream dam passage survival at Detroit for juvenile spring Chinook yearlings under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities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

2.1.2 South Santiam - Foster

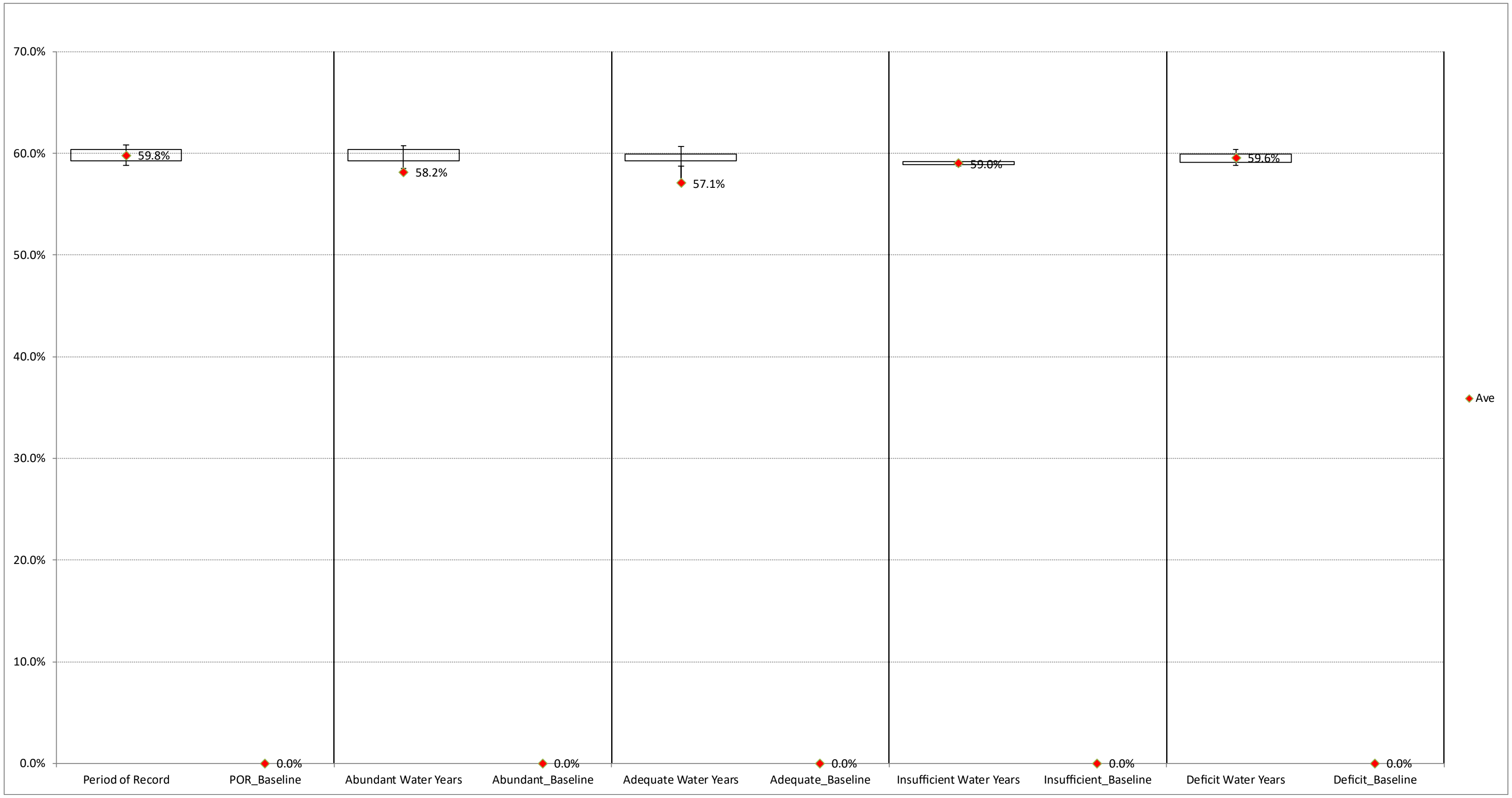


Figure 2-4. Foster Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Foster for juvenile spring Chinook fry under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities are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

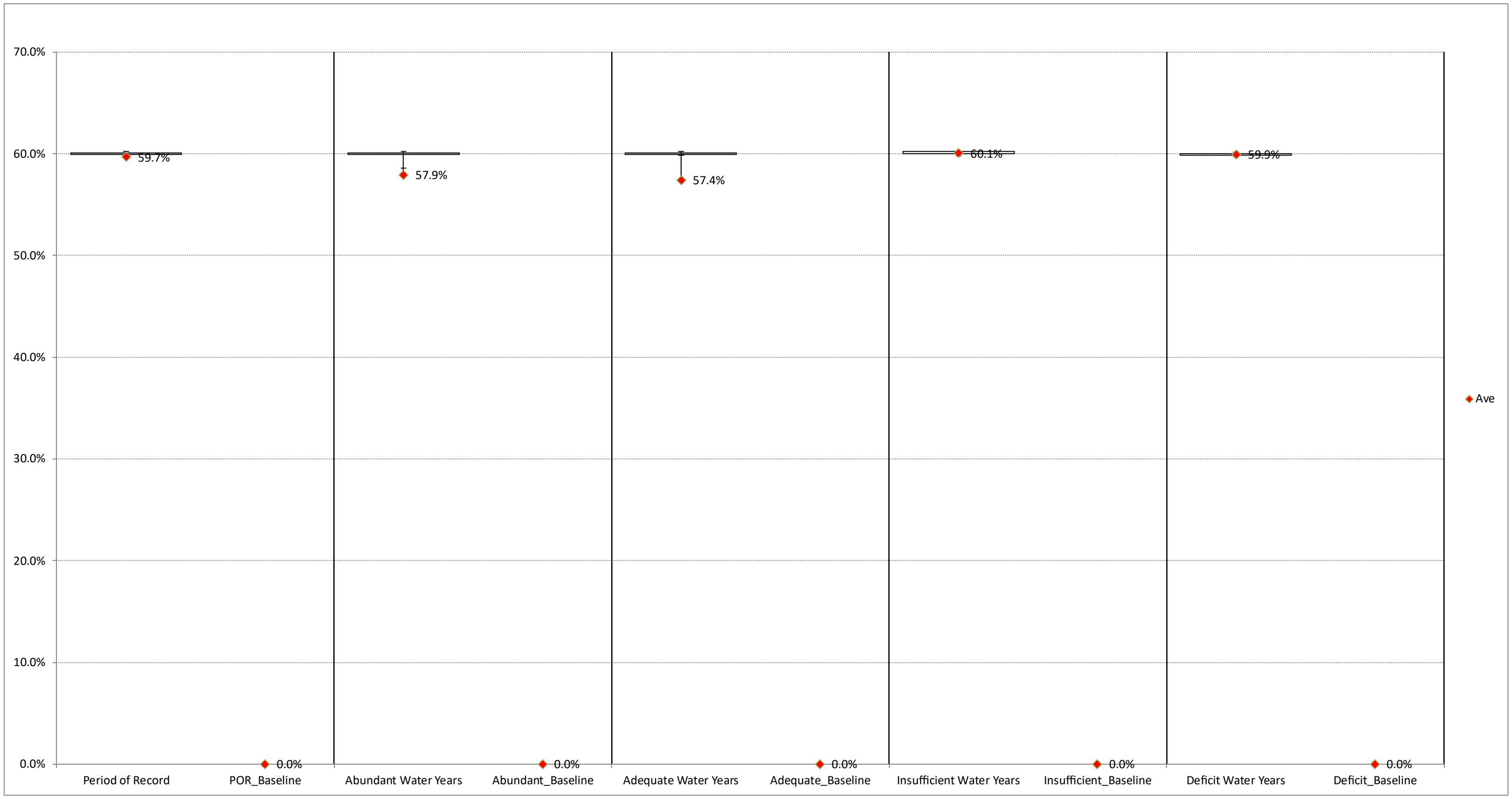


Figure 2-5. Foster Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Foster for juvenile spring Chinook sub-yearlings under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival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

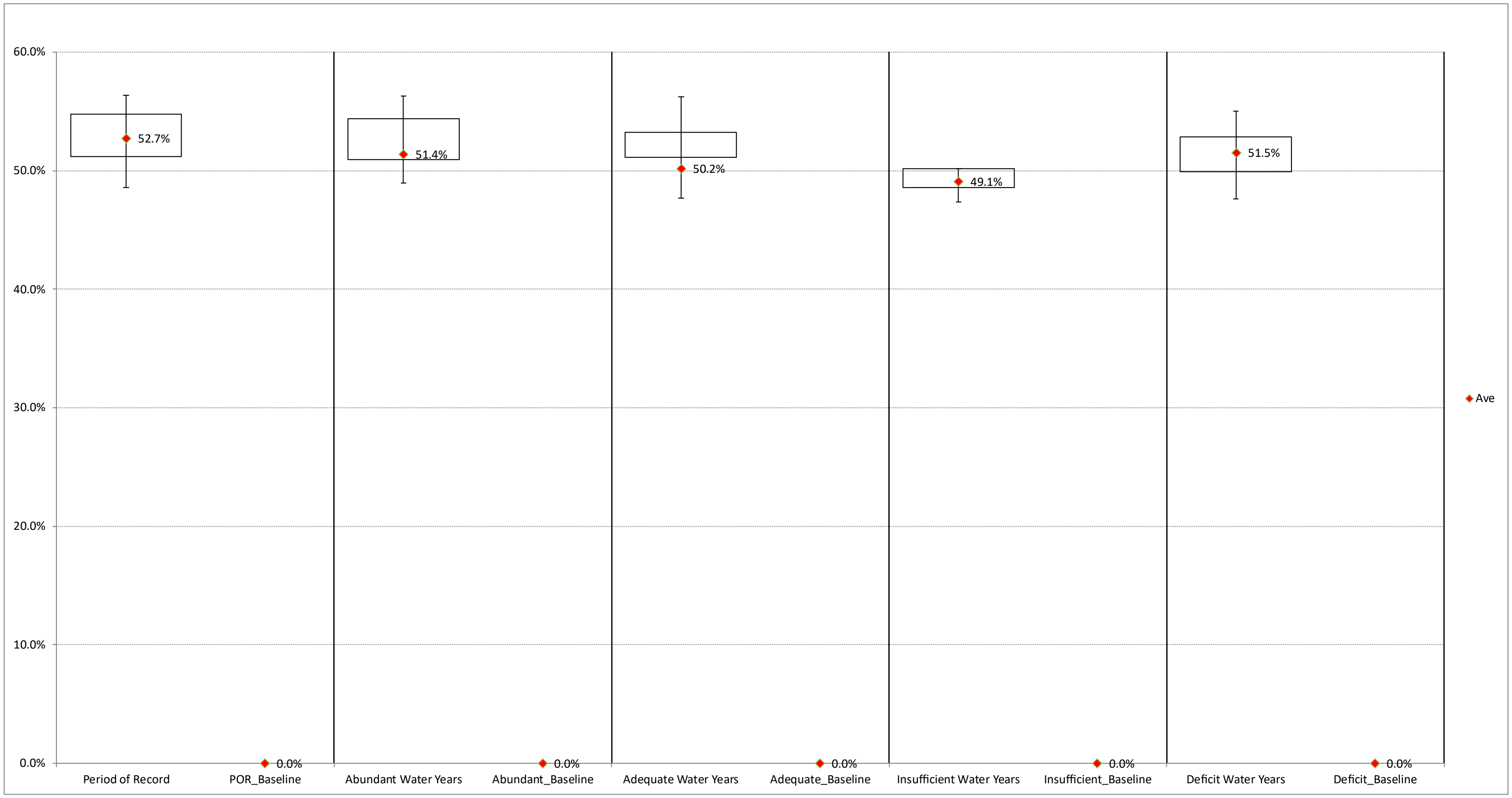


Figure 2-6. Foster Juvenile Spring Chinook Yearlings Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Foster for juvenile spring Chinook yearlings under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities 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

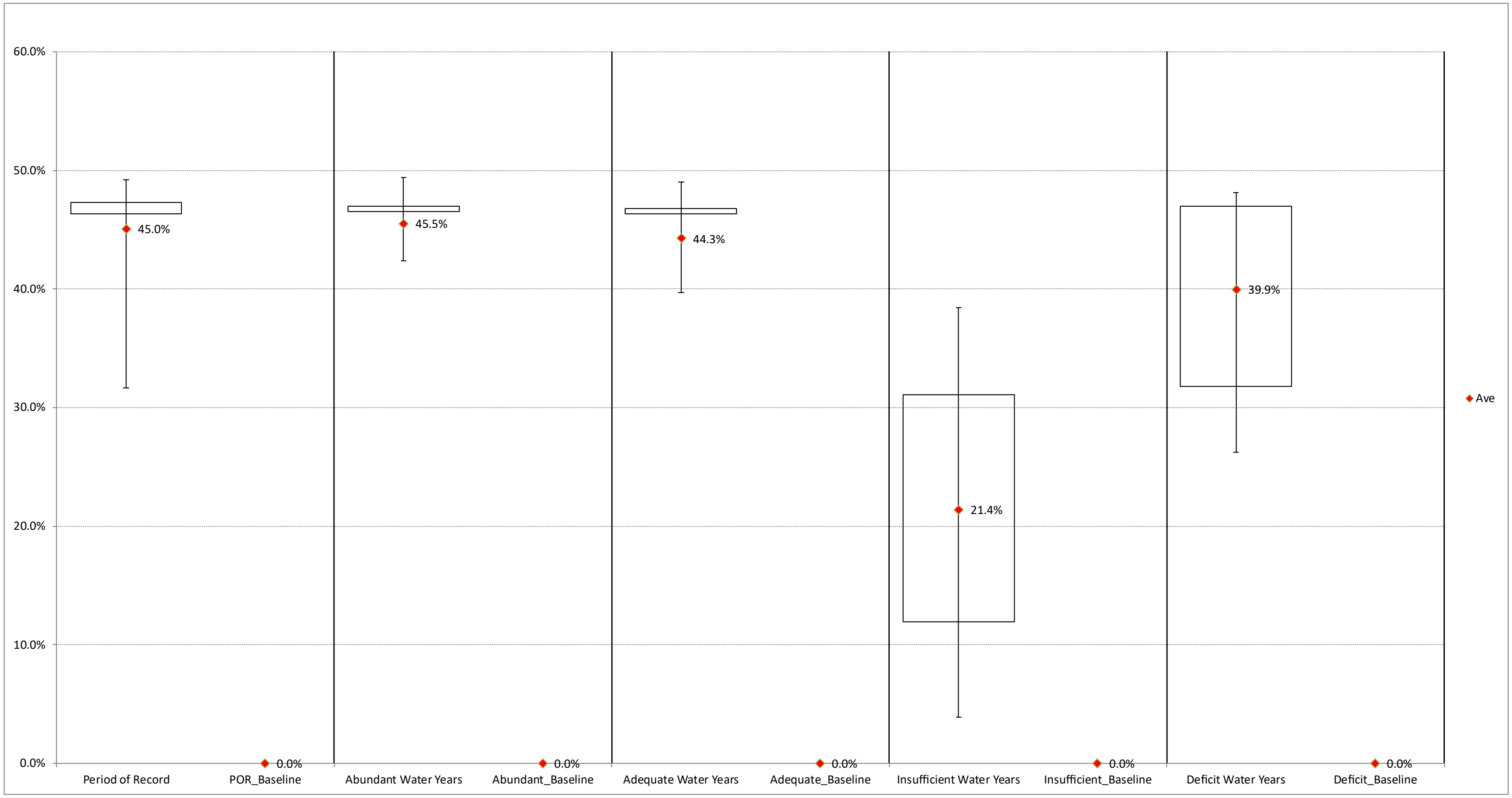


Figure 2-7. Green Peter Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Green Peter for juvenile spring Chinook fry under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities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

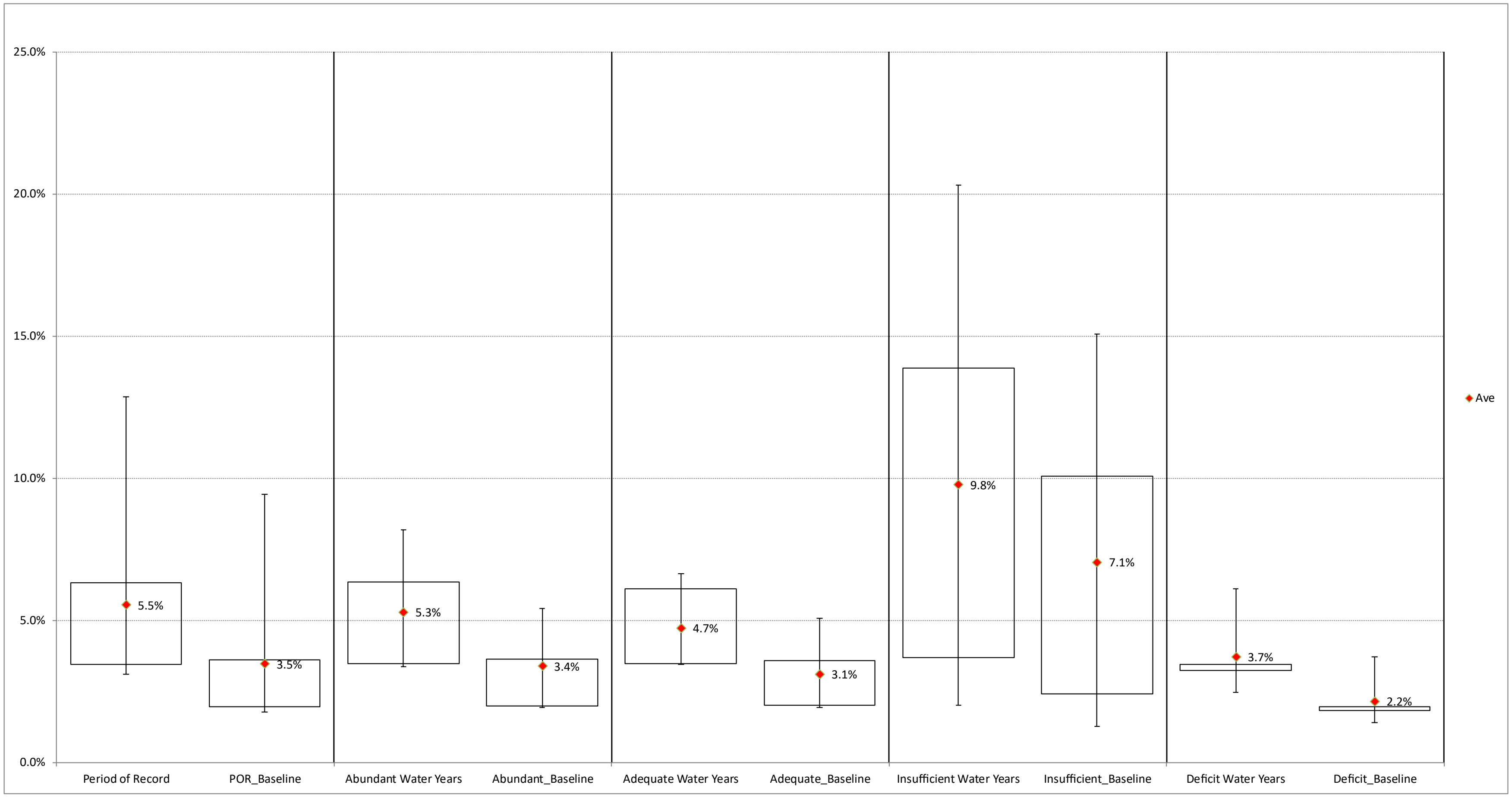


Figure 2-8. Green Peter Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Green Peter for juvenile spring Chinook sub-yearlings under the No Action Alternative. The mean is given by the point estimate (filled dot).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

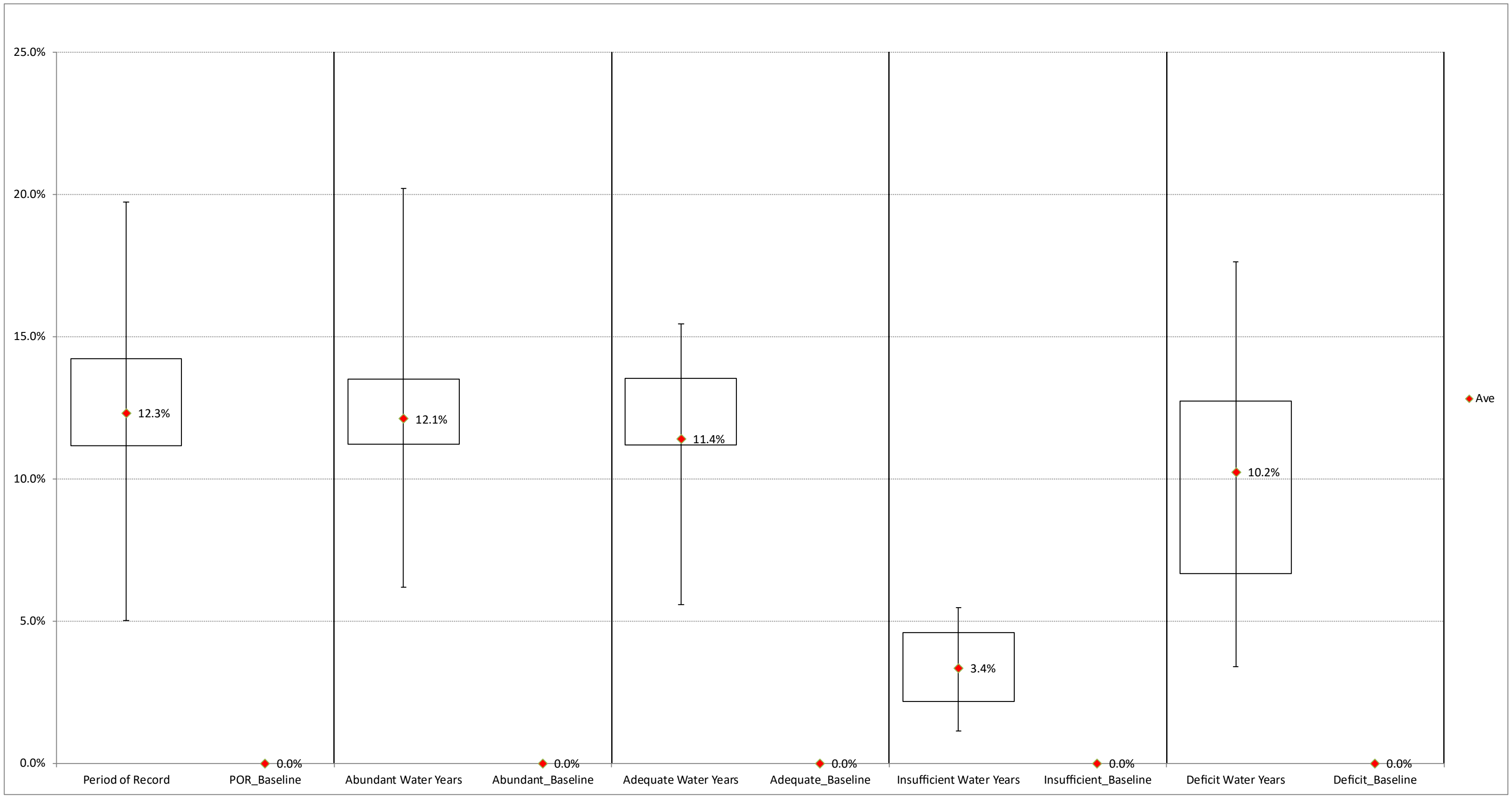


Figure 2-9. Green Peter Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Green Peter for juvenile spring Chinook yearlings under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival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

2.1.4 McKenzie – Cougar

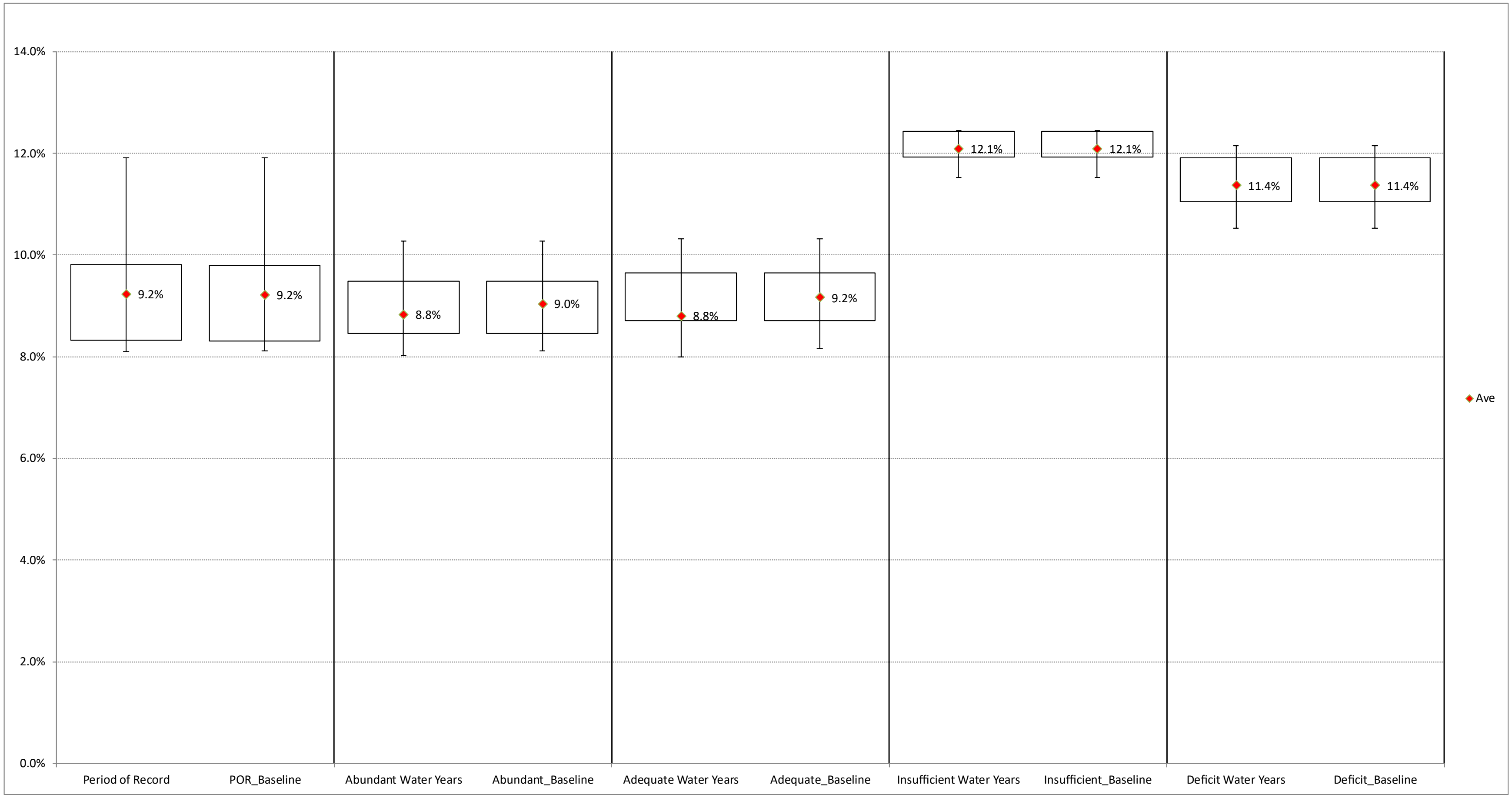


Figure 2-10. Cougar Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Cougar for juvenile spring Chinook fry under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities are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

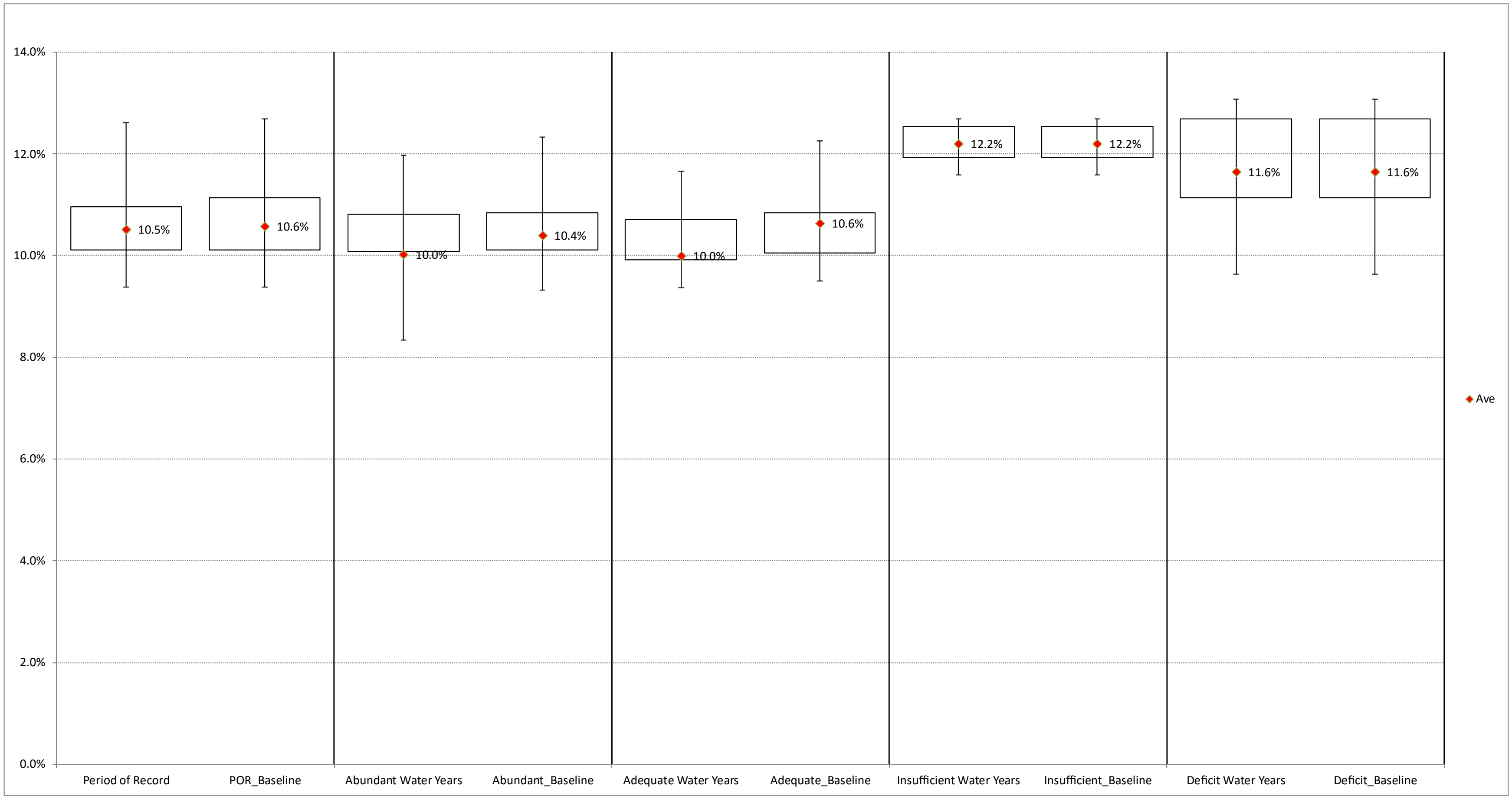


Figure 2-11. Cougar Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Cougar for juvenile spring Chinook sub-yearlings under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival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

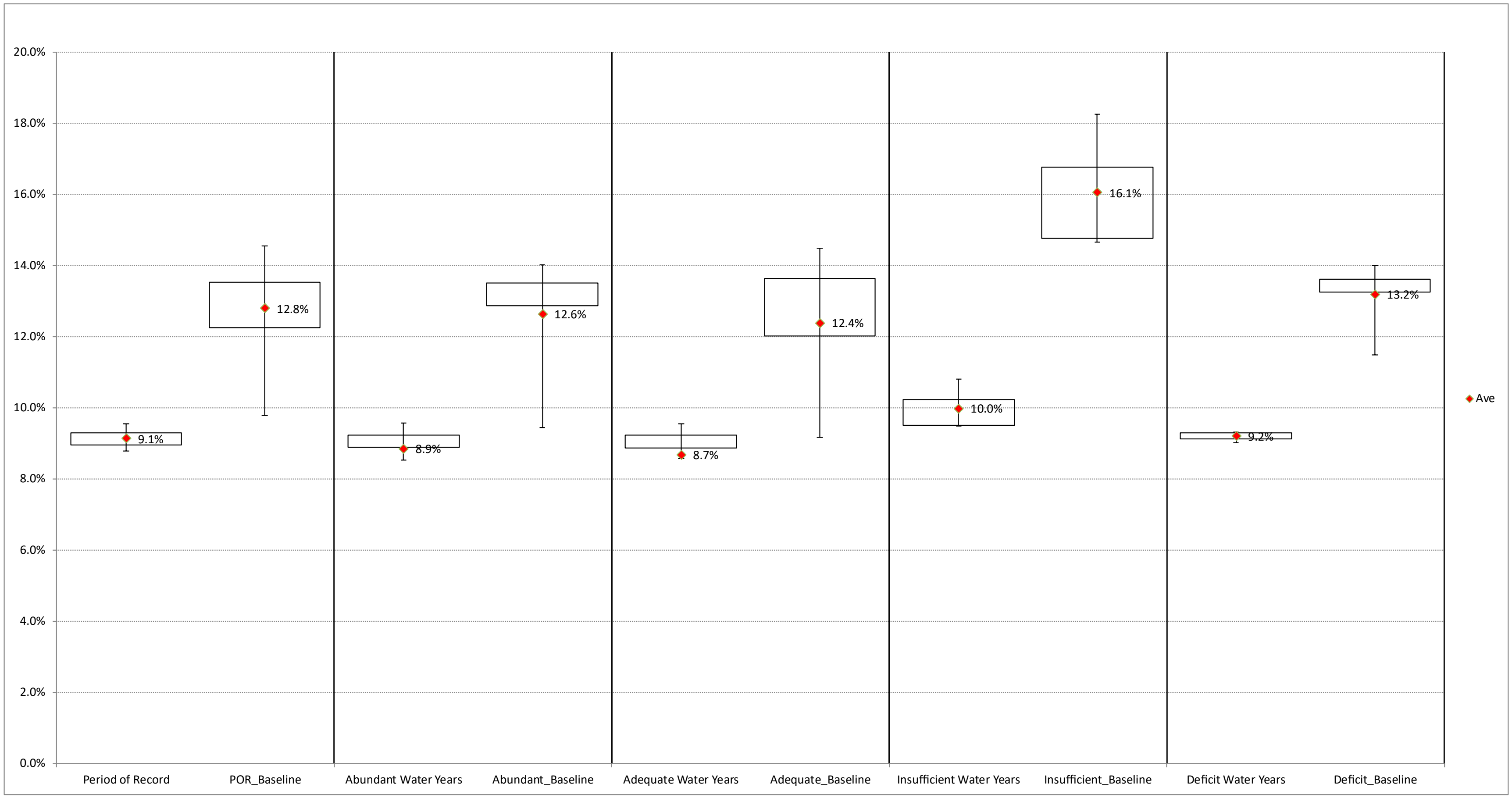


Figure 2-12. Cougar Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Cougar for juvenile spring Chinook yearlings under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities 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

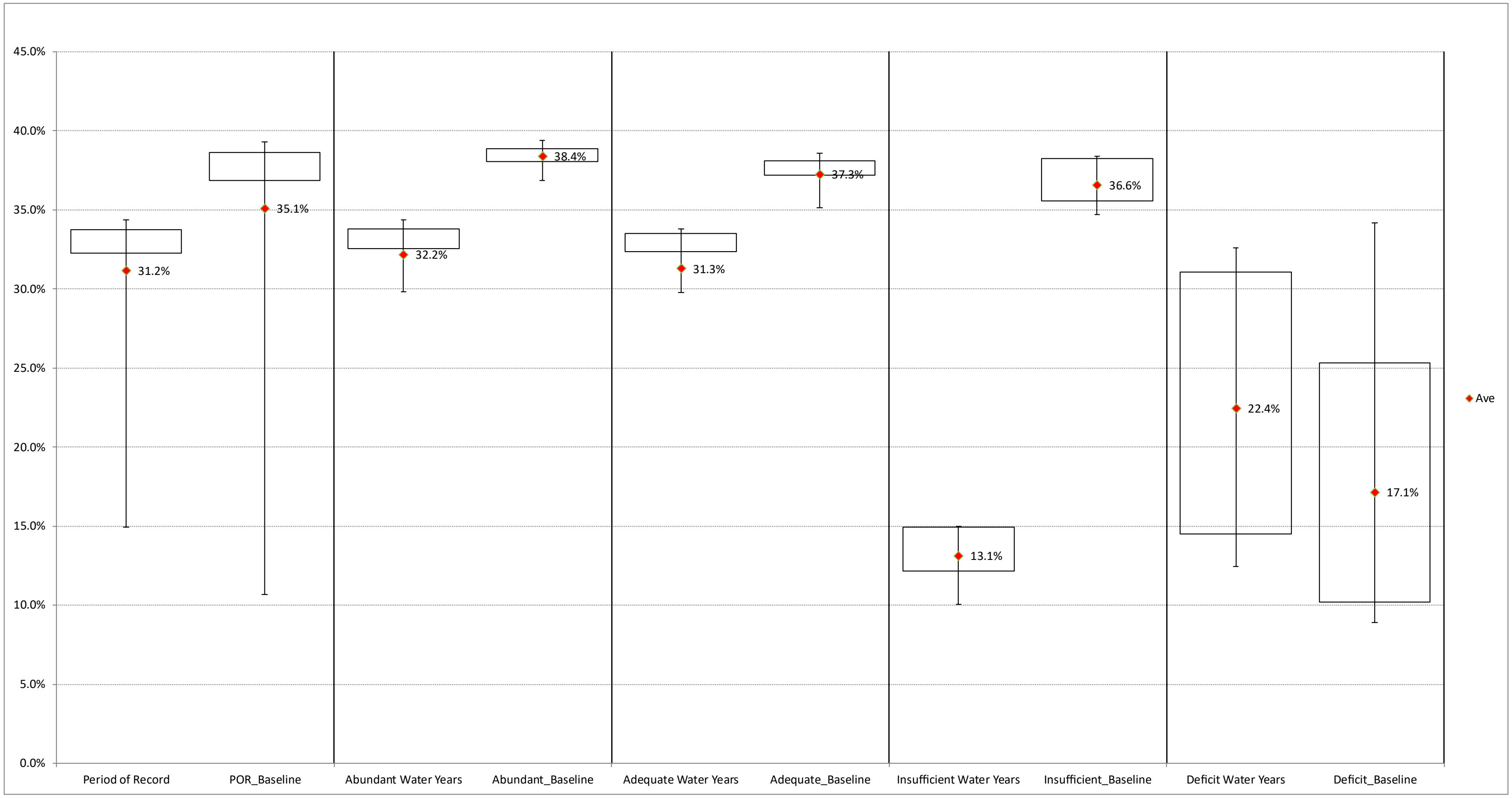


Figure 2-13. Lookout Point Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook fry under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival probabilities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

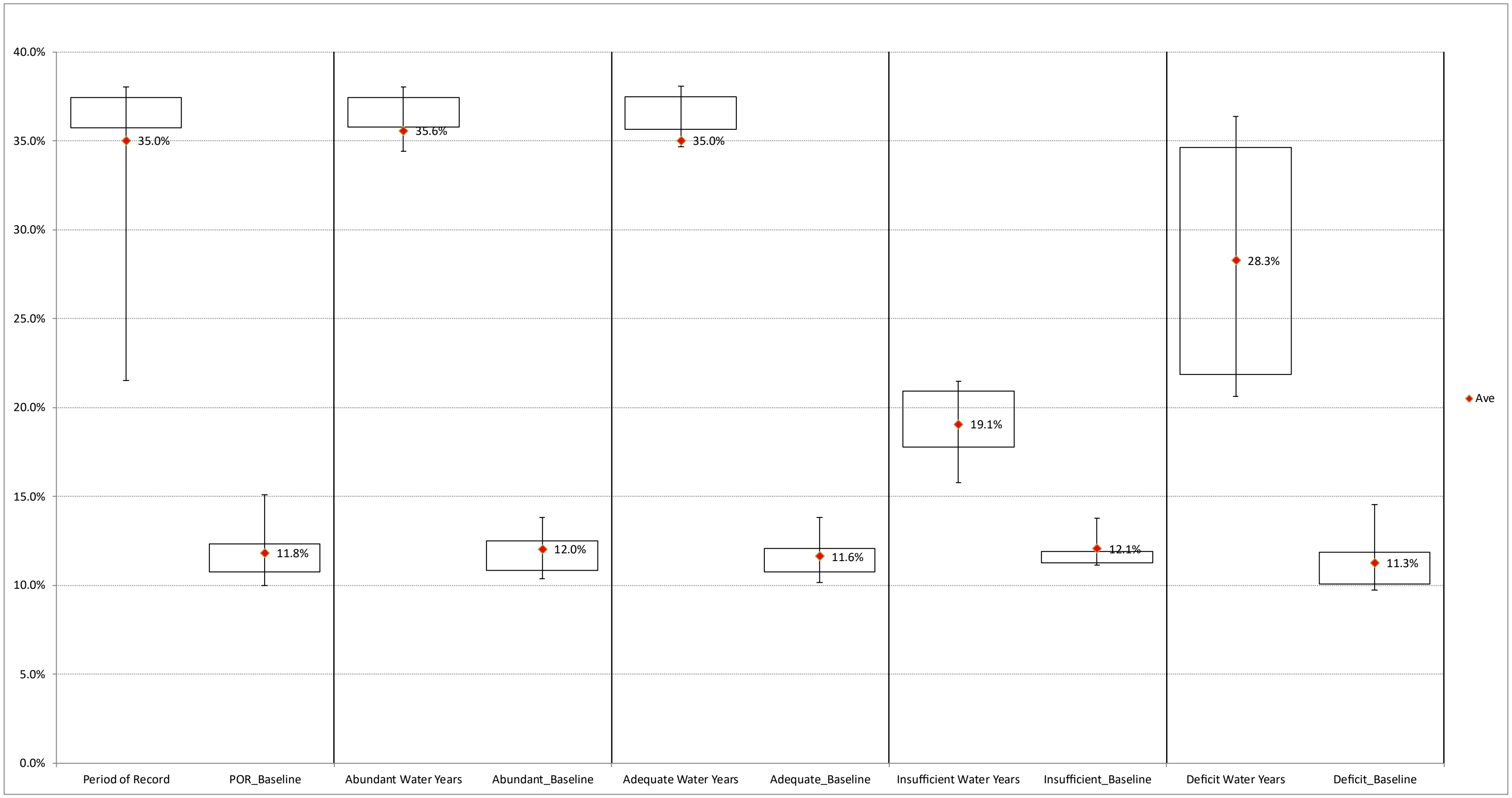


Figure 2-14. Lookout Point Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook sub-yearlings under the No Action Alternative. The mean is given by the point estimate (filled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

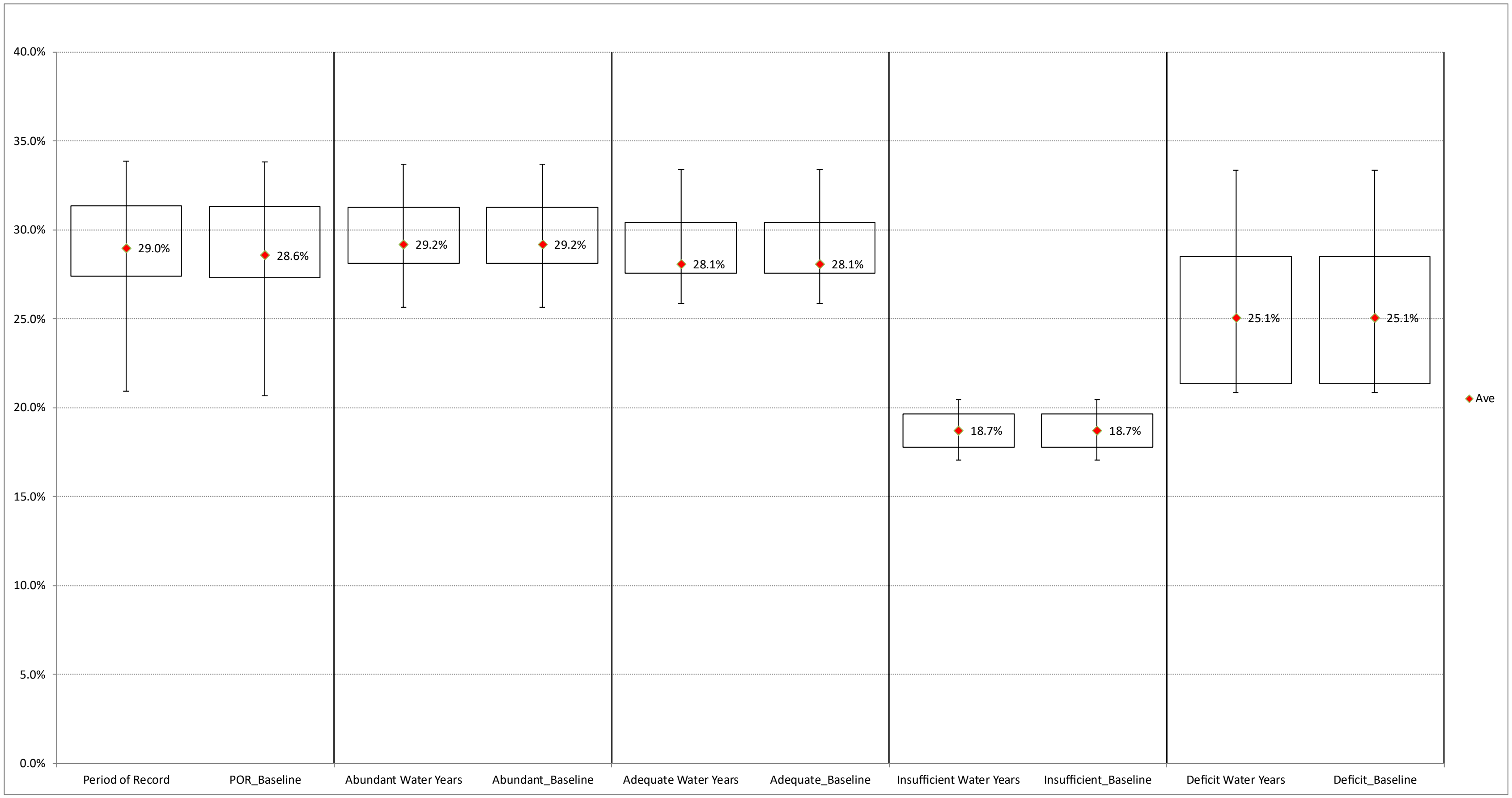


Figure 2-15. Lookout Point Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook yearlings under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival 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

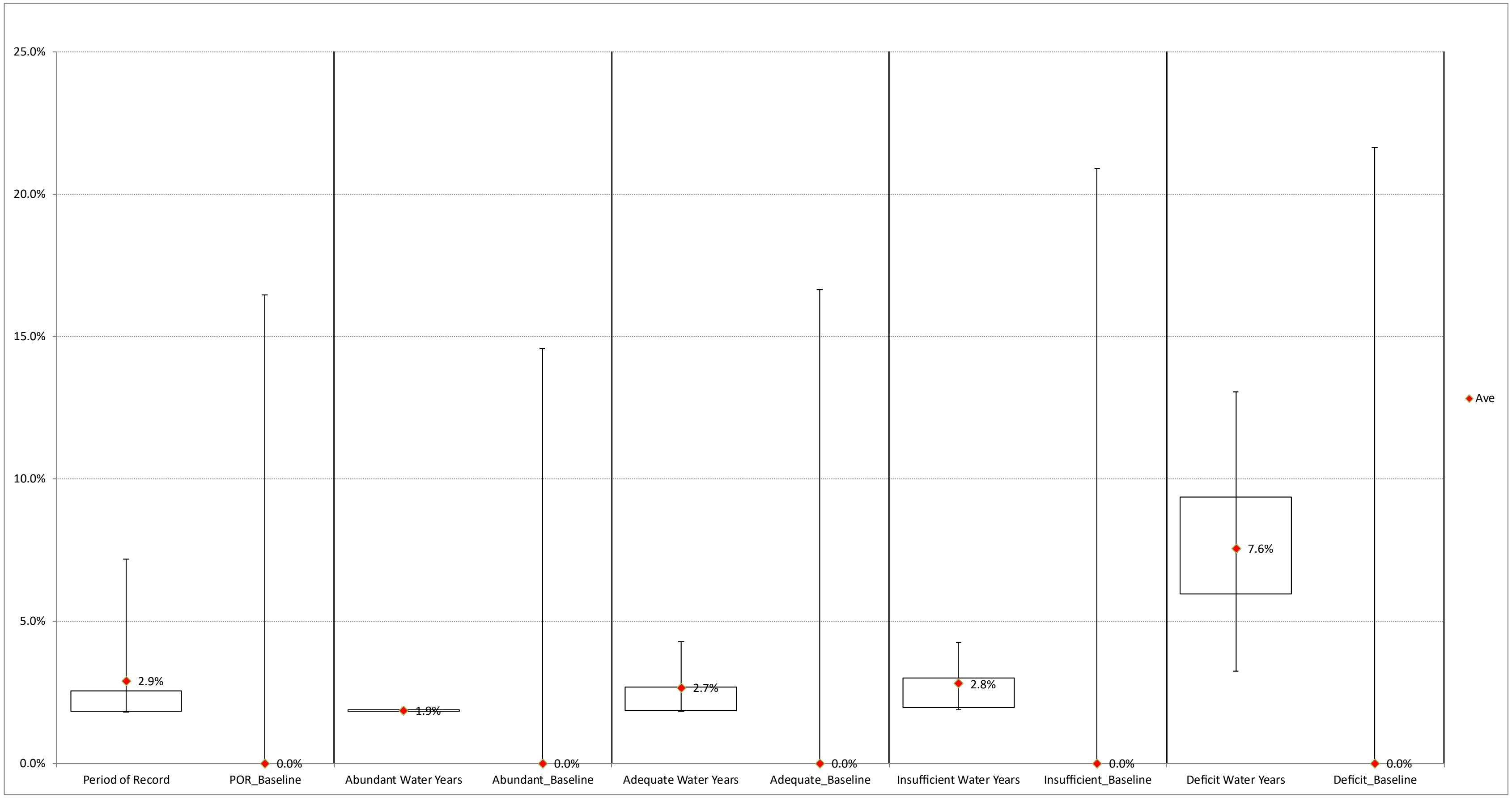


Figure 2-16. Downstream dam passage survival at Hills Creek for juvenile spring Chinook fry under the No Action Alternative. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook fry under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival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

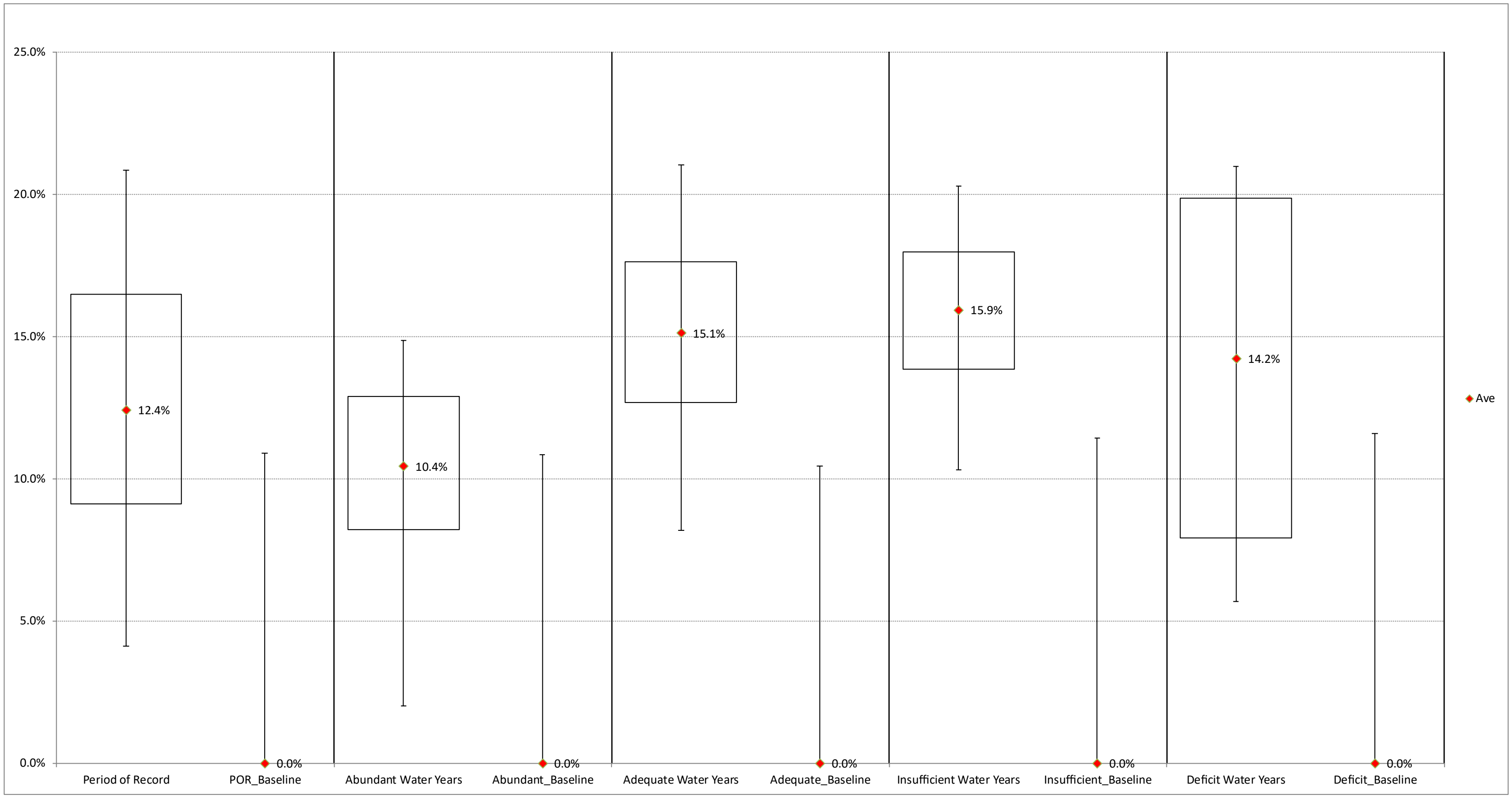


Figure 2-17. Hills Creek Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook sub-yearlings under the No Action Alternative. The mean is given by the point estimate (filled dot).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

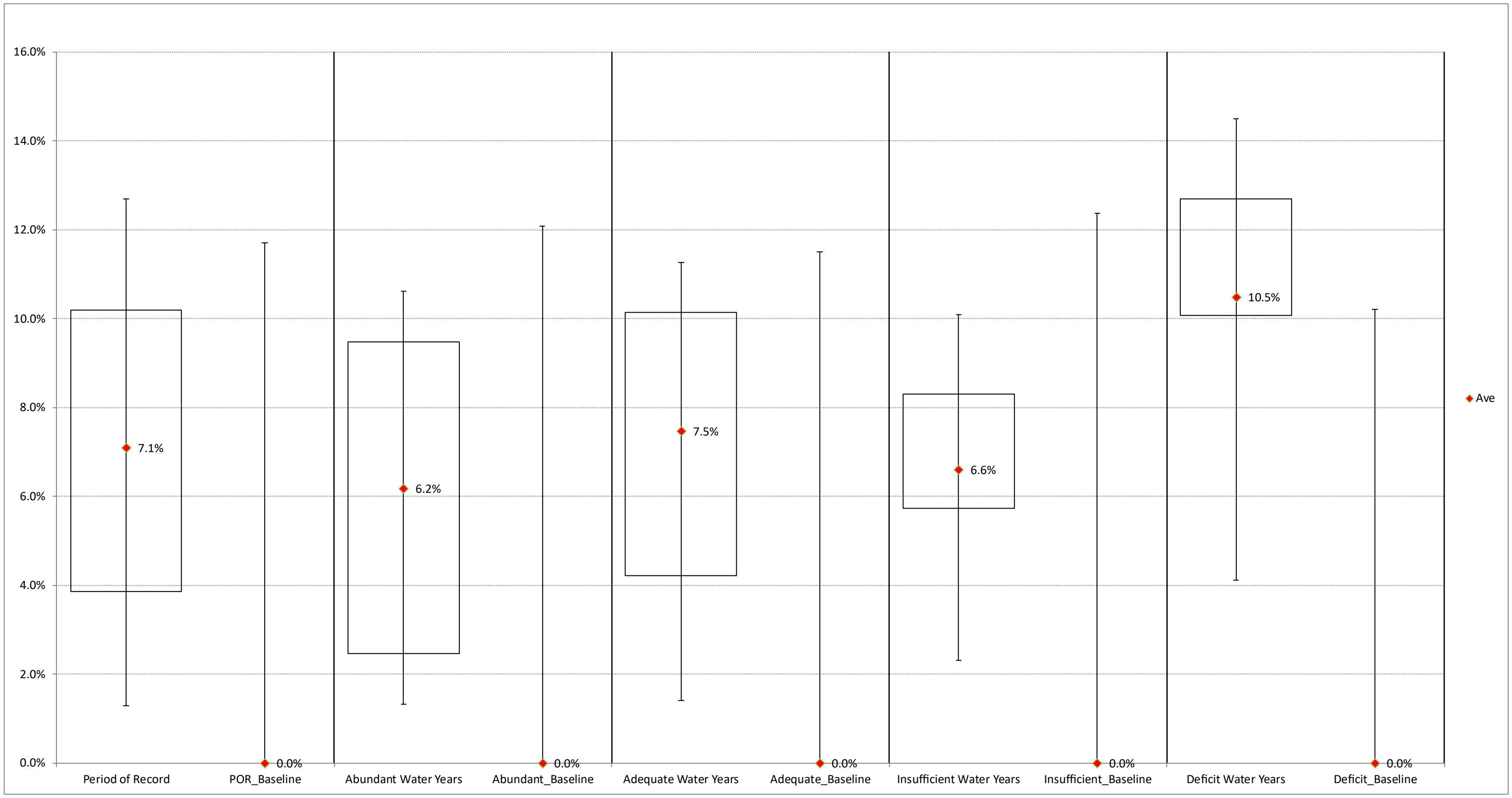


Figure 2-18. Hills Creek Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under the No Action Alternative. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook yearlings under the No Action Alternative. The mean is given by the point estimate (filled dot). Survival 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

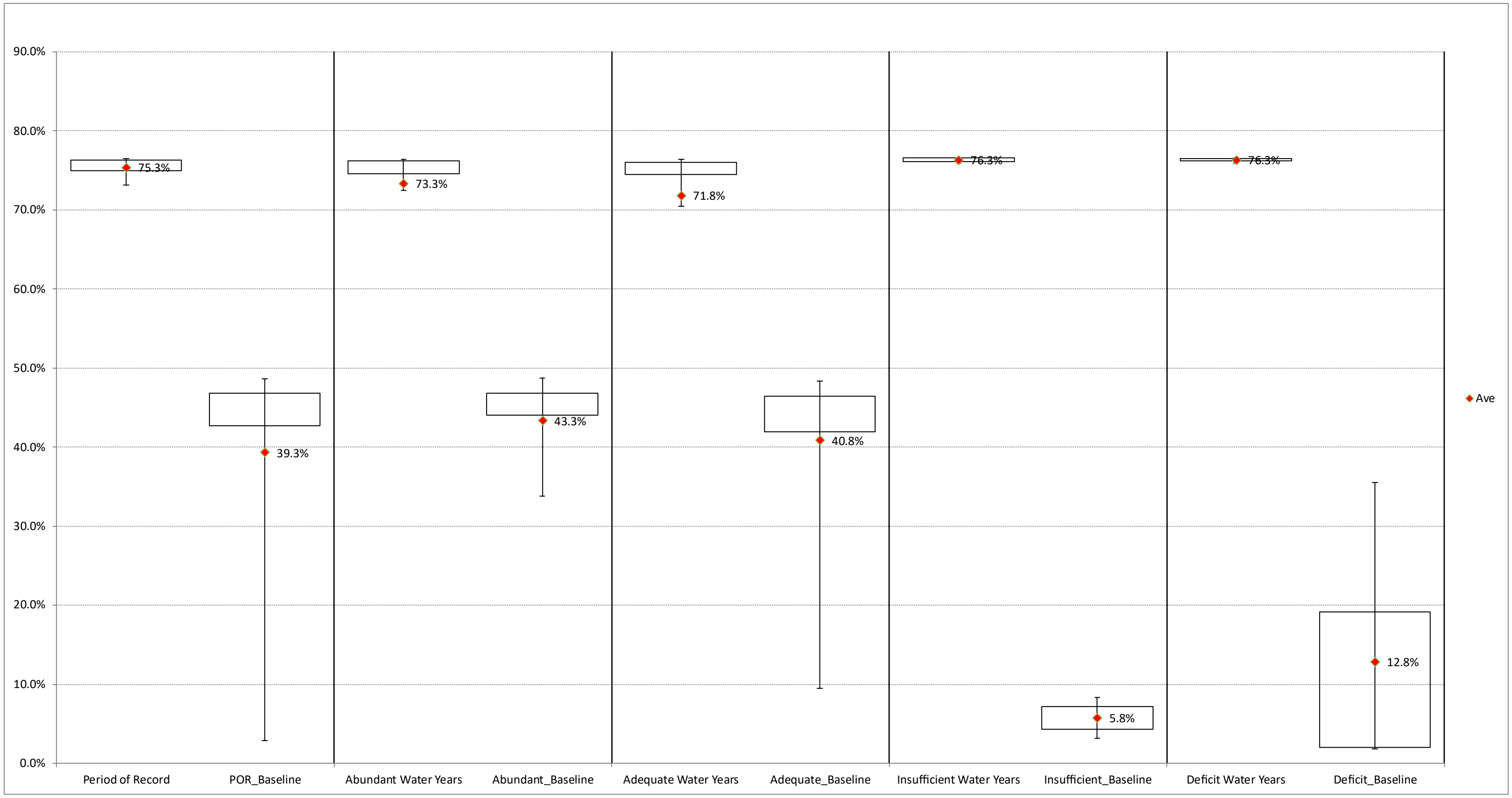


Figure 2-19. Detroit Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 1. *The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

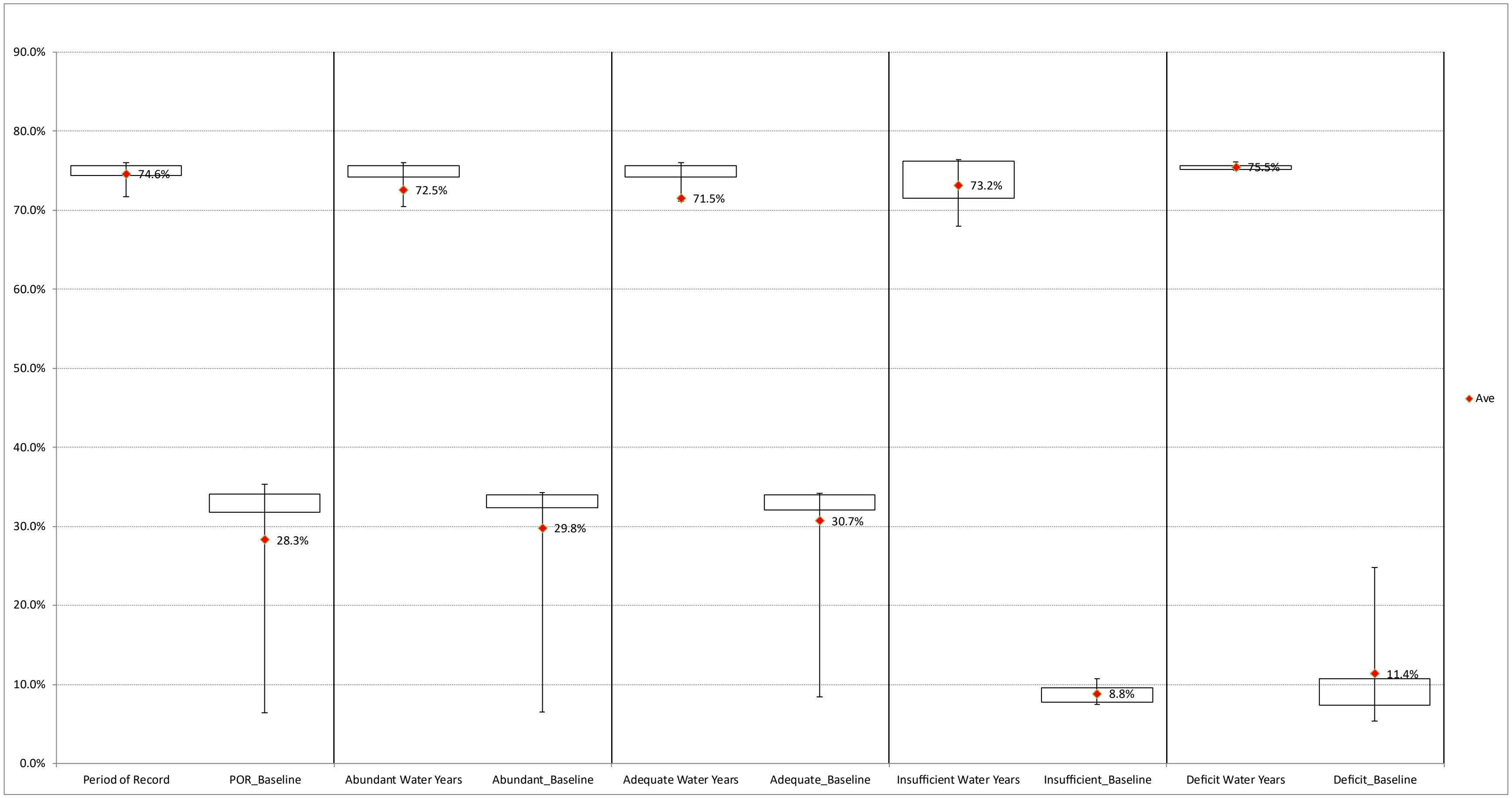


Figure 2-20. Detroit Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Detroit for juvenile spring Chinook sub-yearling under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given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

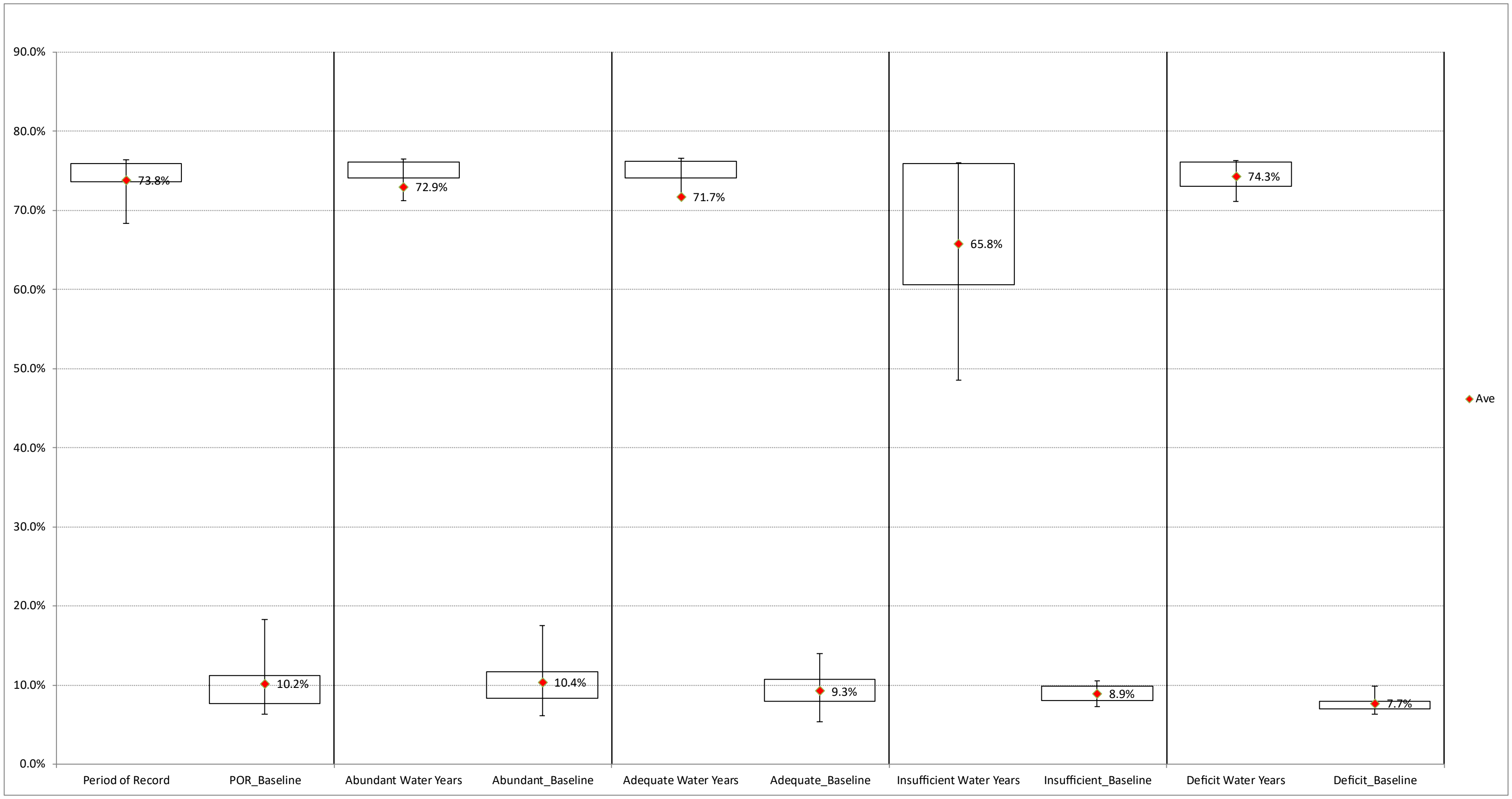


Figure 2-21. Detroit Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Detroit for juvenile spring Chinook yearling under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the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

2.2.2 South Santiam - Foster

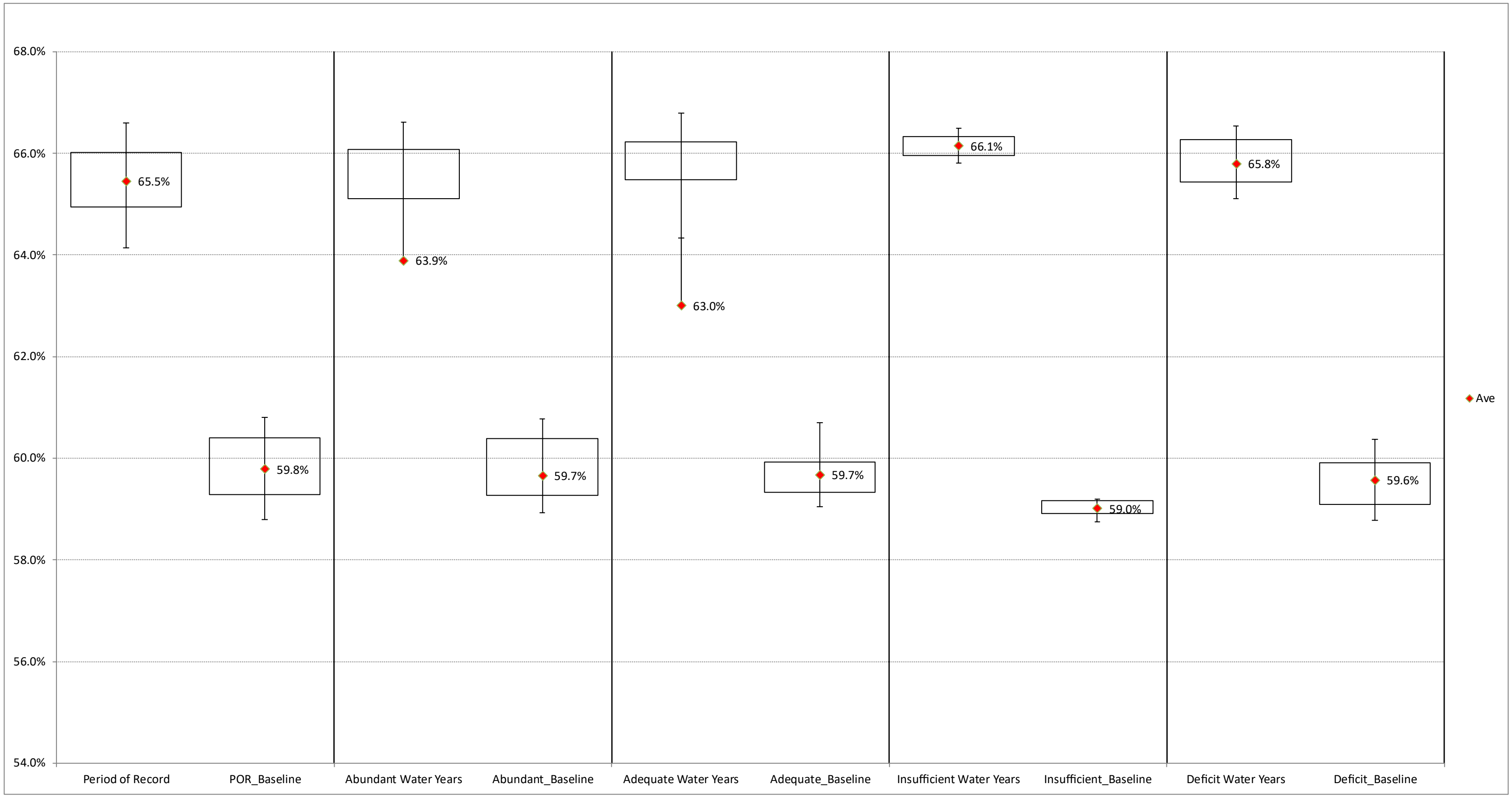


Figure 2-22. Foster juvenile spring Chinook fry Downstream dam passage survival under Alternative 1. *Downstream dam passage survival at Foster for juvenile spring Chinook fry under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of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

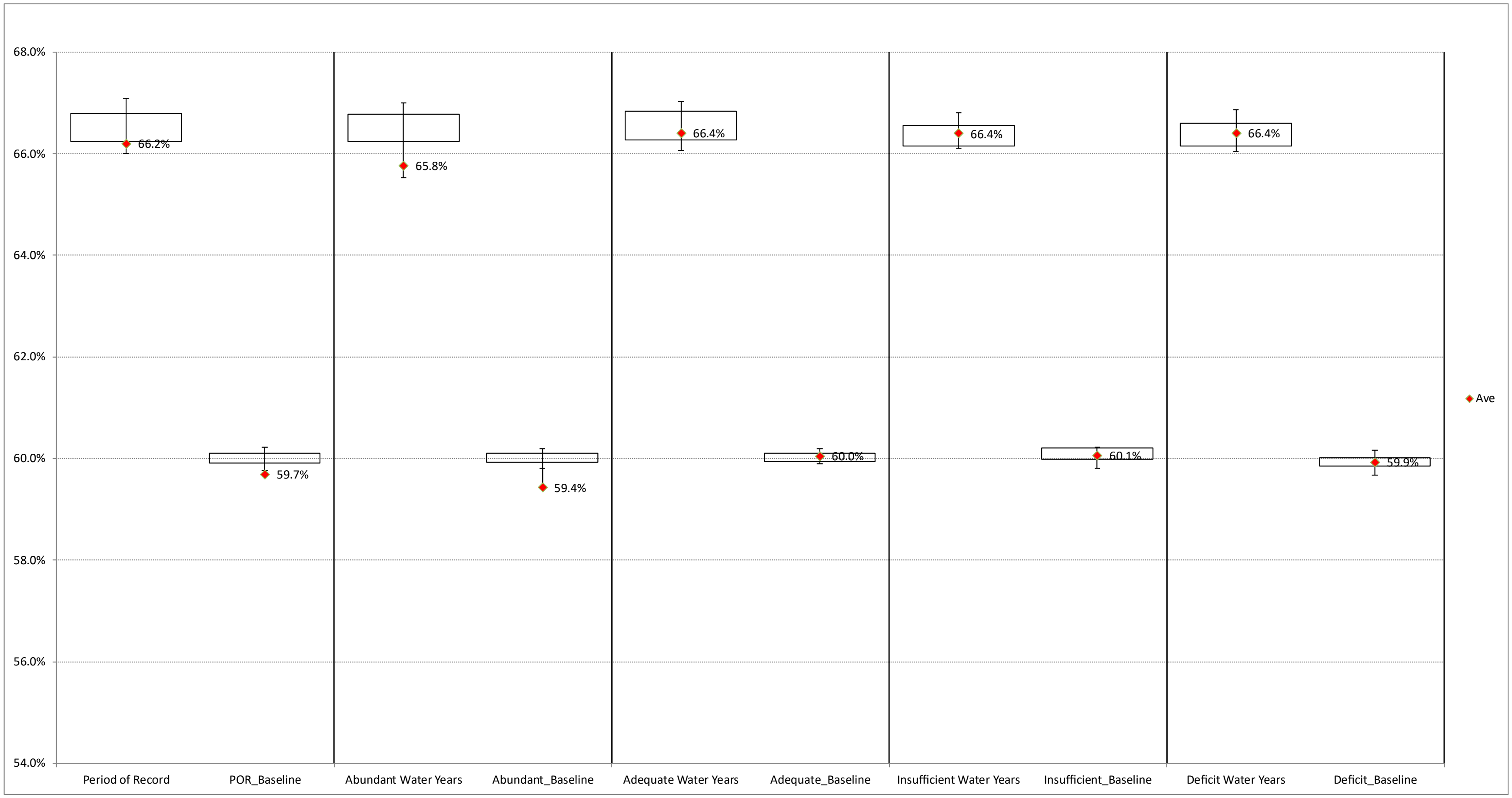


Figure 2-23. Foster Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Foster for juvenile spring Chinook sub-yearlings under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given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

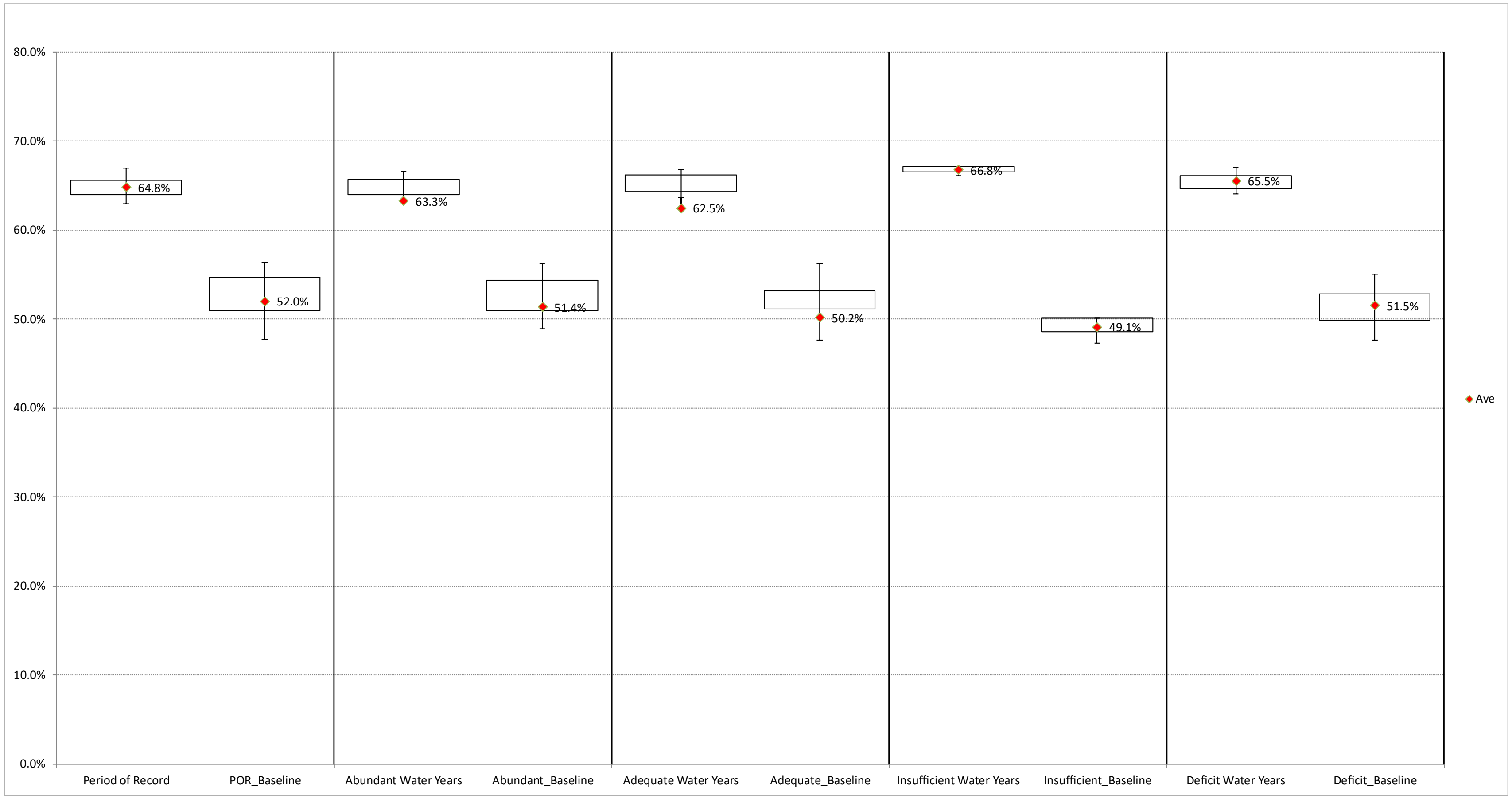


Figure 2-24. Foster Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Foster for juvenile spring Chinook yearlings under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the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

2.2.3 South Santiam – Green Peter

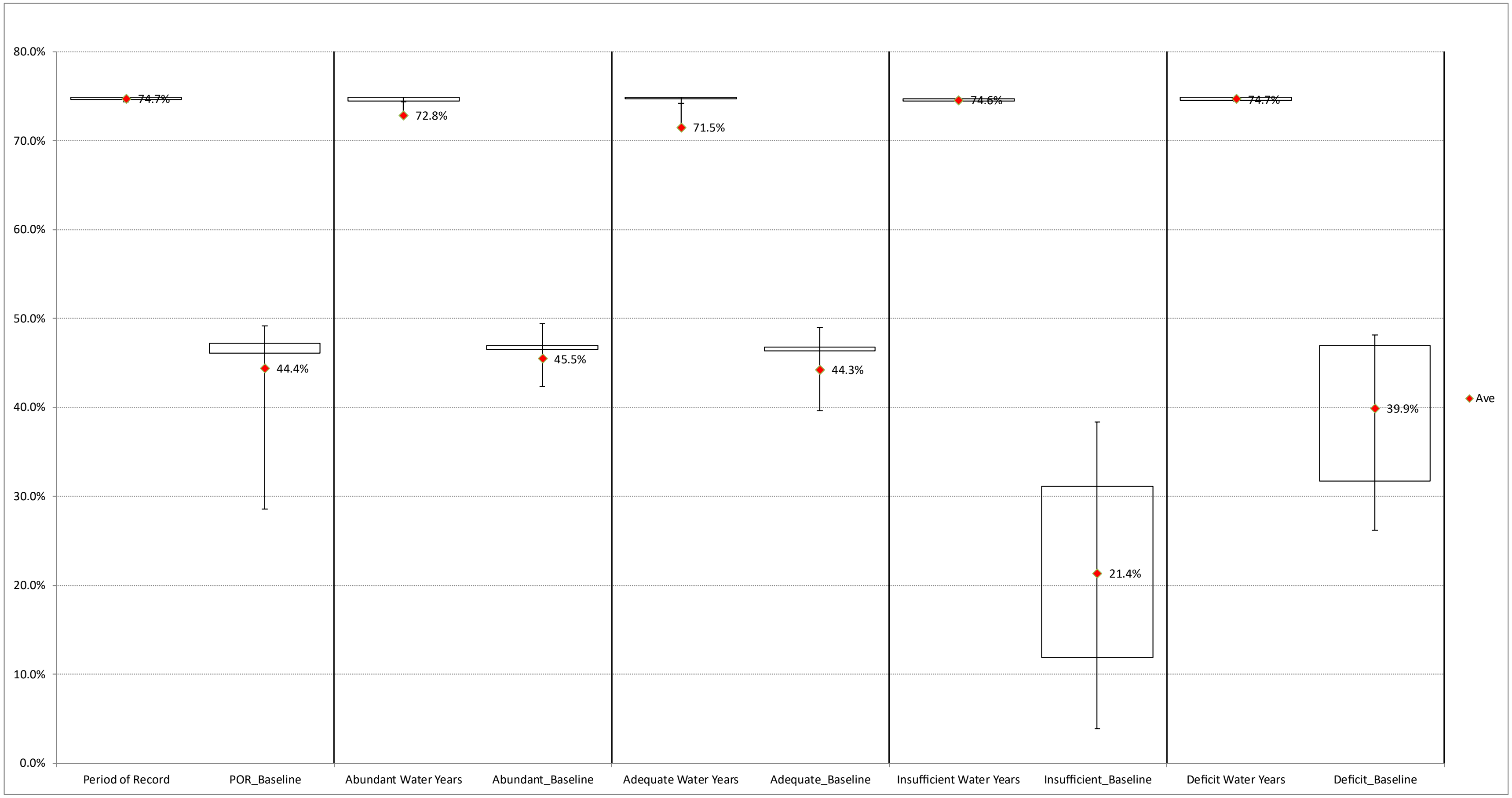


Figure 2-25. Green Peter Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Green Peter for juvenile spring Chinook fry under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the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

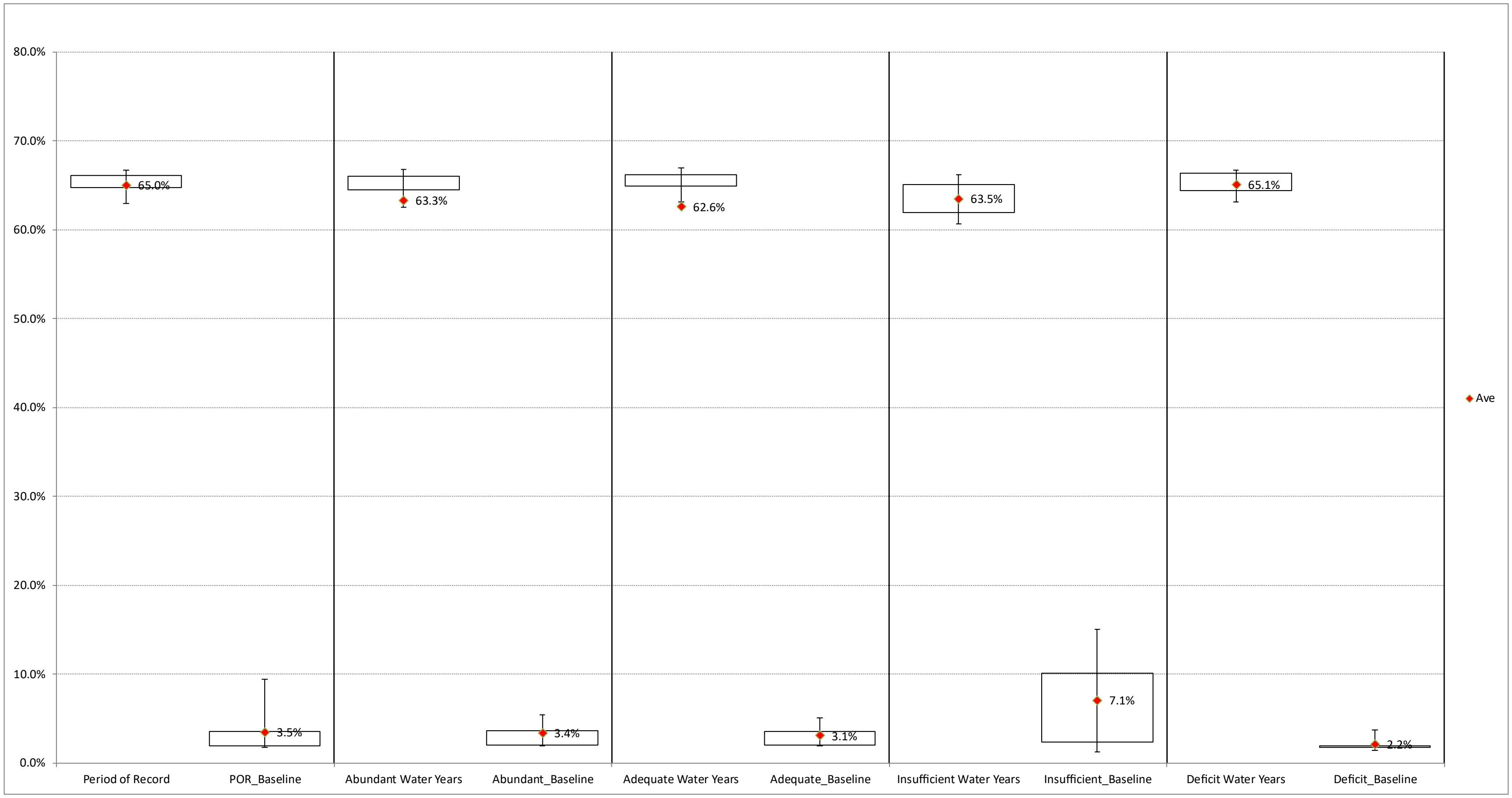


Figure 2-26. Green Peter Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Green Peter for juvenile spring Chinook sub-yearling under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities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

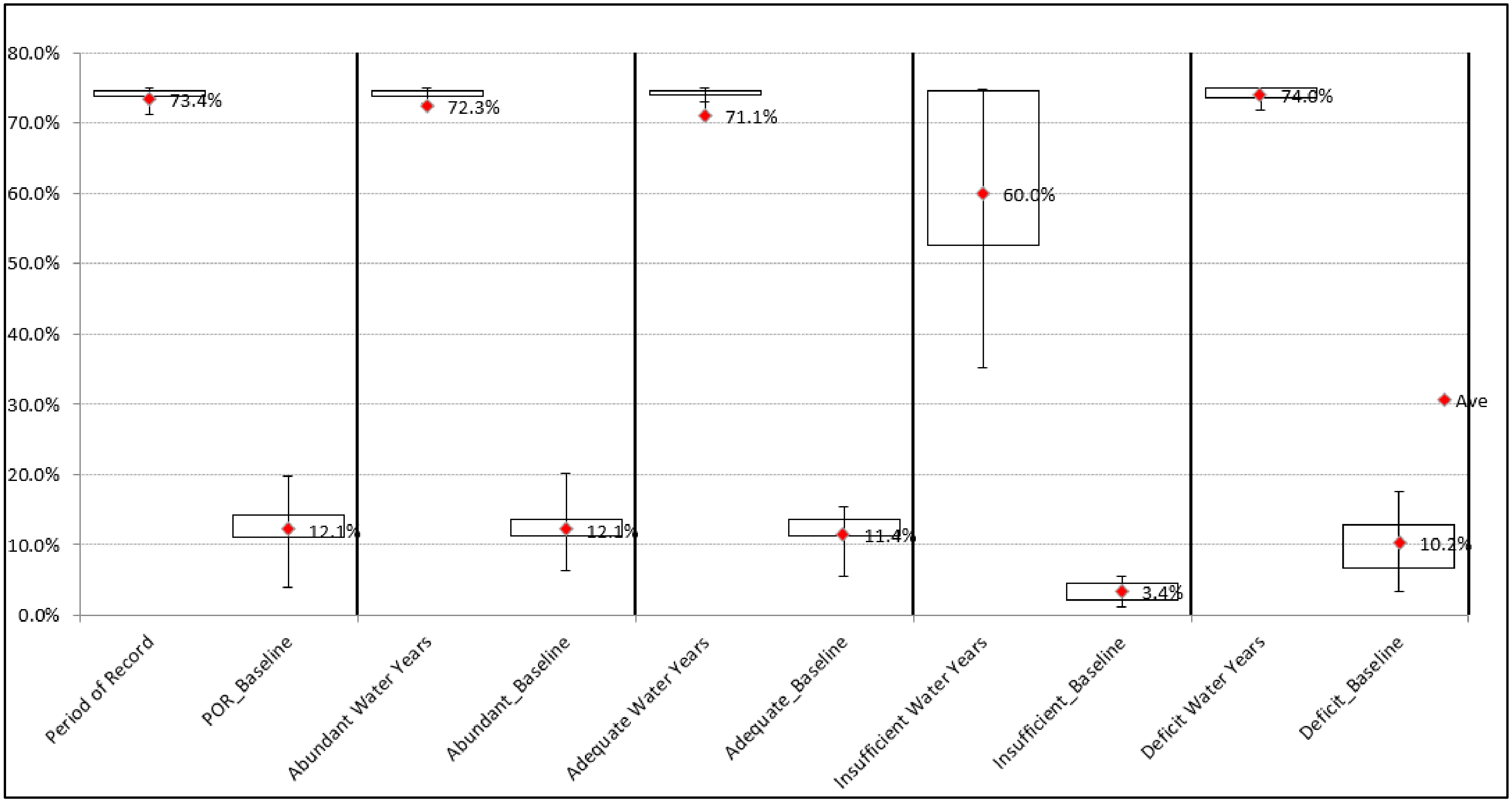


Figure 2-27. Green Peter Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Green Peter for juvenile spring Chinook yearling under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given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

2.2.4 McKenzie – Cougar

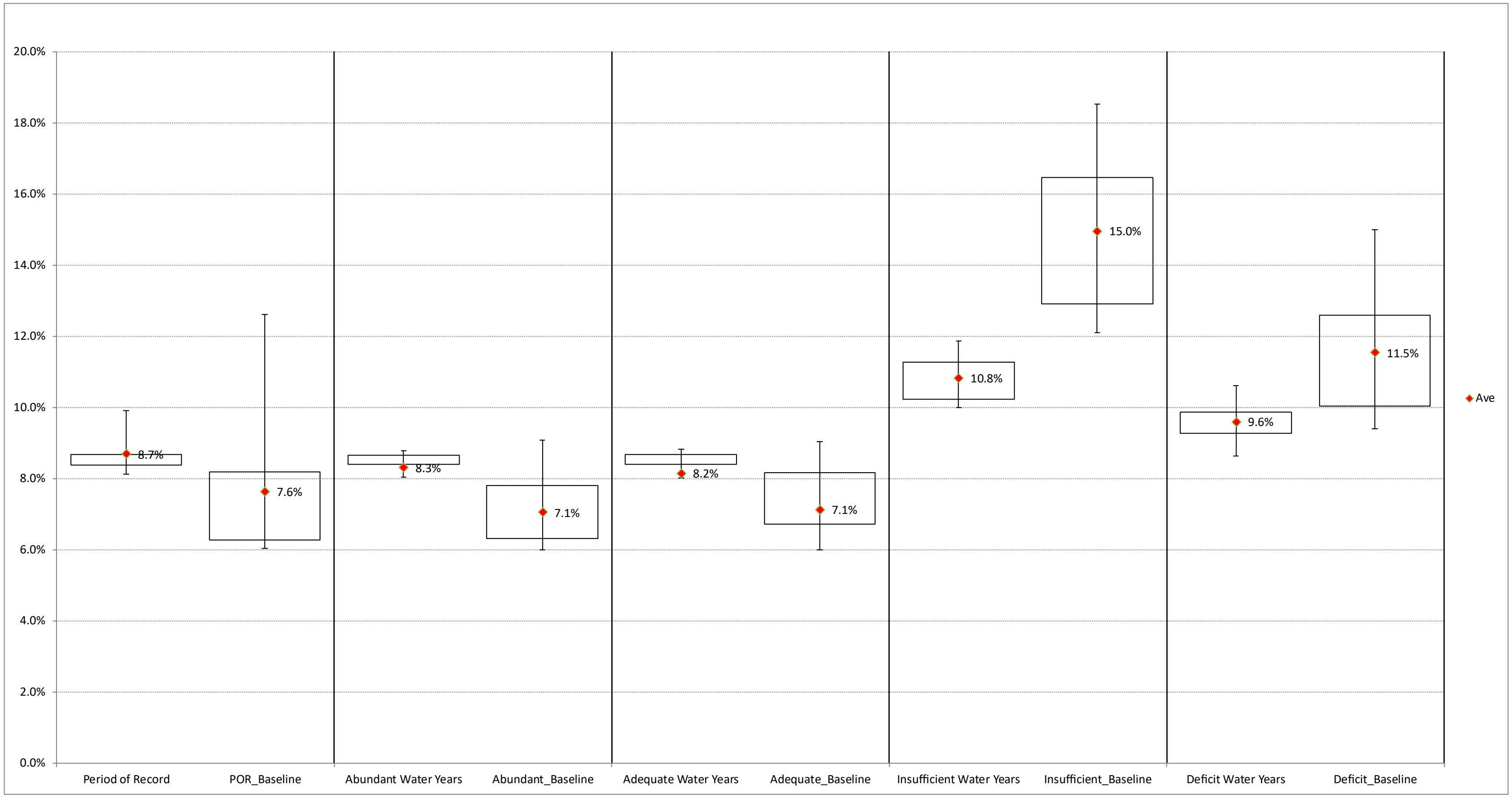


Figure 2-28. Cougar Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Cougar for juvenile spring Chinook fry under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of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

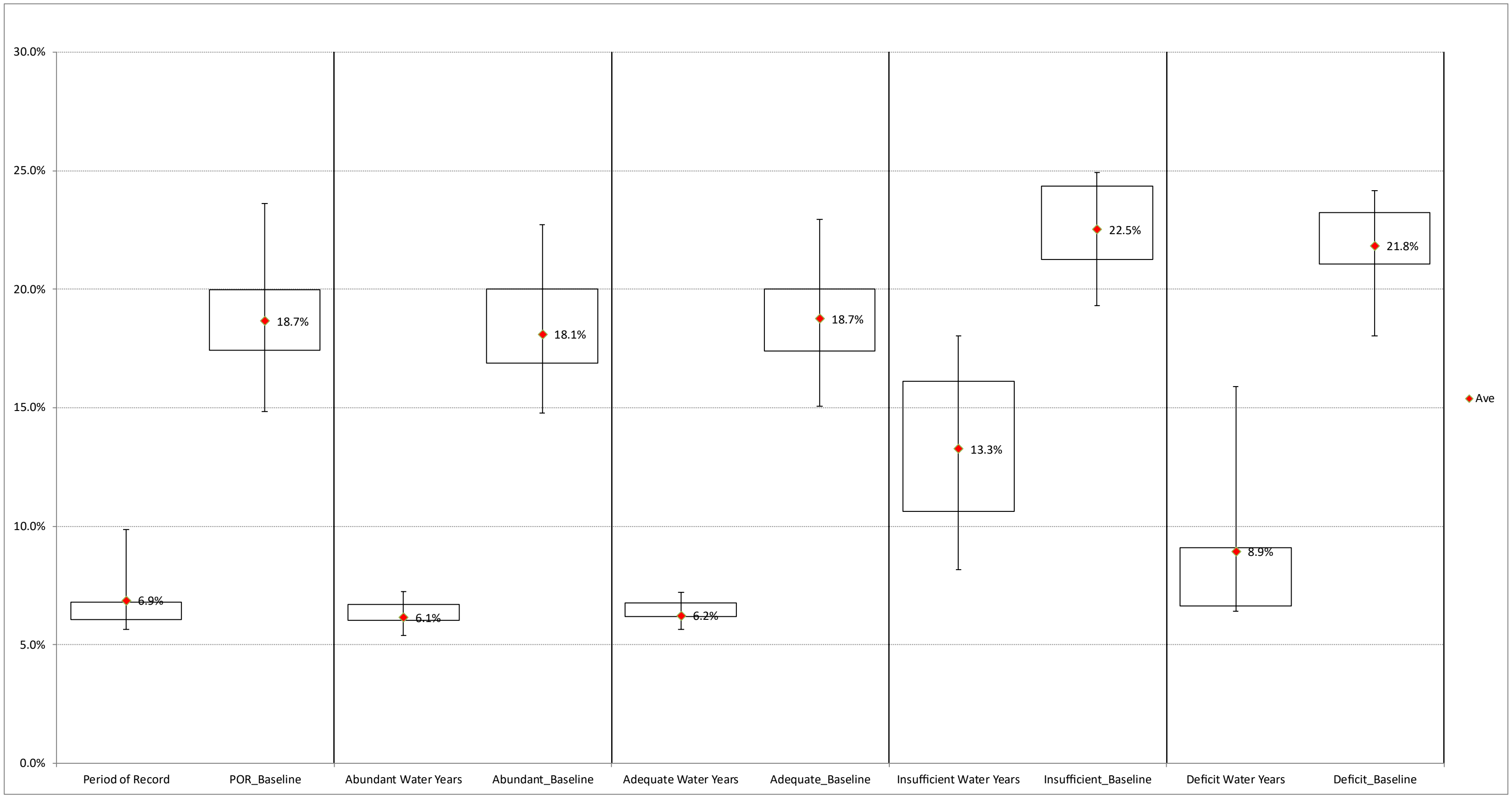


Figure 2-29. Cougar Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Cougar for juvenile spring Chinook sub-yearlings under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given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

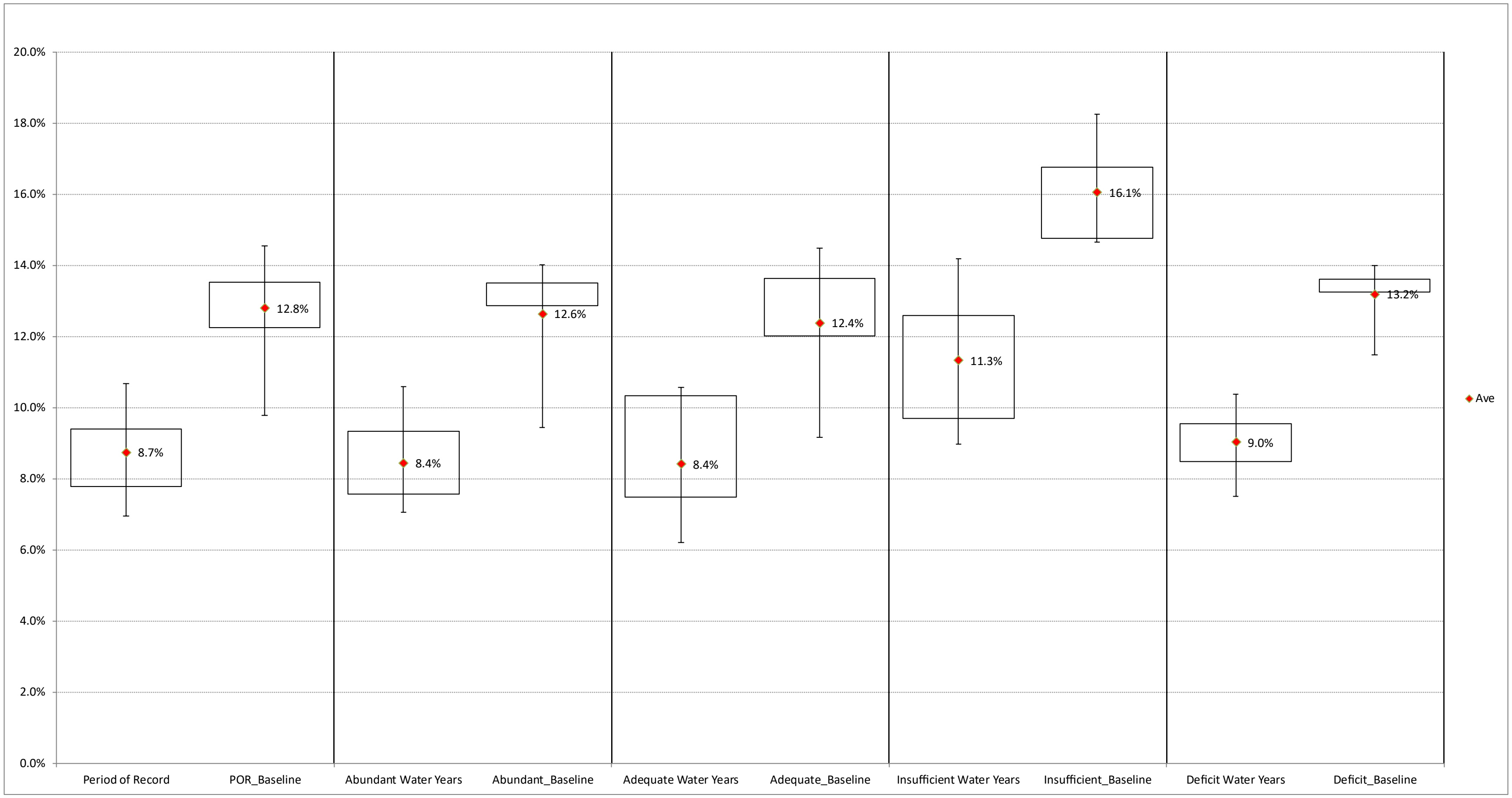


Figure 2-30. Cougar Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Cougar for juvenile spring Chinook yearlings under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the 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.*

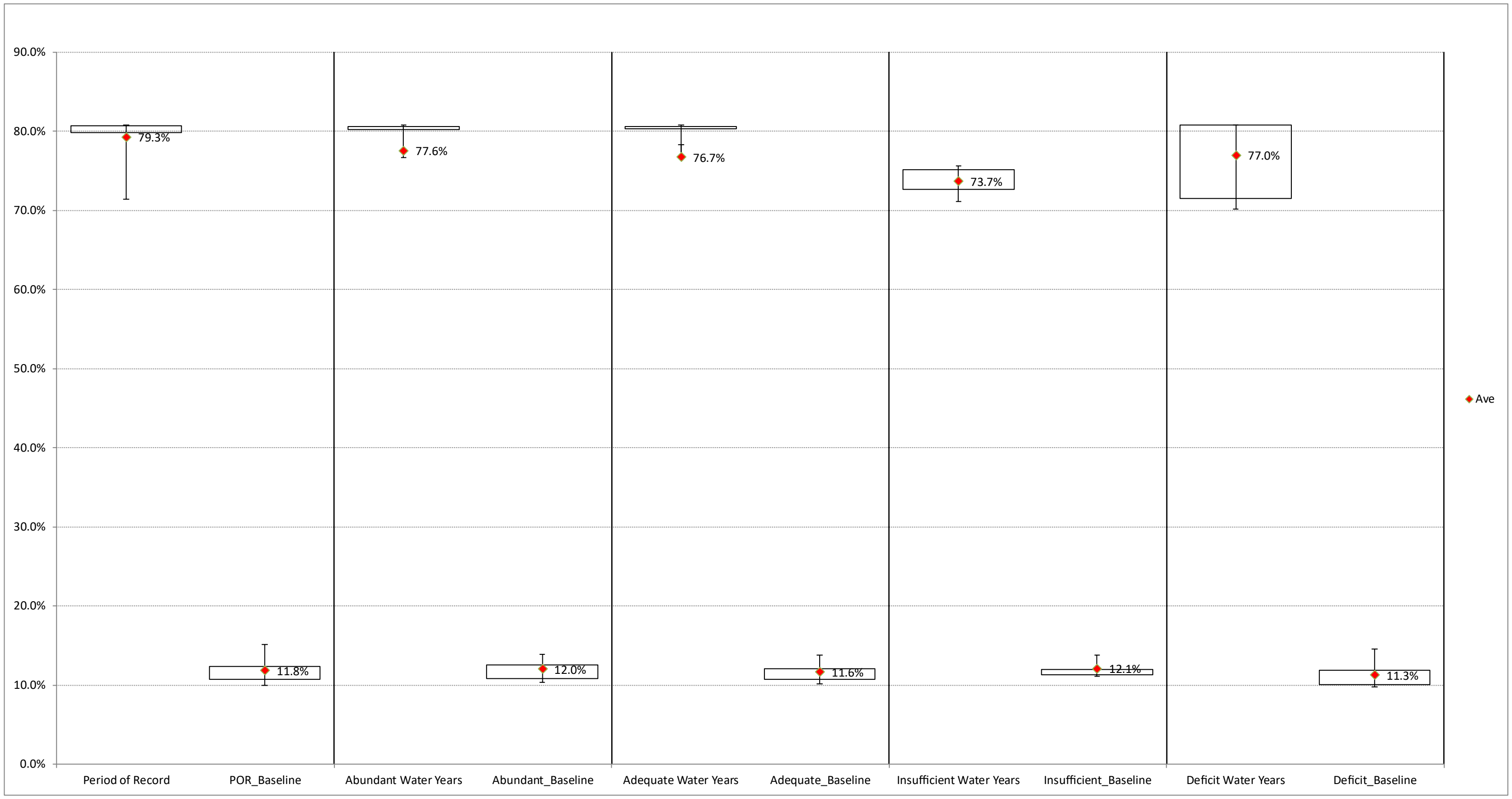


Figure 2-32. Lookout Point Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook sub-yearlings under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities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

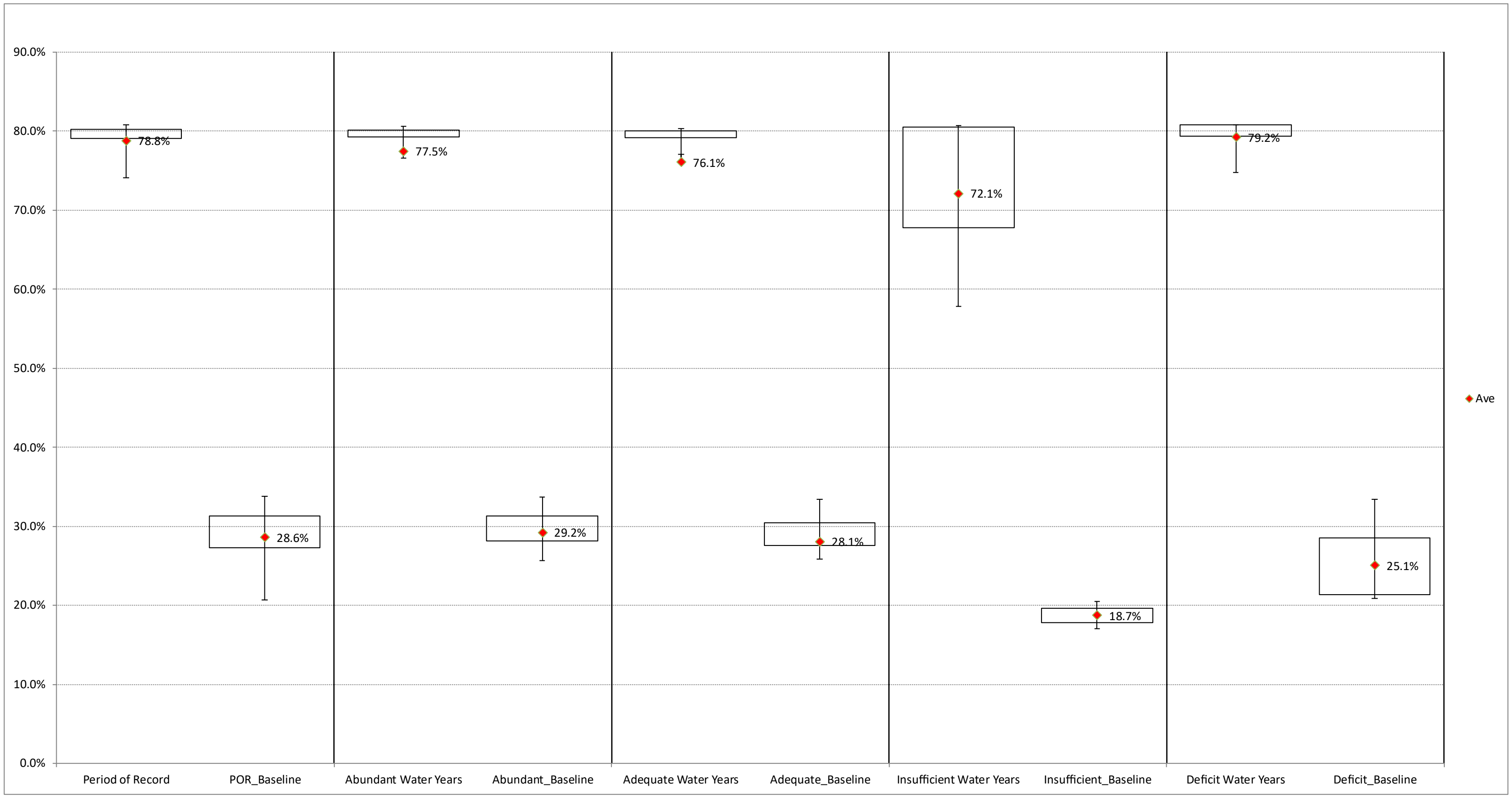


Figure 2-33. Lookout Point Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook yearlings under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are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

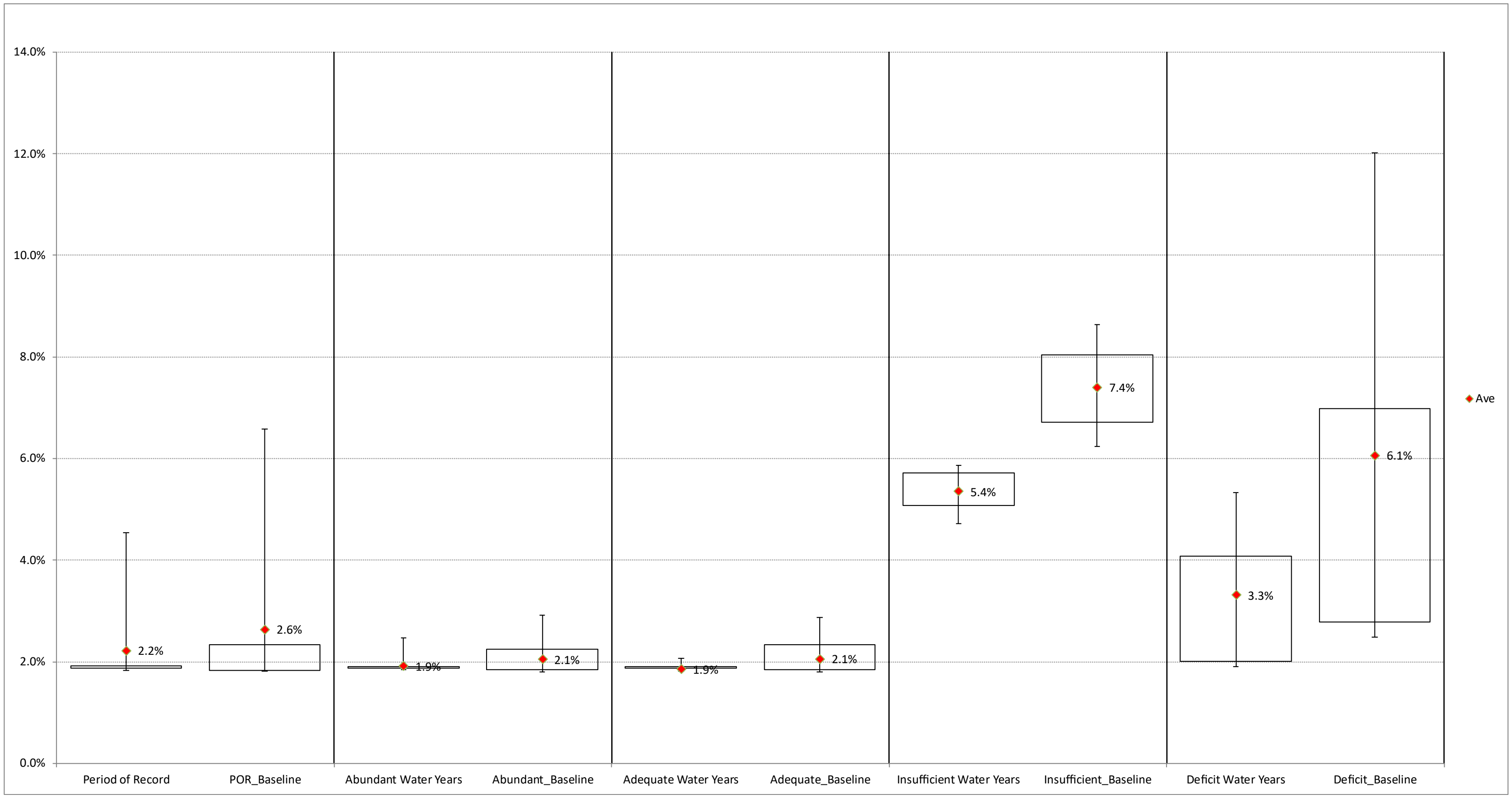


Figure 2-34. Hills Creek Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook fry under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the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

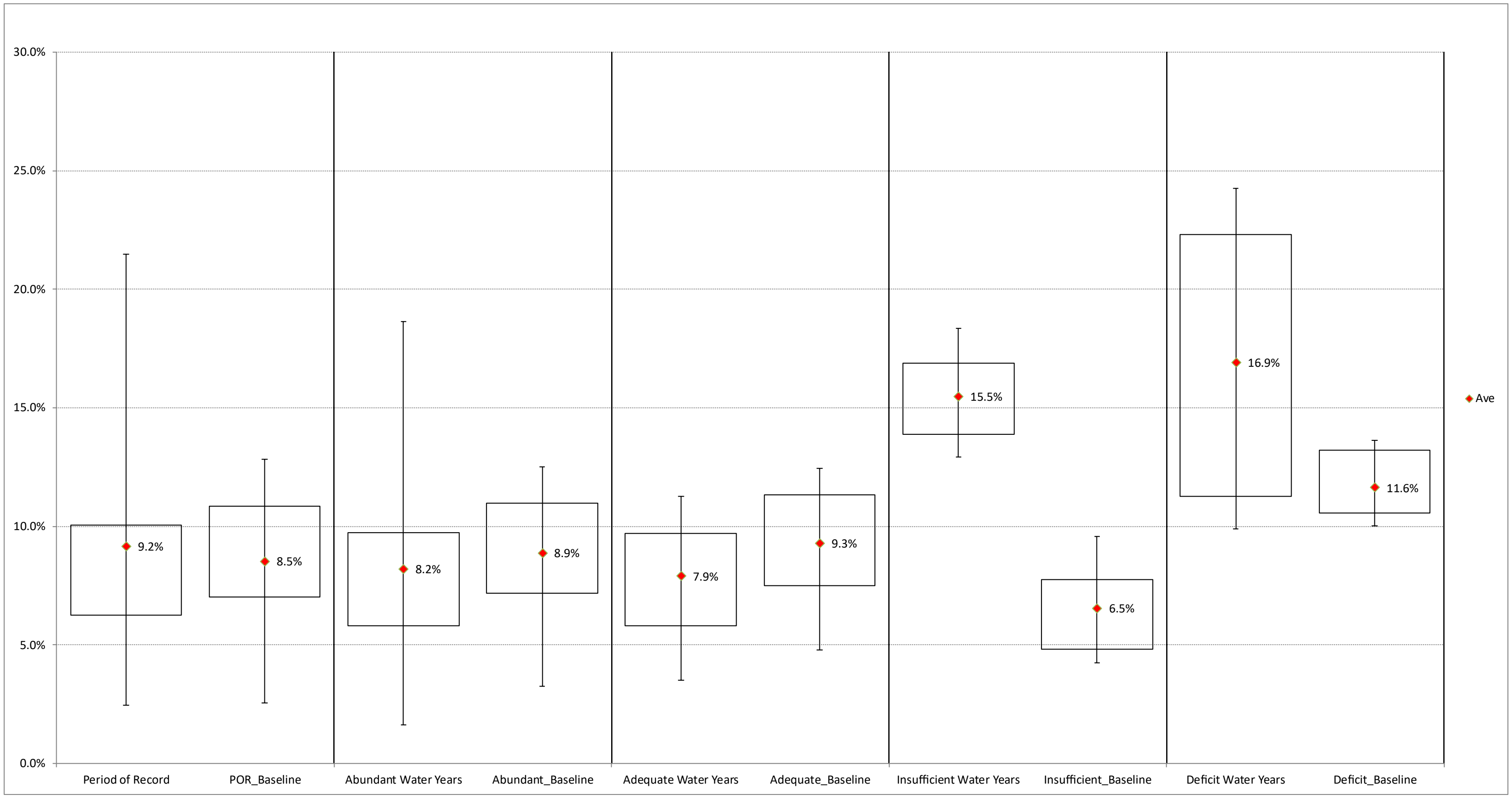


Figure 2-35. Hills Creek Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook sub-yearlings under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities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

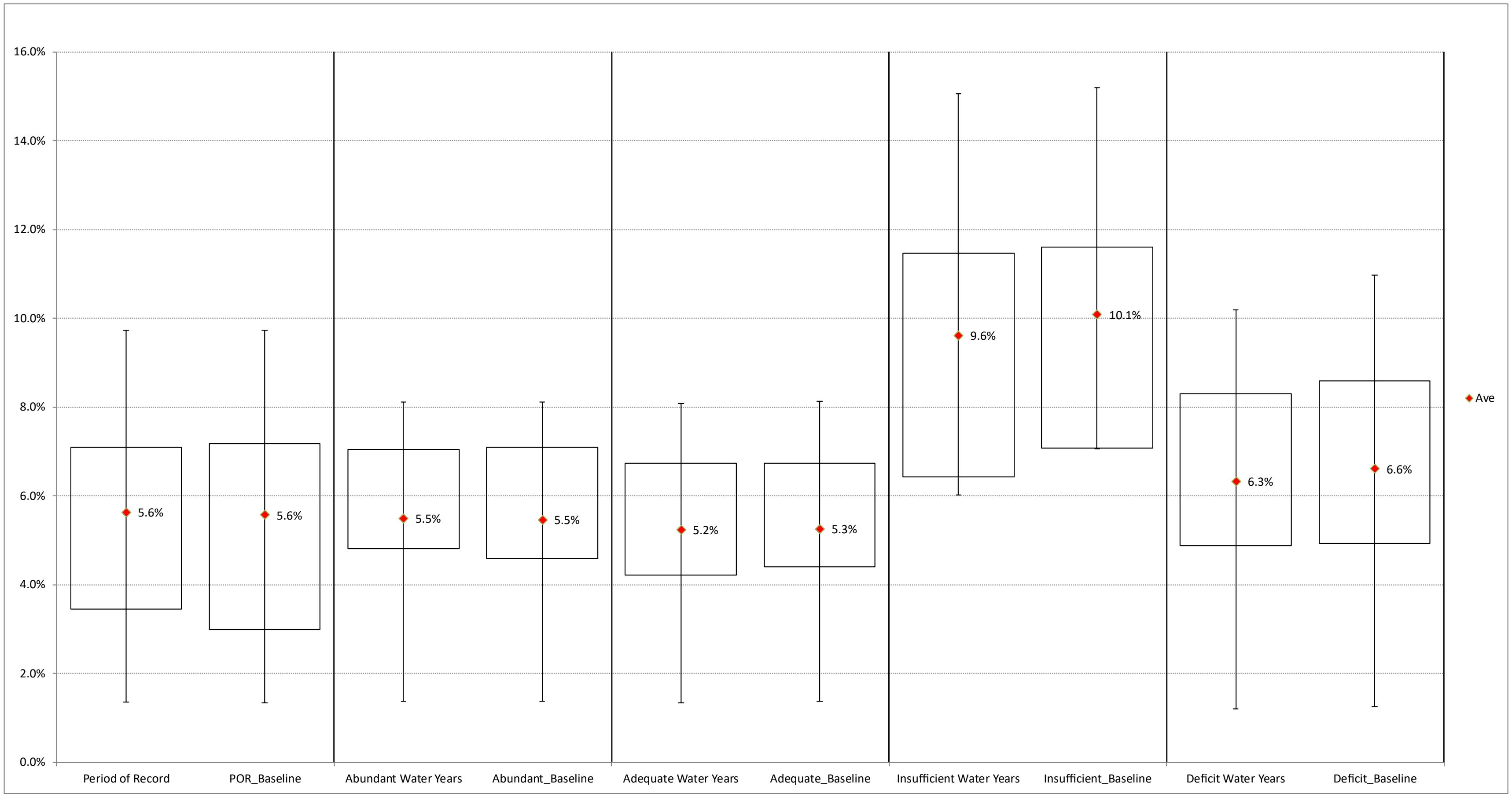


Figure 2-36. Hills Creek Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook yearlings under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given 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

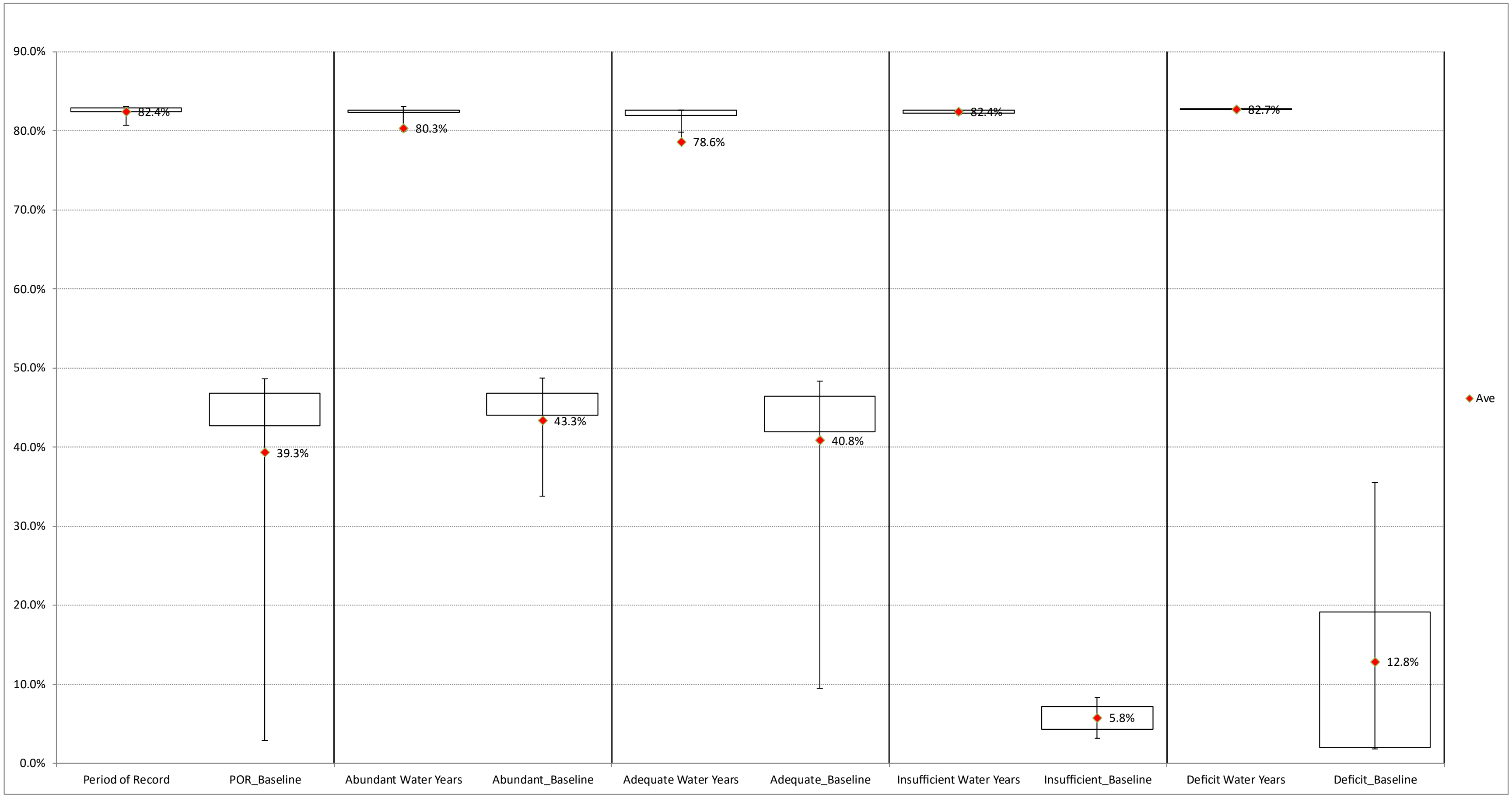


Figure 2-37. Detroit Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Detroit for juvenile spring Chinook fry under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period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

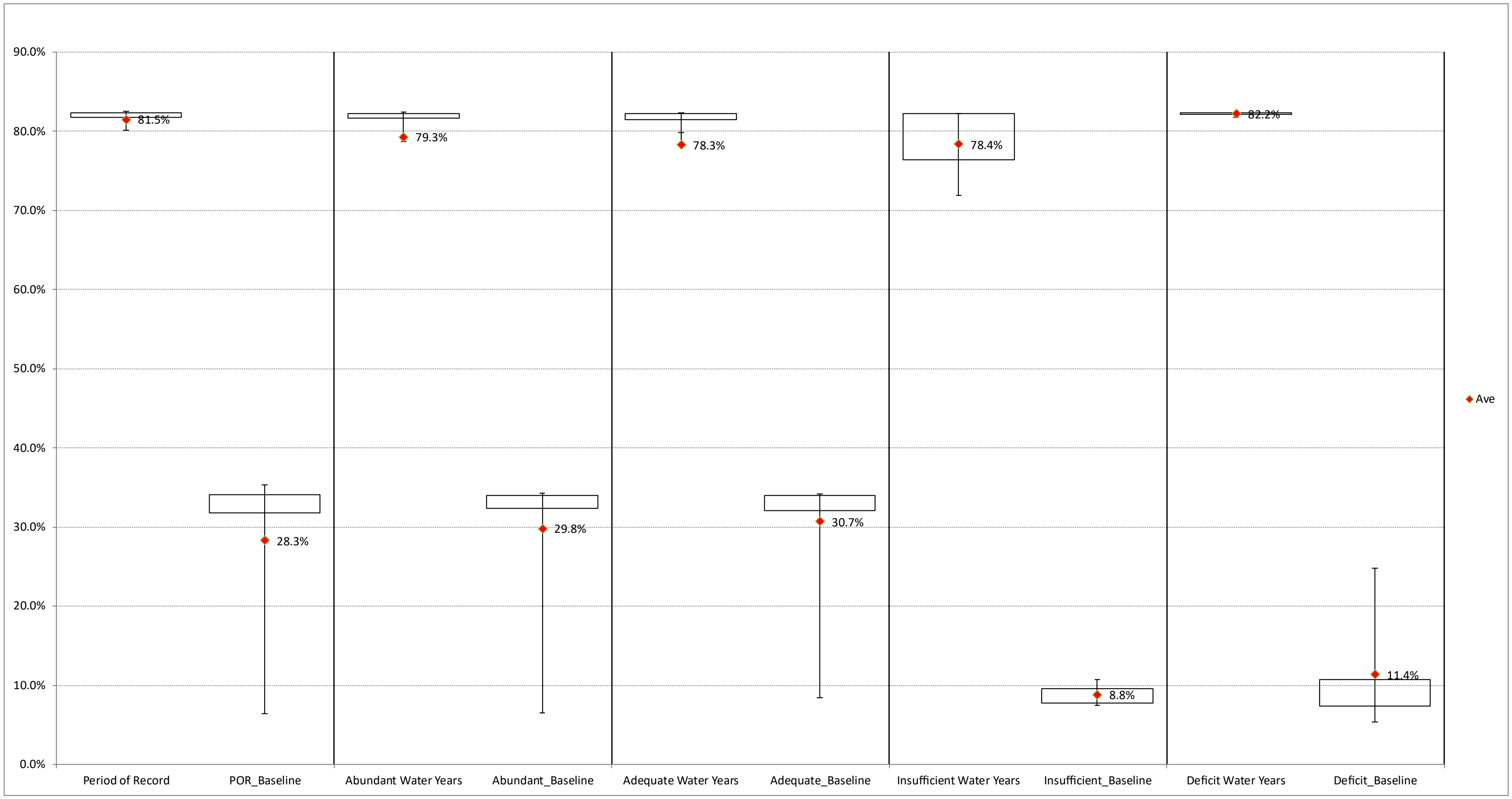


Figure 2-38. Detroit Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Detroit for juvenile spring Chinook sub-yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are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

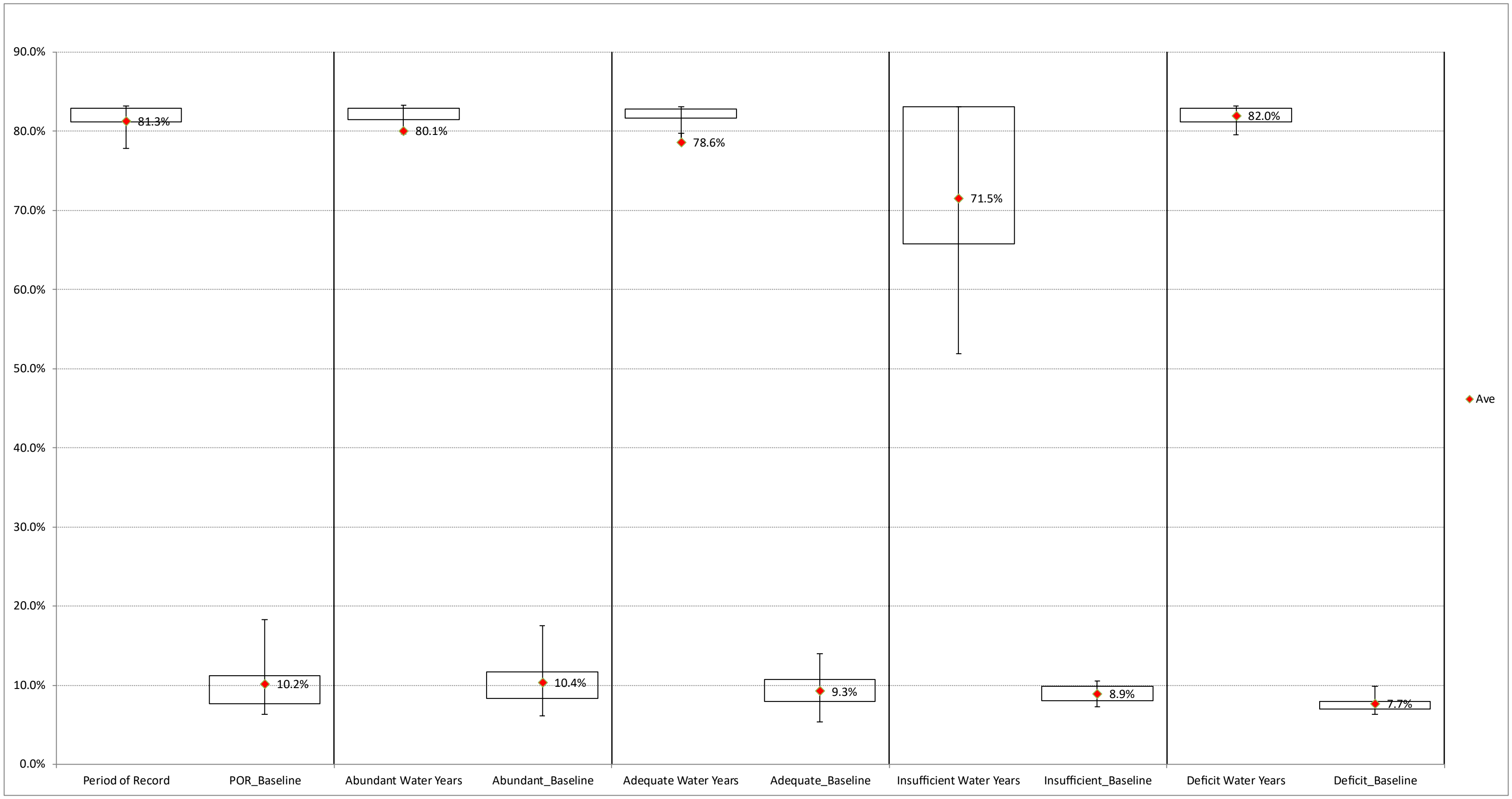


Figure 2-39. Detroit Juvenile Spring Chinook Yearlings Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Detroit for juvenile spring Chinook yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for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

2.3.2 South Santiam – Foster

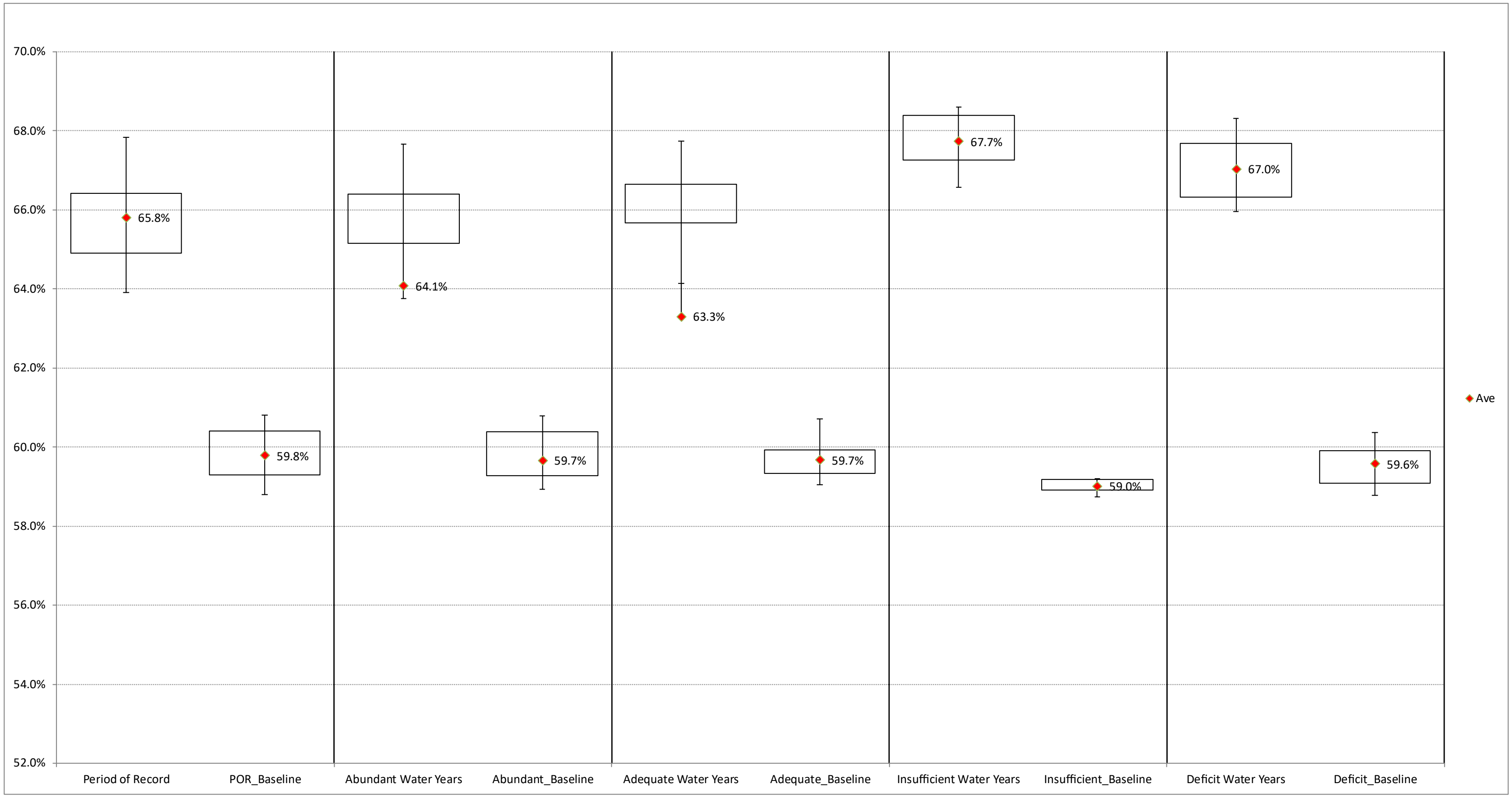


Figure 2-40. Foster Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Foster for juvenile spring Chinook fry under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period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

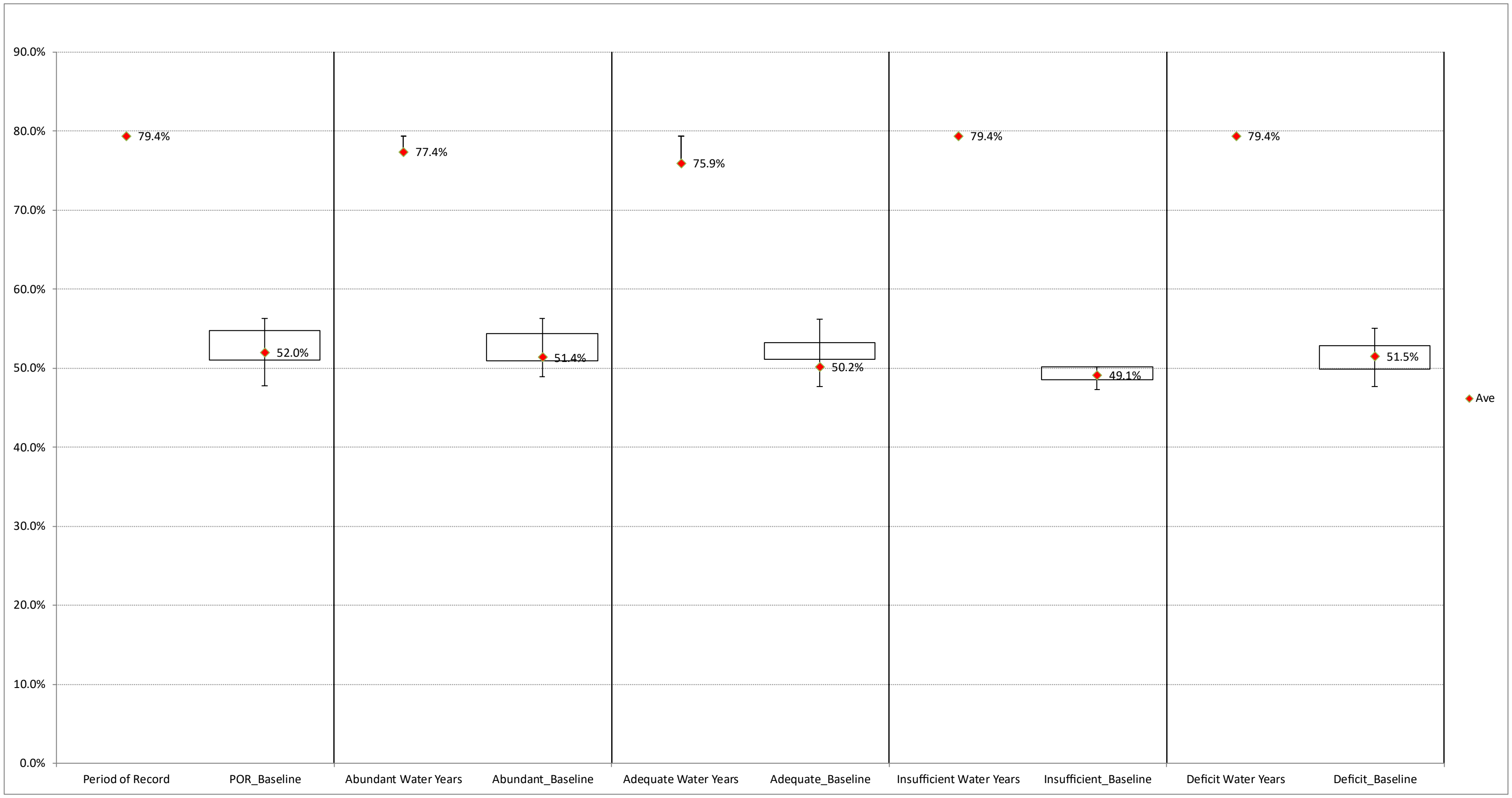


Figure 2-41. Foster Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Foster for juvenile spring Chinook sub-yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given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

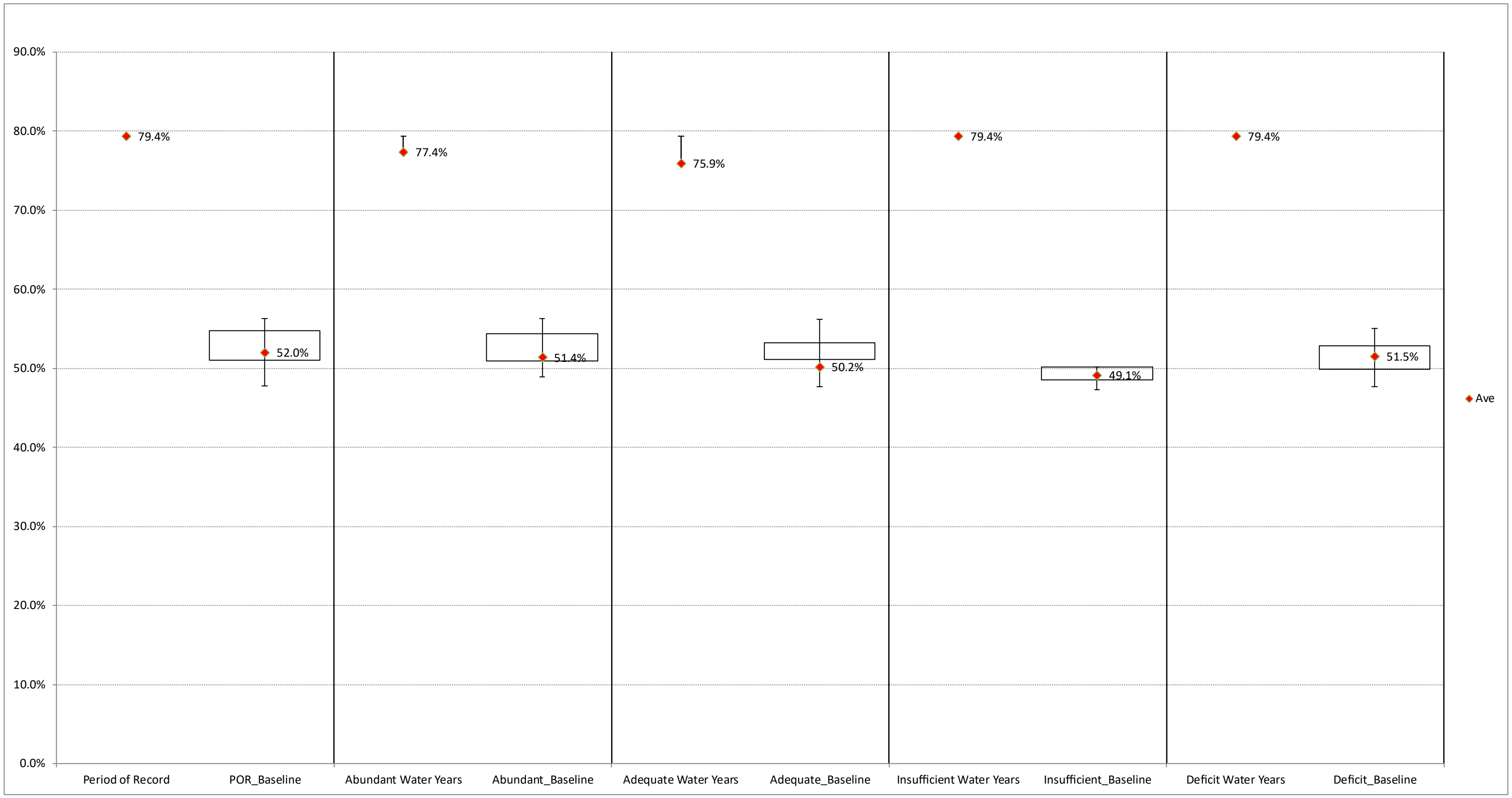


Figure 2-42. Foster Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Foster for juvenile spring Chinook yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for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

2.3.3 South Santiam – Green Peter

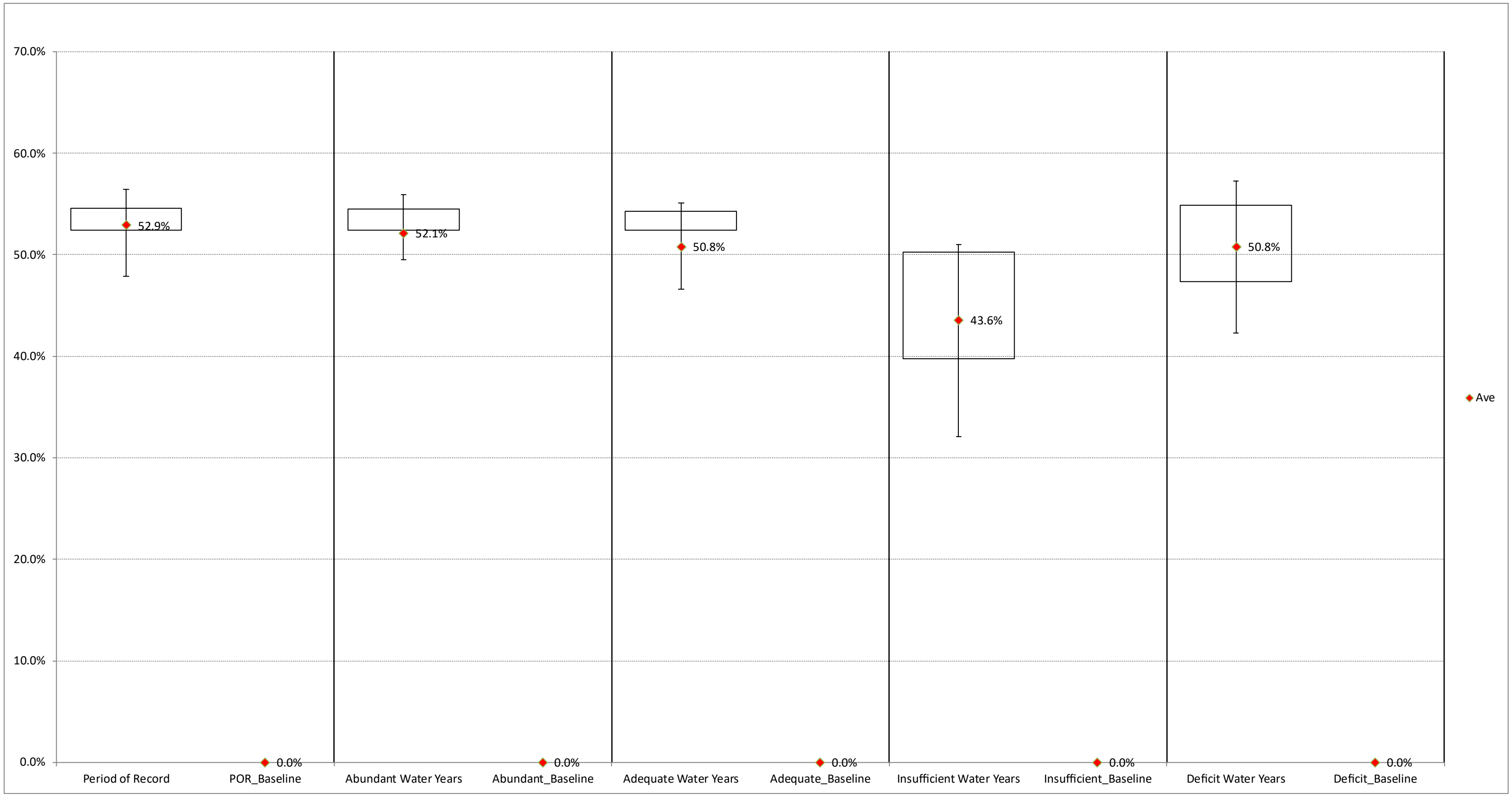


Figure 2-43. Green Peter Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Green Peter for juvenile spring Chinook fry under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the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

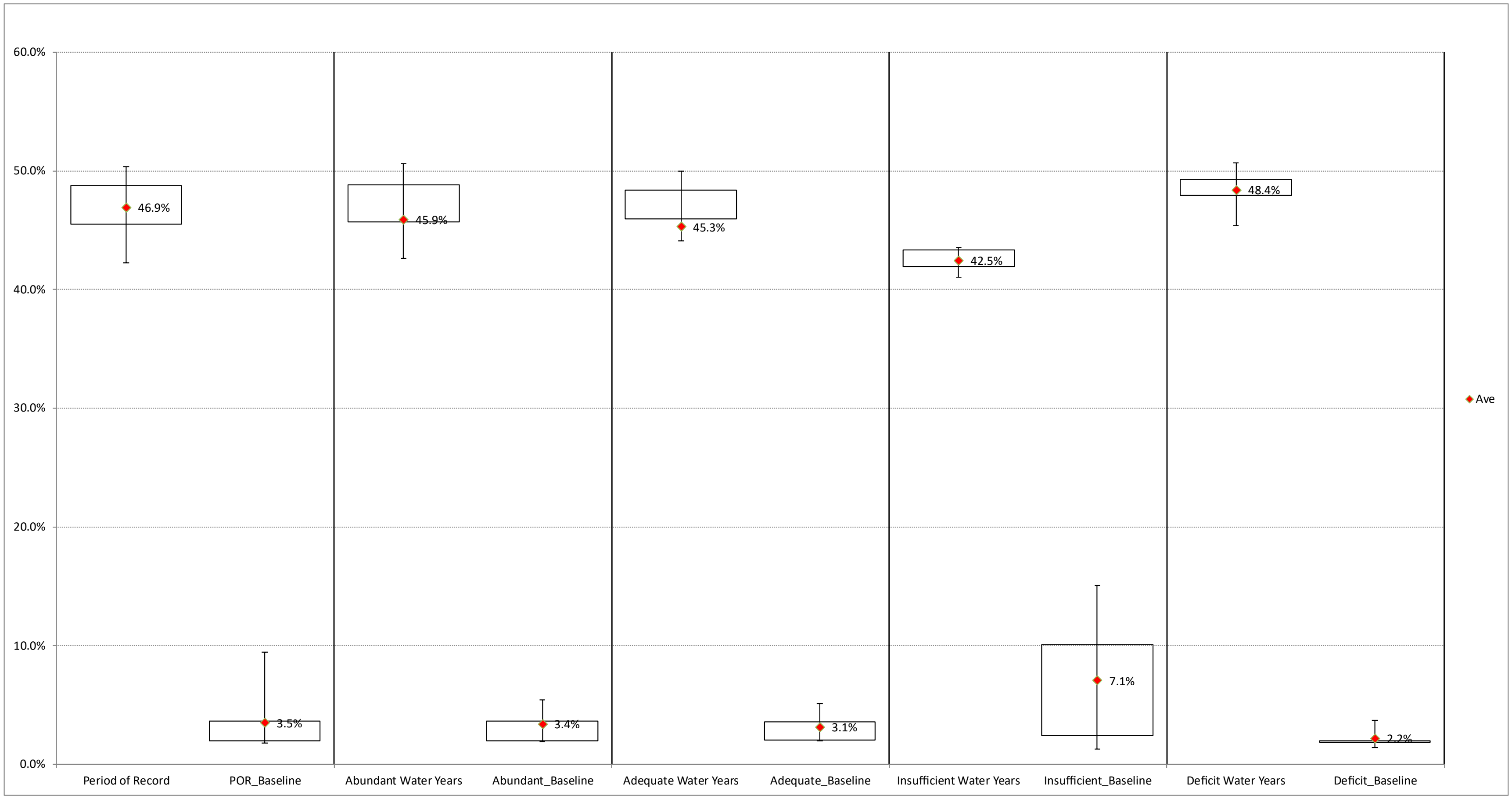


Figure 2-44. Green Peter Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Green Peter for juvenile spring Chinook sub-yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities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

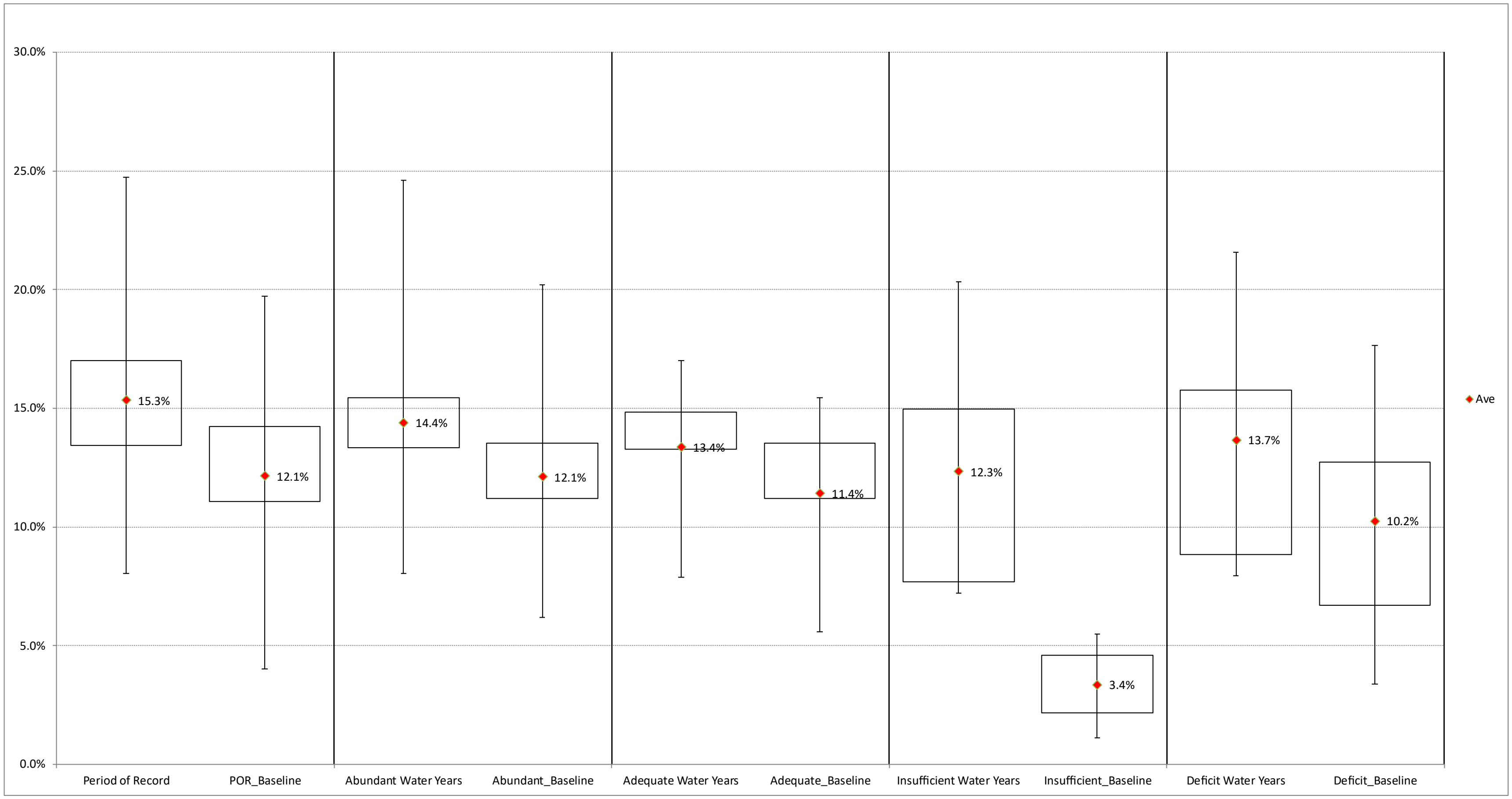


Figure 2-45. Green Peter Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Green Peter for juvenile spring Chinook yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are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

2.3.4 McKenzie - Cougar

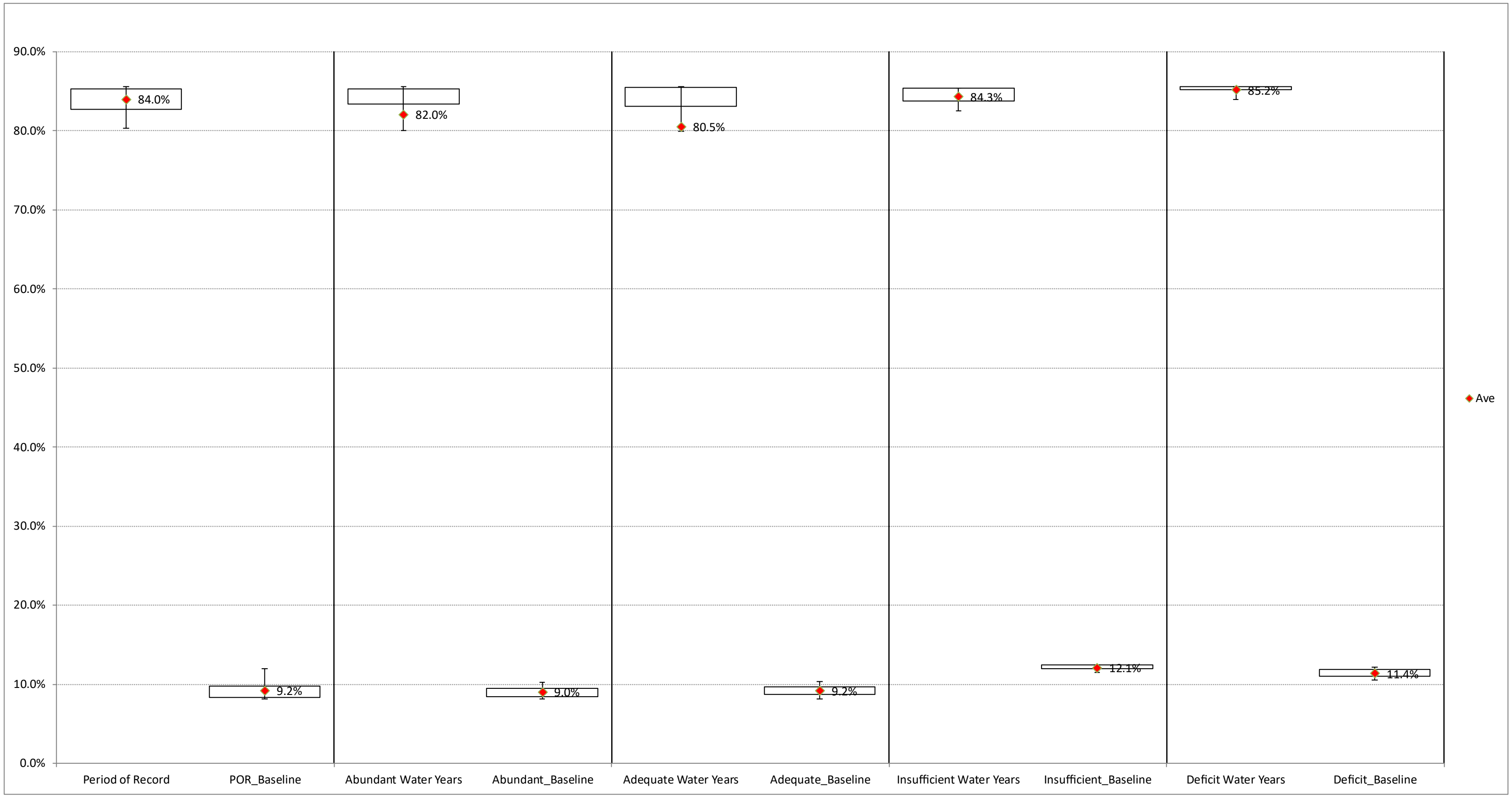


Figure 2-46. Cougar Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Cougar for juvenile spring Chinook fry under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period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

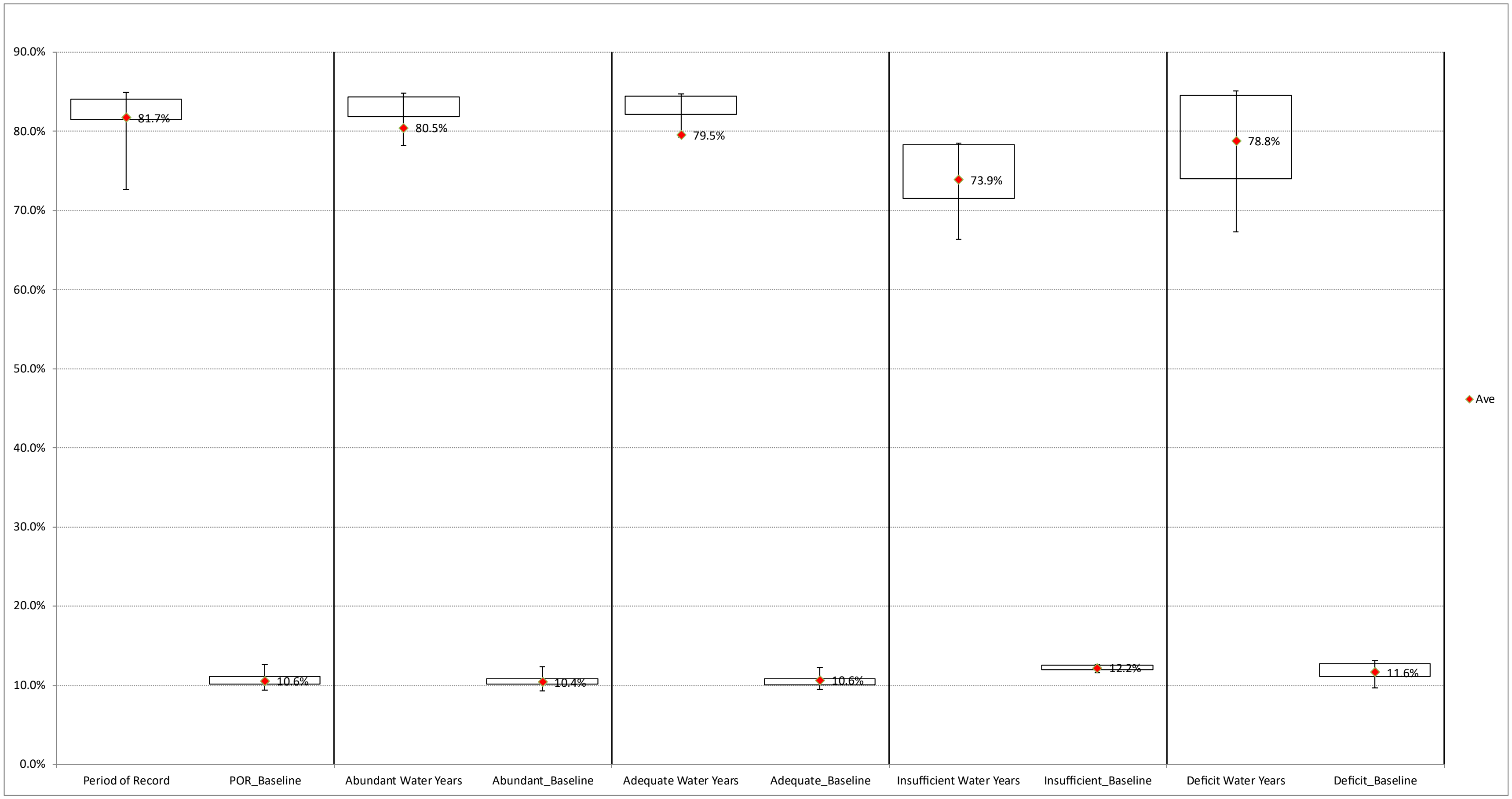


Figure 2-47. Cougar Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Cougar for juvenile spring Chinook sub-yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given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

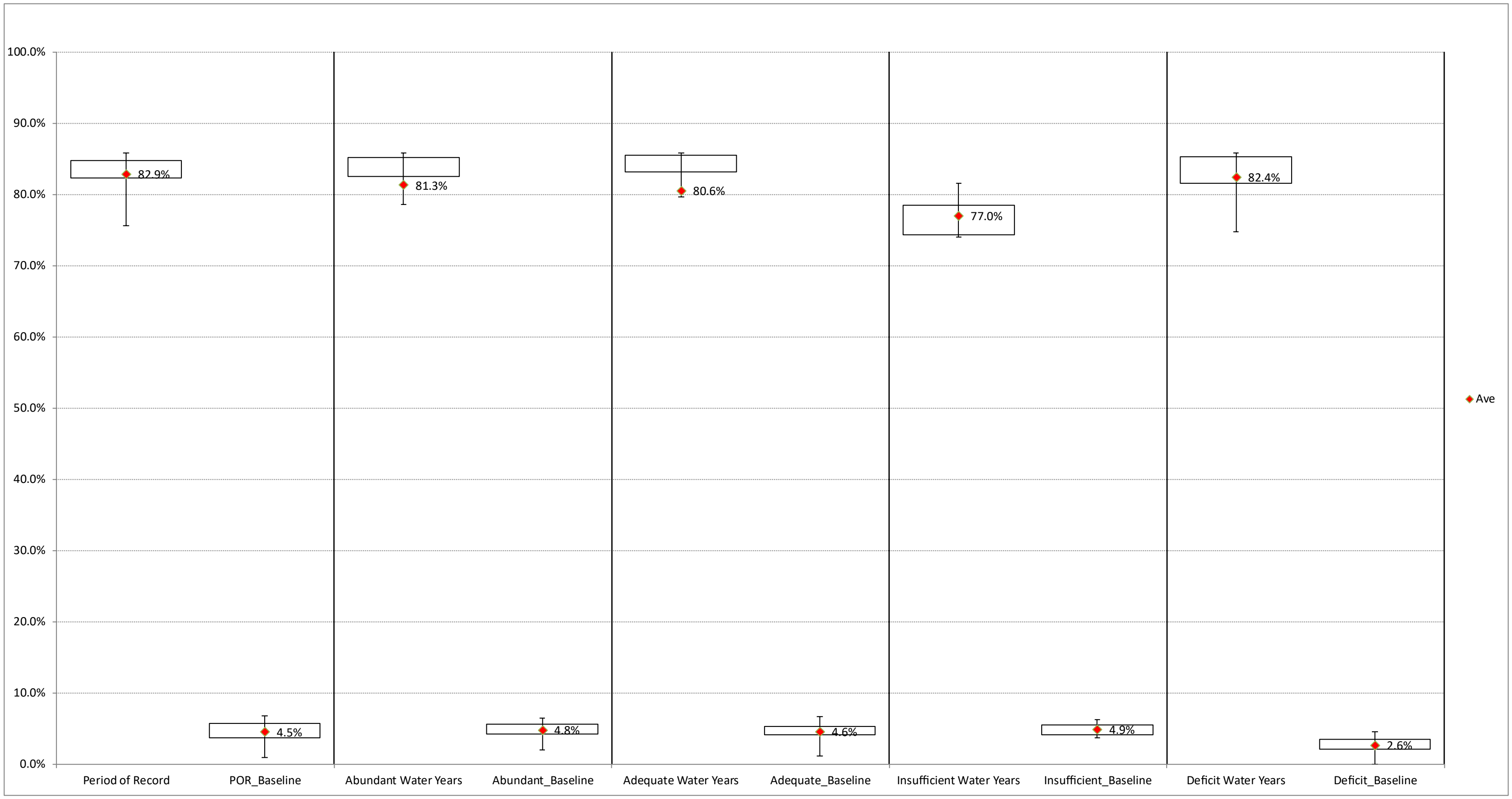


Figure 2-48. Cougar Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Cougar for juvenile spring Chinook yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities are given for 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.*

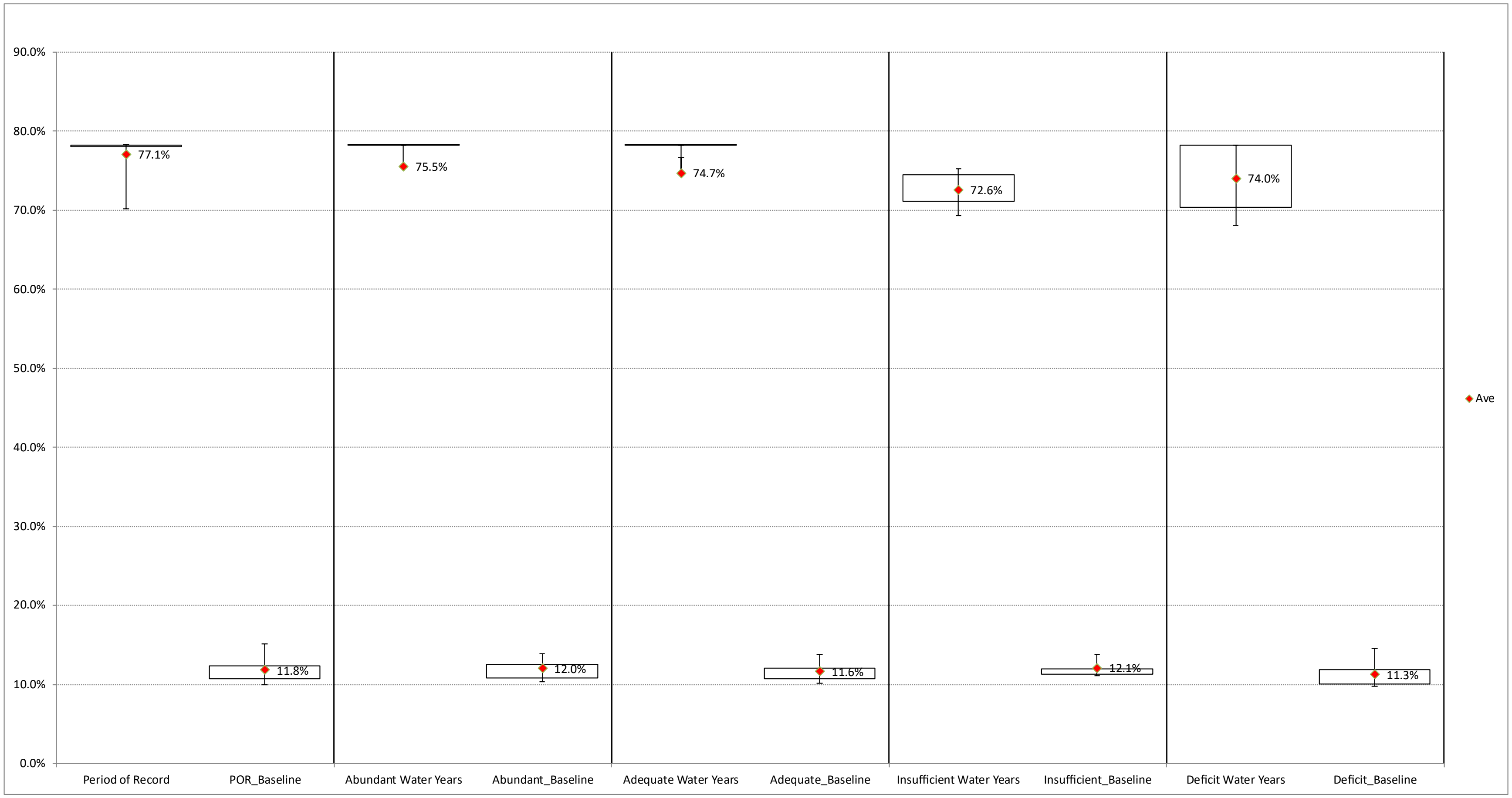


Figure 2-50. Lookout Point Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 2a. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook sub-yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities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

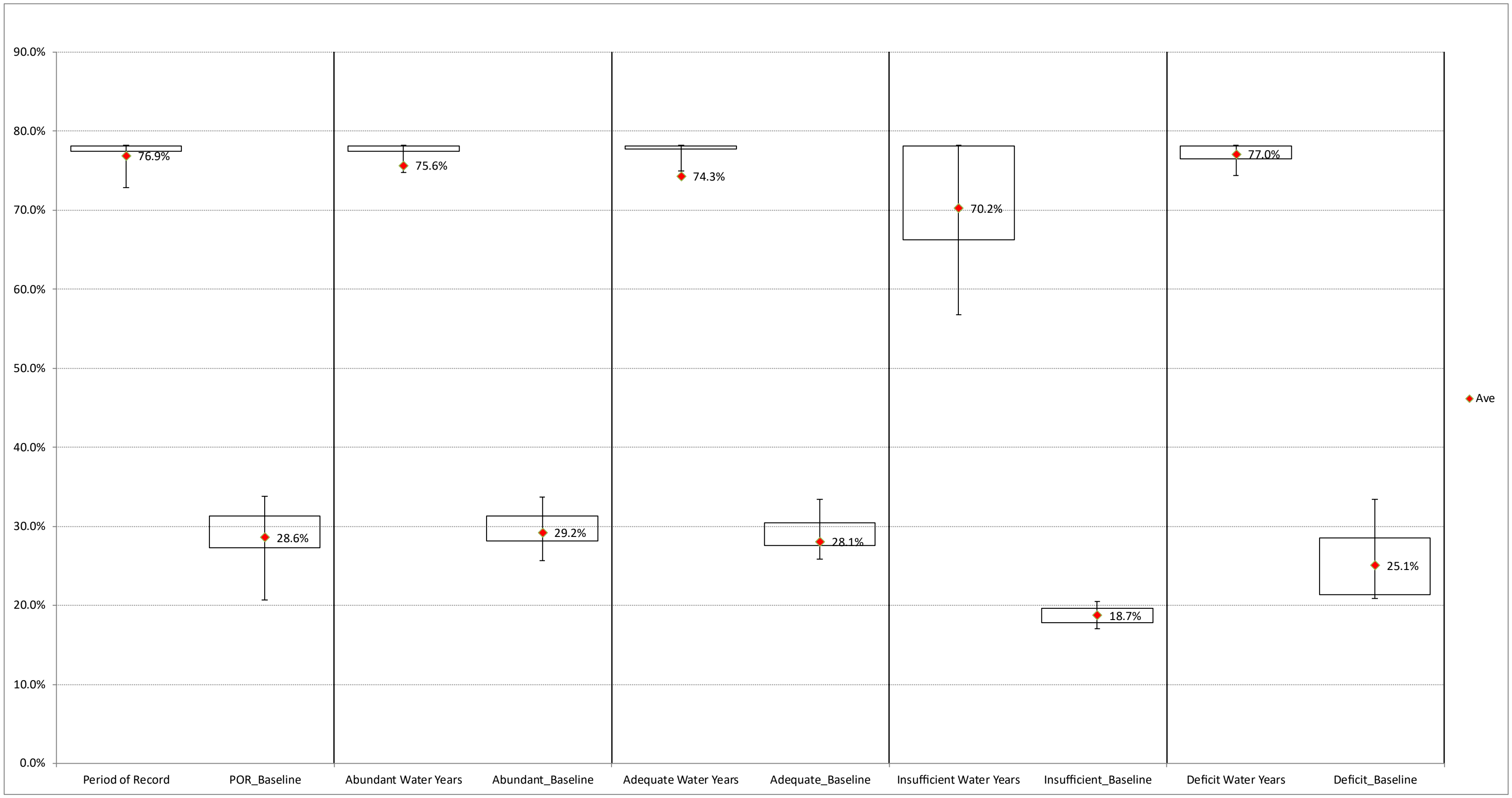


Figure 2-51. Lookout Point for juvenile spring Chinook yearling Downstream dam passage survival at s under Alternative 2a. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities 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

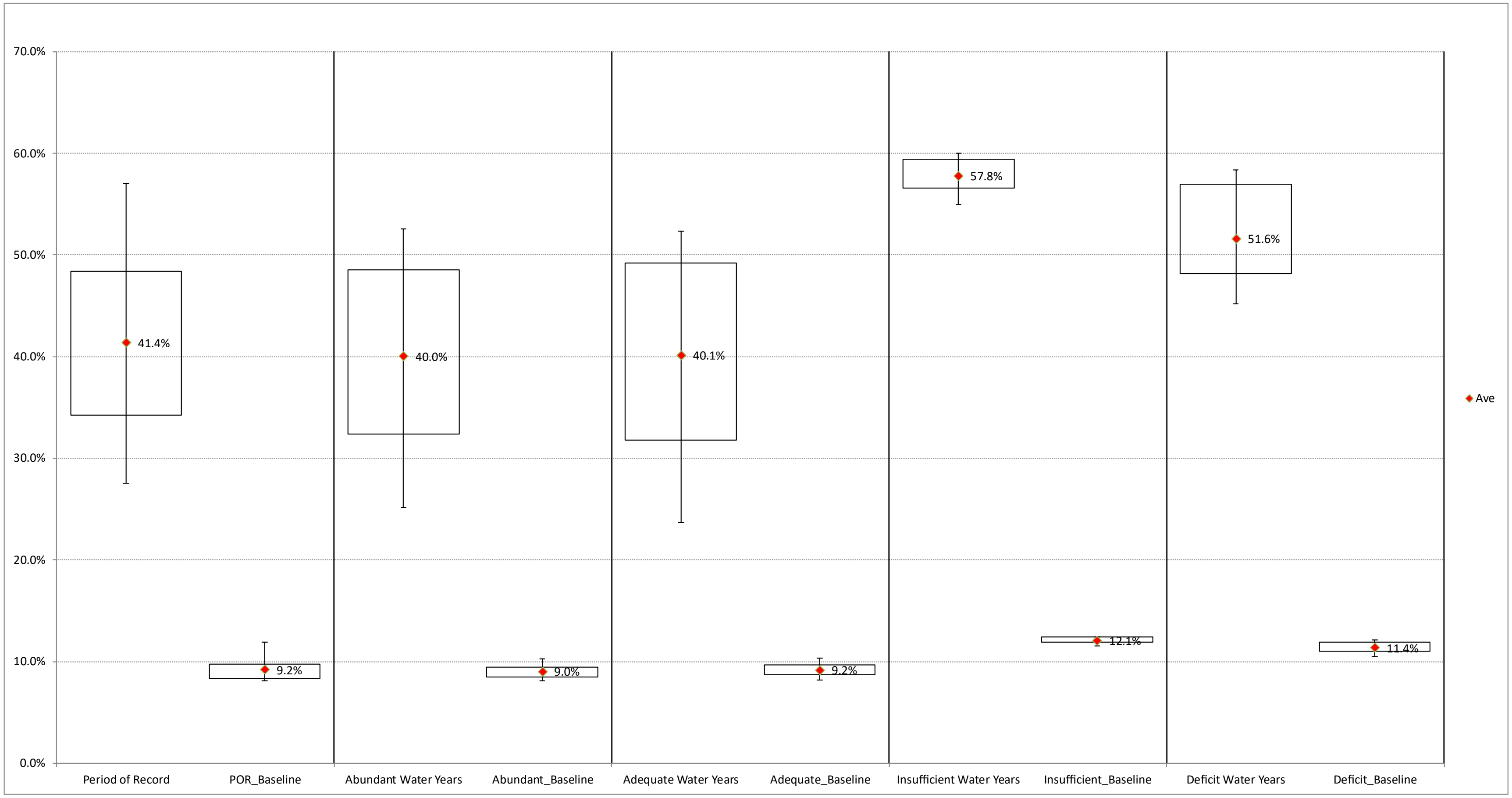


Figure 2-52. Cougar Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 2b. *Downstream dam passage survival at Cougar for juvenile spring Chinook fry under Alternative 2b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period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

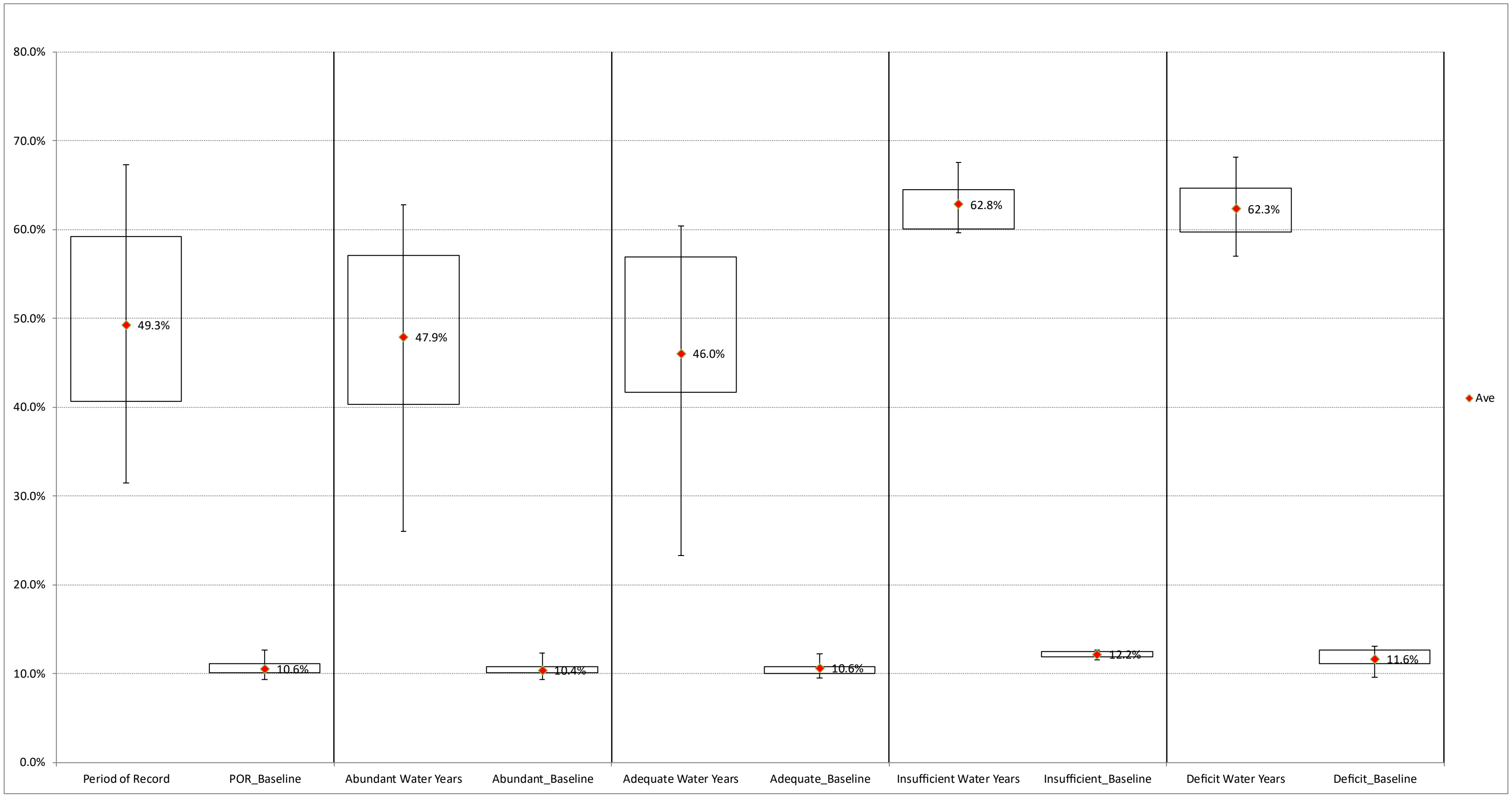


Figure 2-53. Cougar Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 2b. *The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

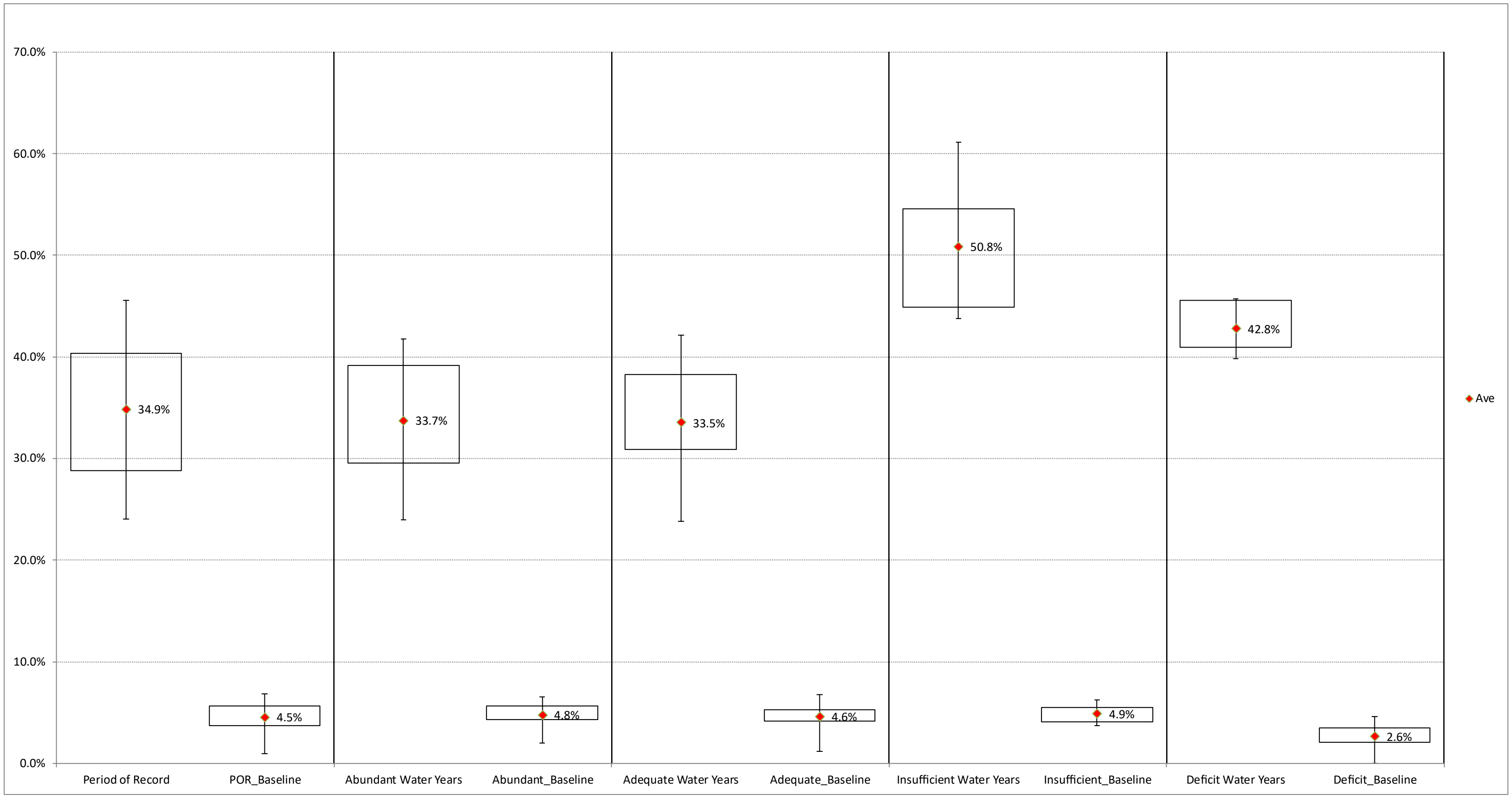


Figure 2-54. Downstream dam passage survival at Cougar for juvenile spring Chinook yearlings under Alternative 2b*. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.4.5 Middle Fork – Lookout Point

See Alternative 2

2.5 CHINOOK SALMON ALTERNATIVE 3A

2.5.1 North Santiam – Detroit

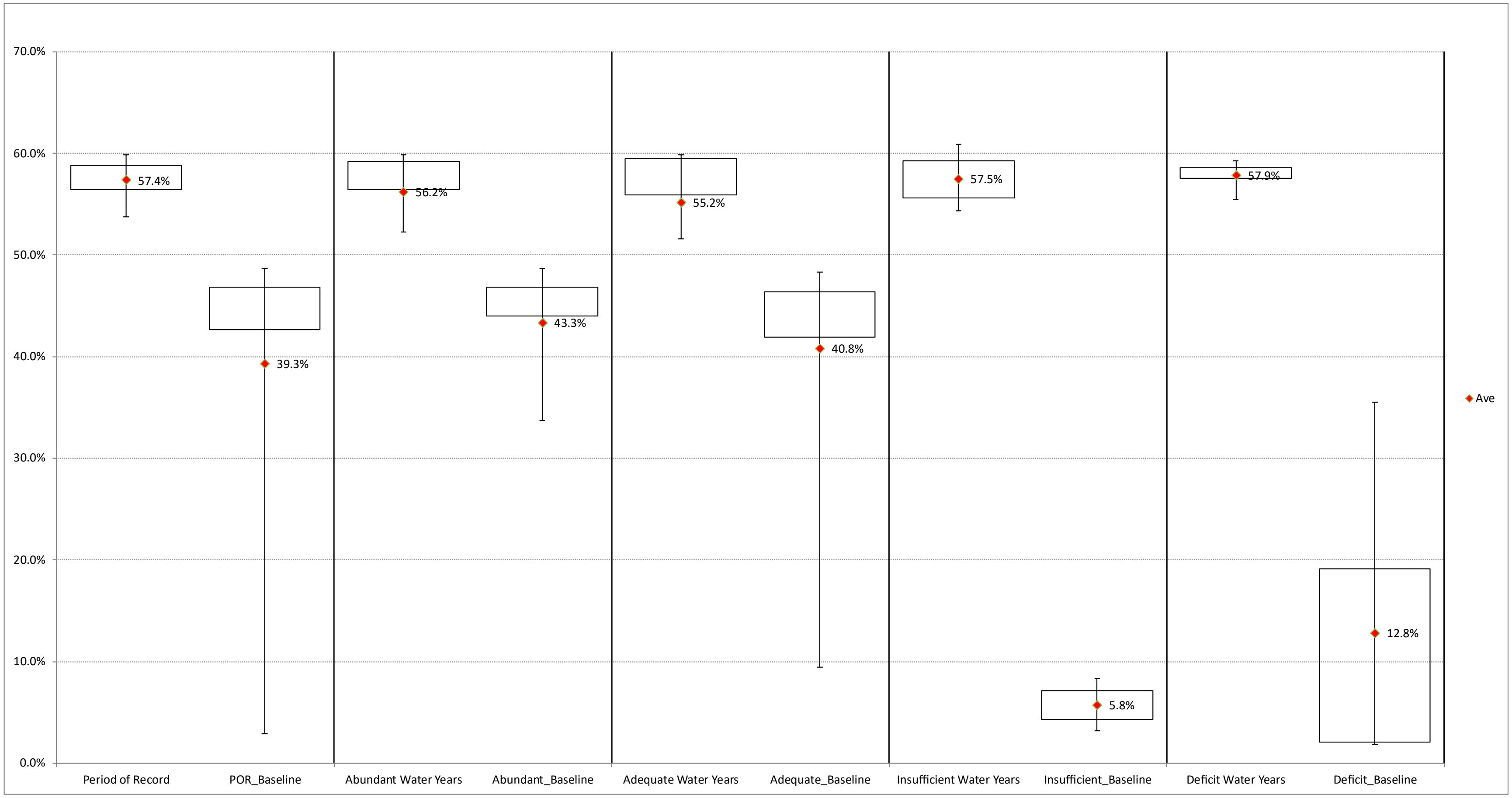


Figure 2-55. Detroit Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Detroit for juvenile spring Chinook fry under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period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

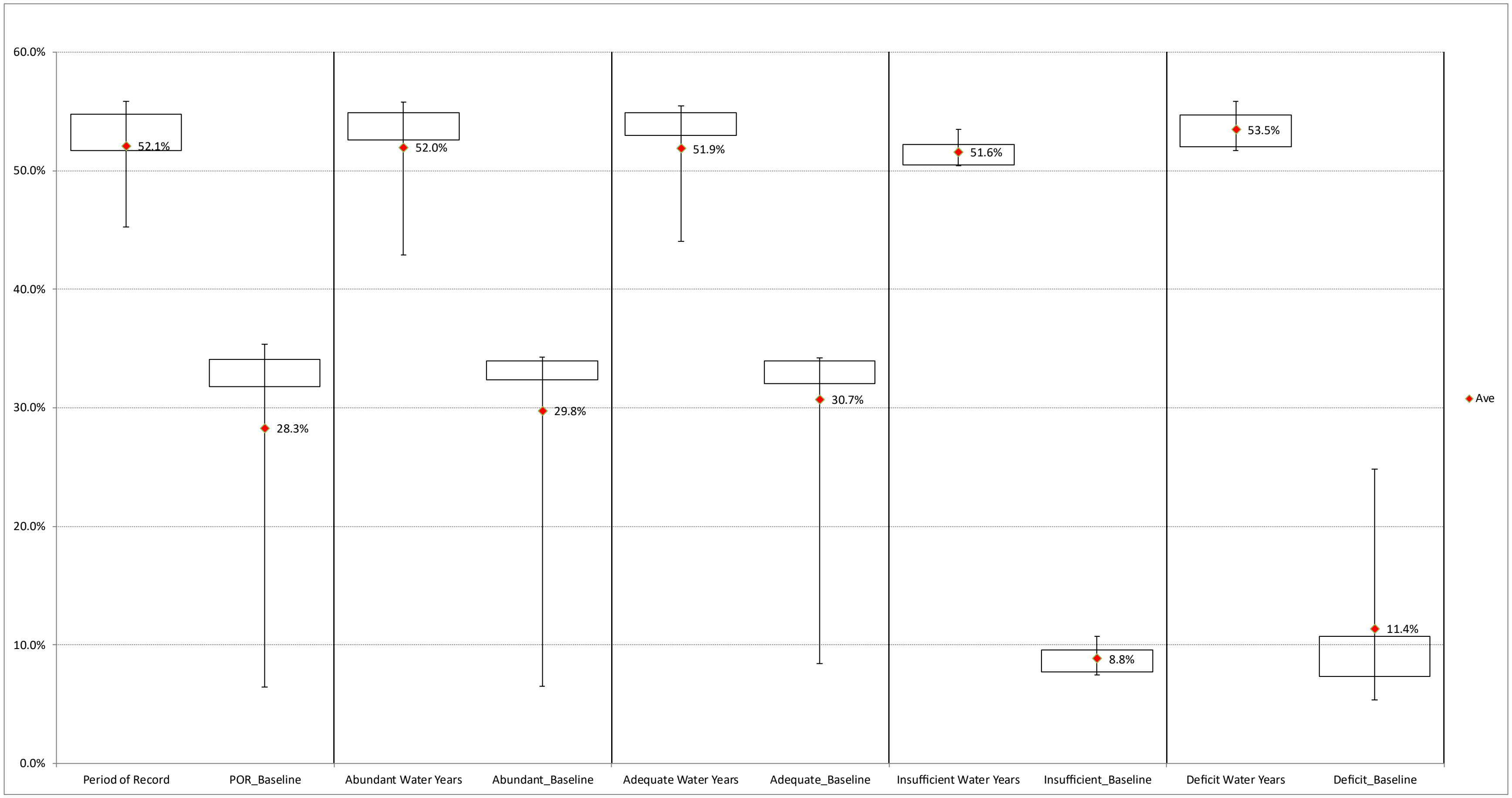


Figure 2-56. Detroit Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Detroit for juvenile spring Chinook sub-yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are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

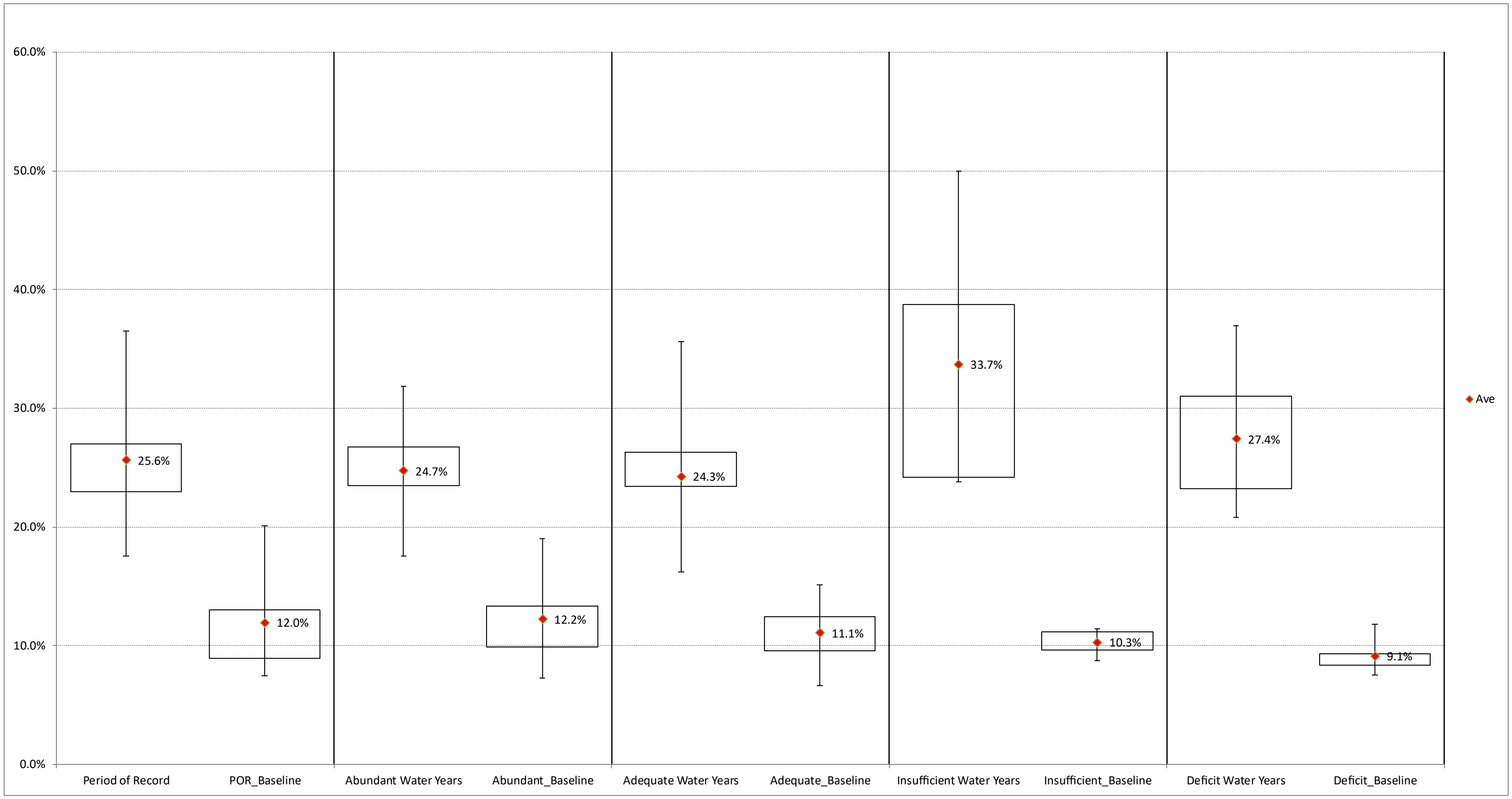


Figure 2-57. Detroit Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Detroit for juvenile spring Chinook yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for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

2.5.2 South Santiam - Foster

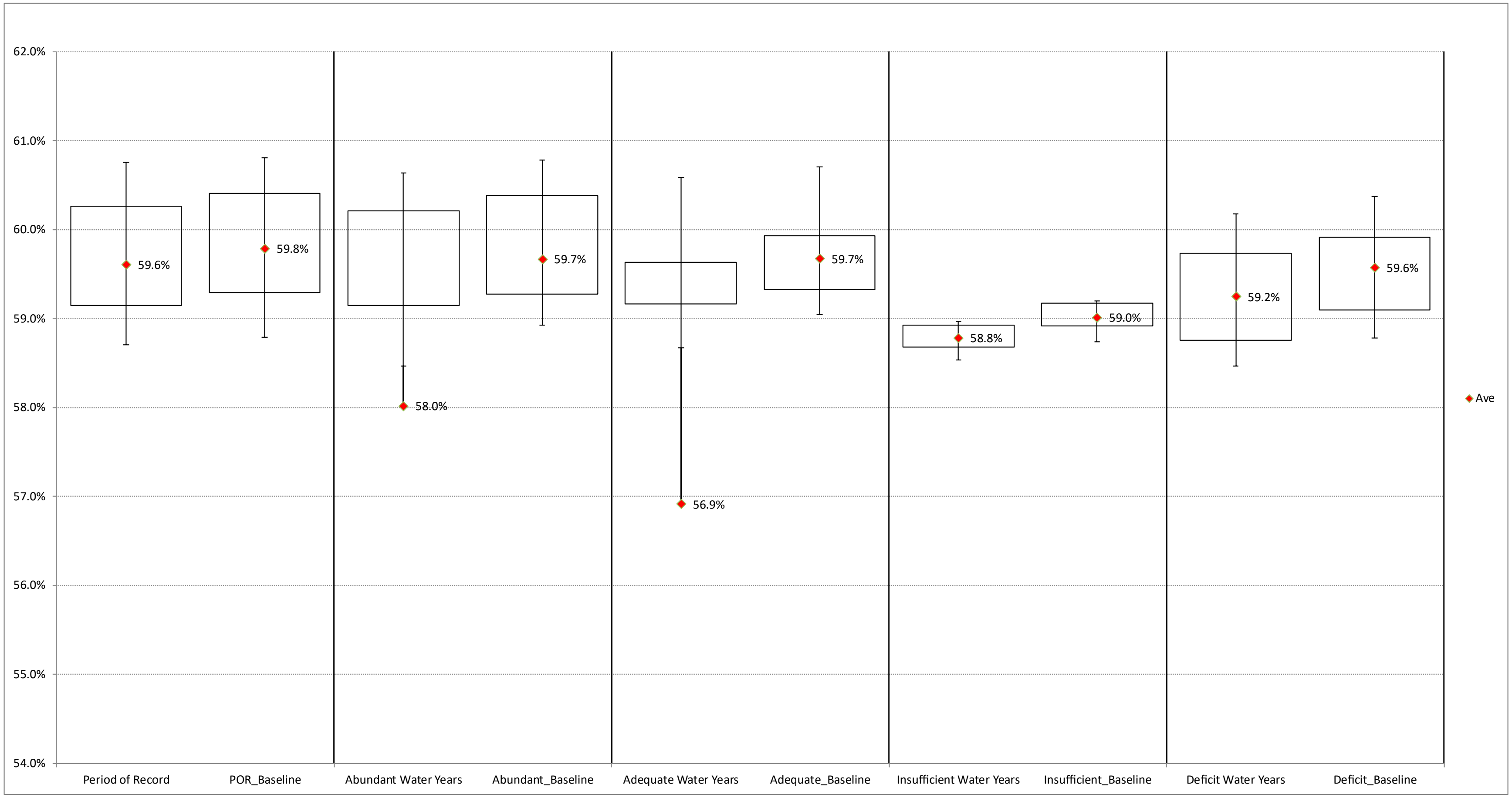


Figure 2-58. Foster Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Foster for juvenile spring Chinook fry under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period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

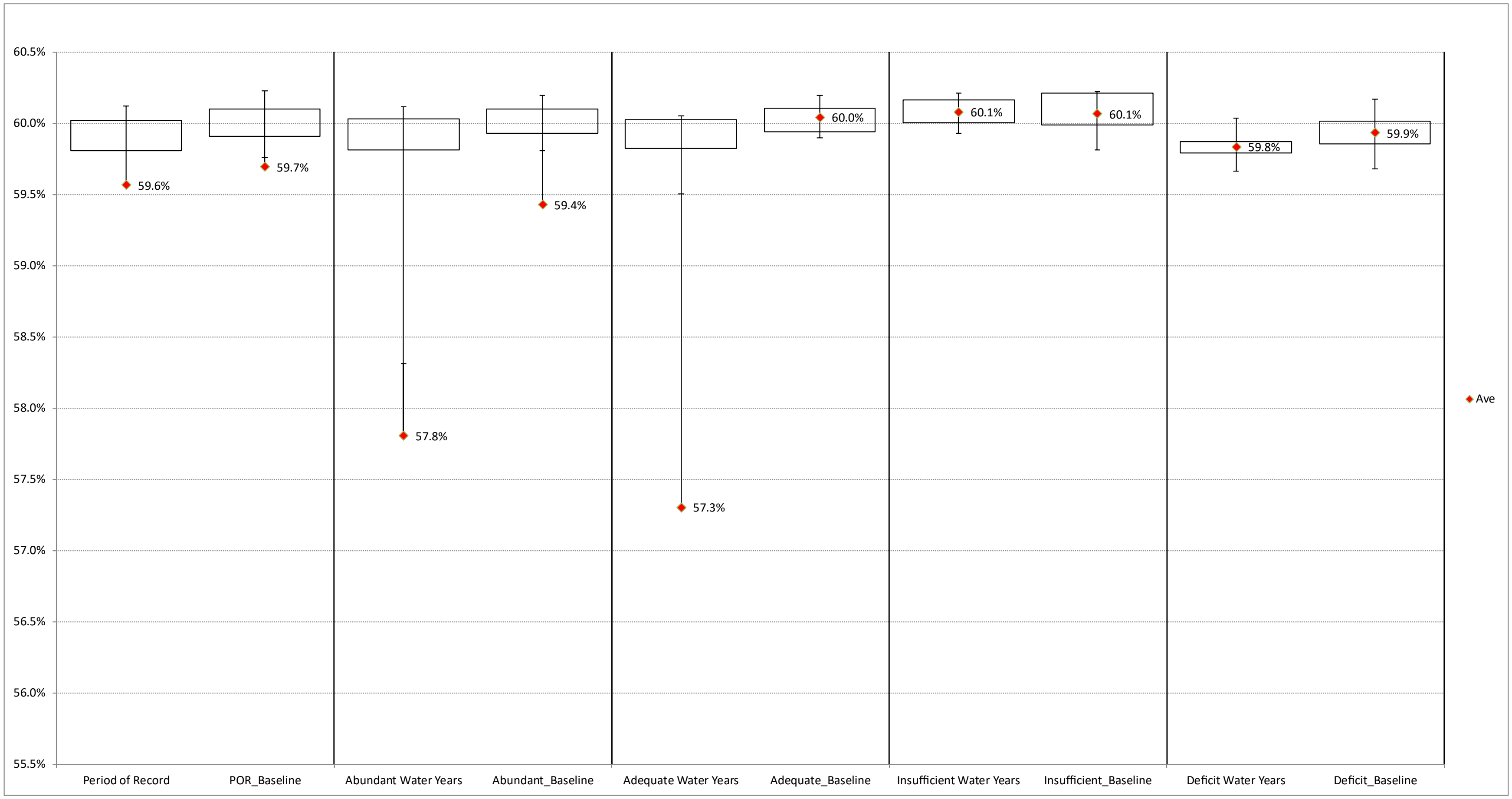


Figure 2-59. Foster Juvenile Spring Chinook Sub-Yearlings Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Foster for juvenile spring Chinook sub-yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given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

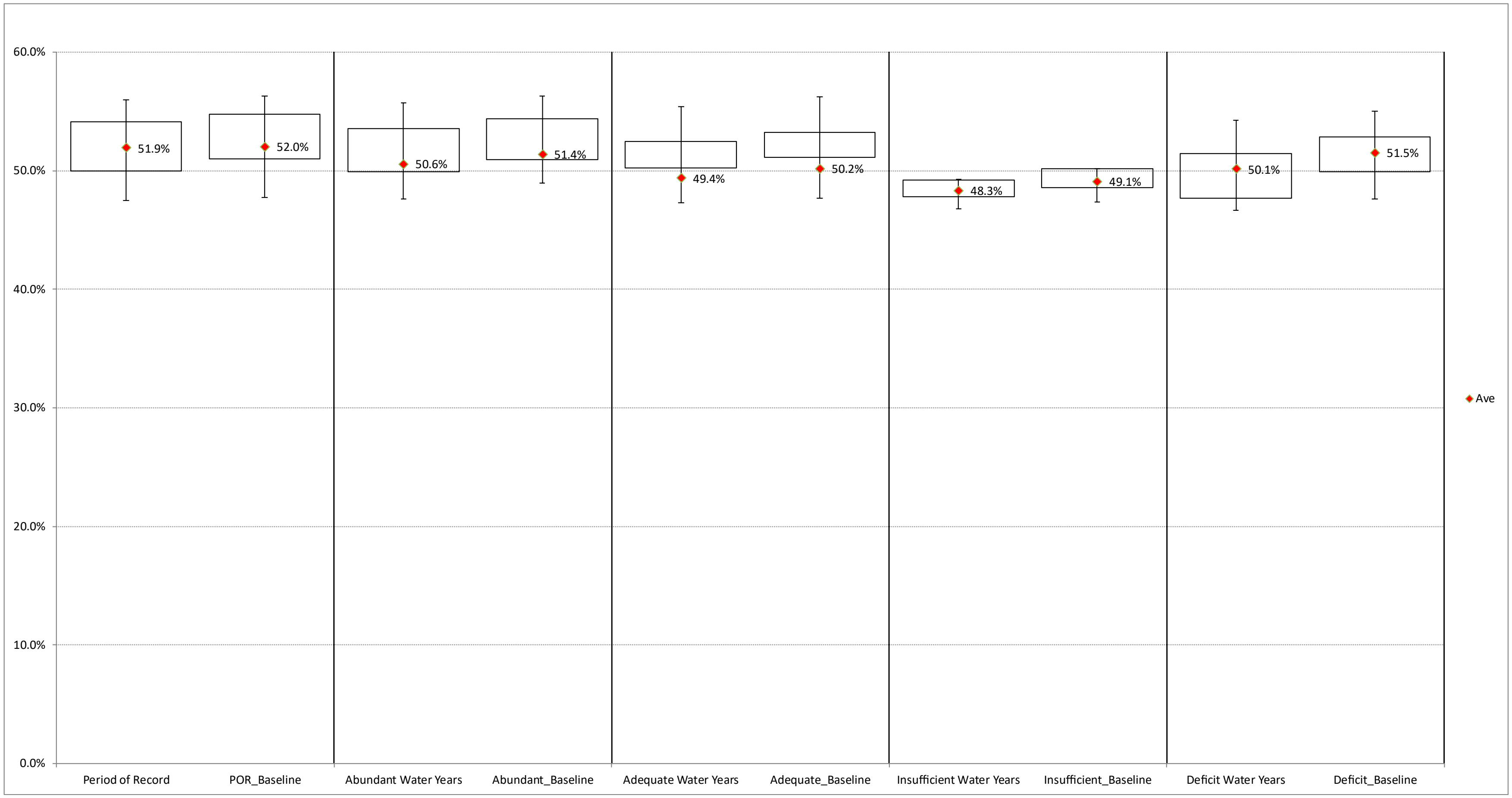


Figure 2-60. Foster For Juvenile Spring Chinook Yearlings Downstream Dam Passage Survival At Under Alternative 3a. *Downstream dam passage survival at Foster for juvenile spring Chinook yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given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

2.5.3 South Santiam – Green Peter

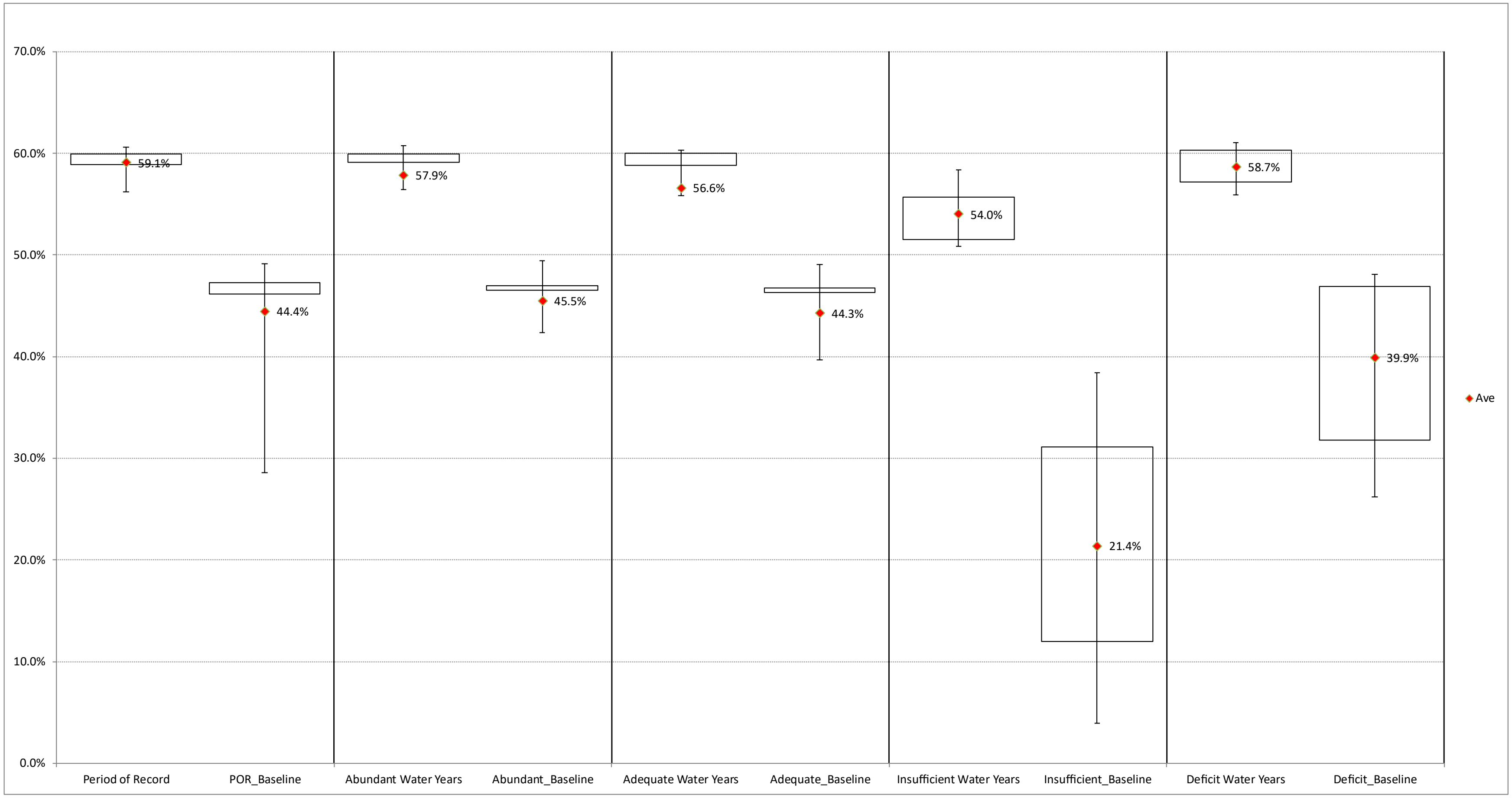


Figure 2-61. Green Peter Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Green Peter for juvenile spring Chinook fry under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the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

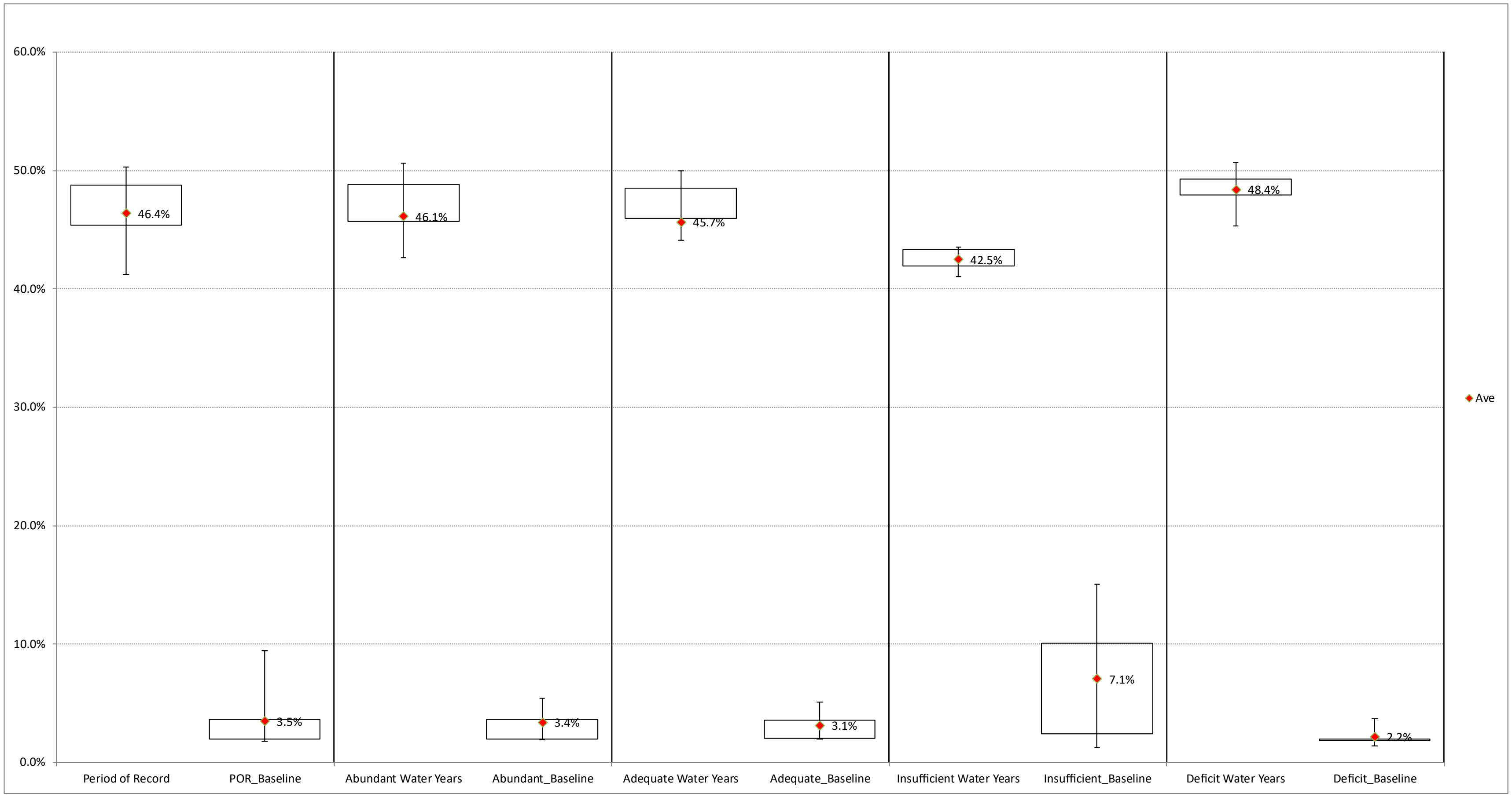


Figure 2-62. Green Peter Juvenile Spring Chinook Sub-Yearlings Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Green Peter for juvenile spring Chinook sub-yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities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

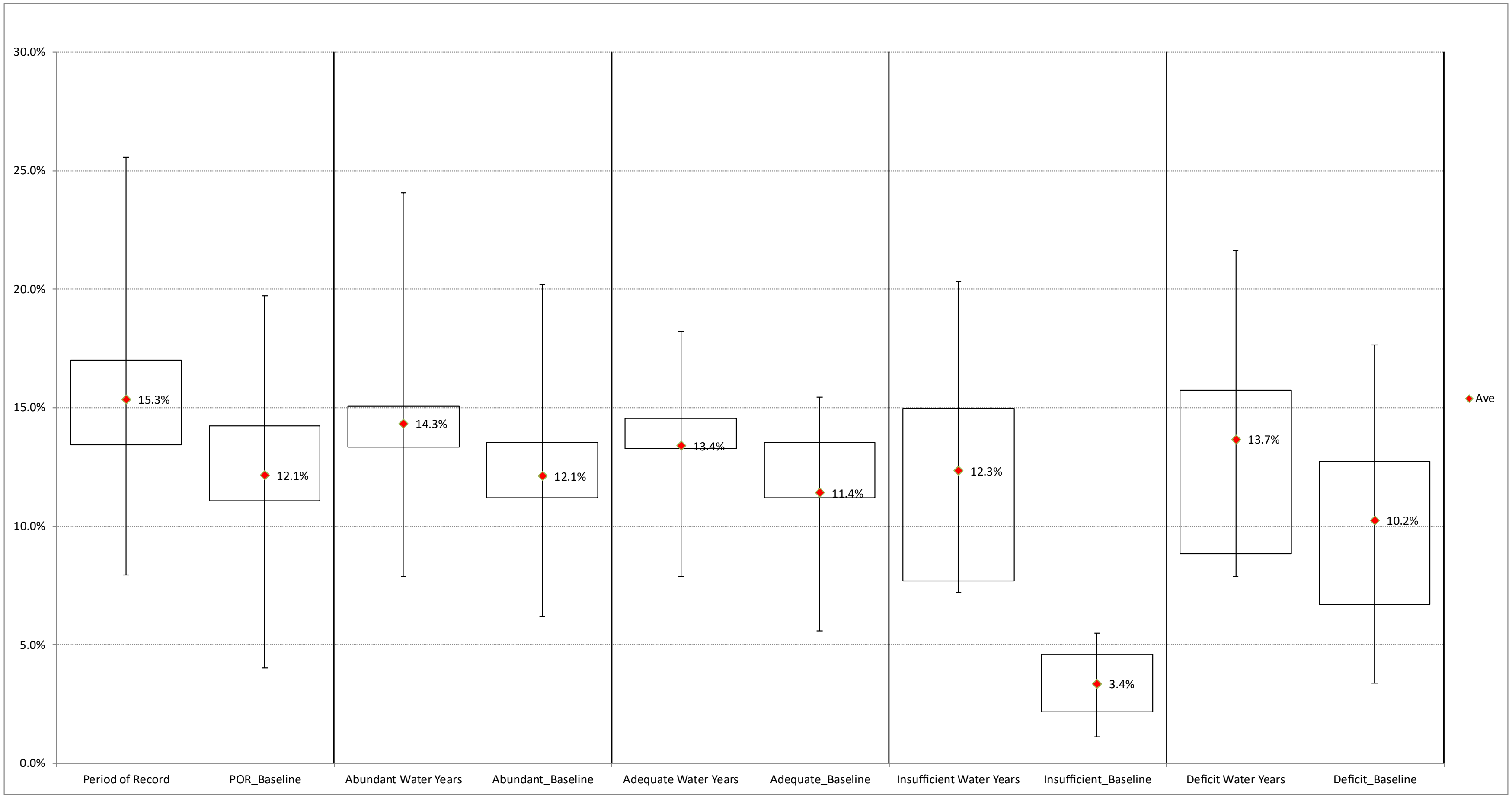


Figure 2-63. Green Peter Juvenile Spring Chinook Yearlings Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Green Peter for juvenile spring Chinook yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are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

2.5.4 McKenzie - Cougar

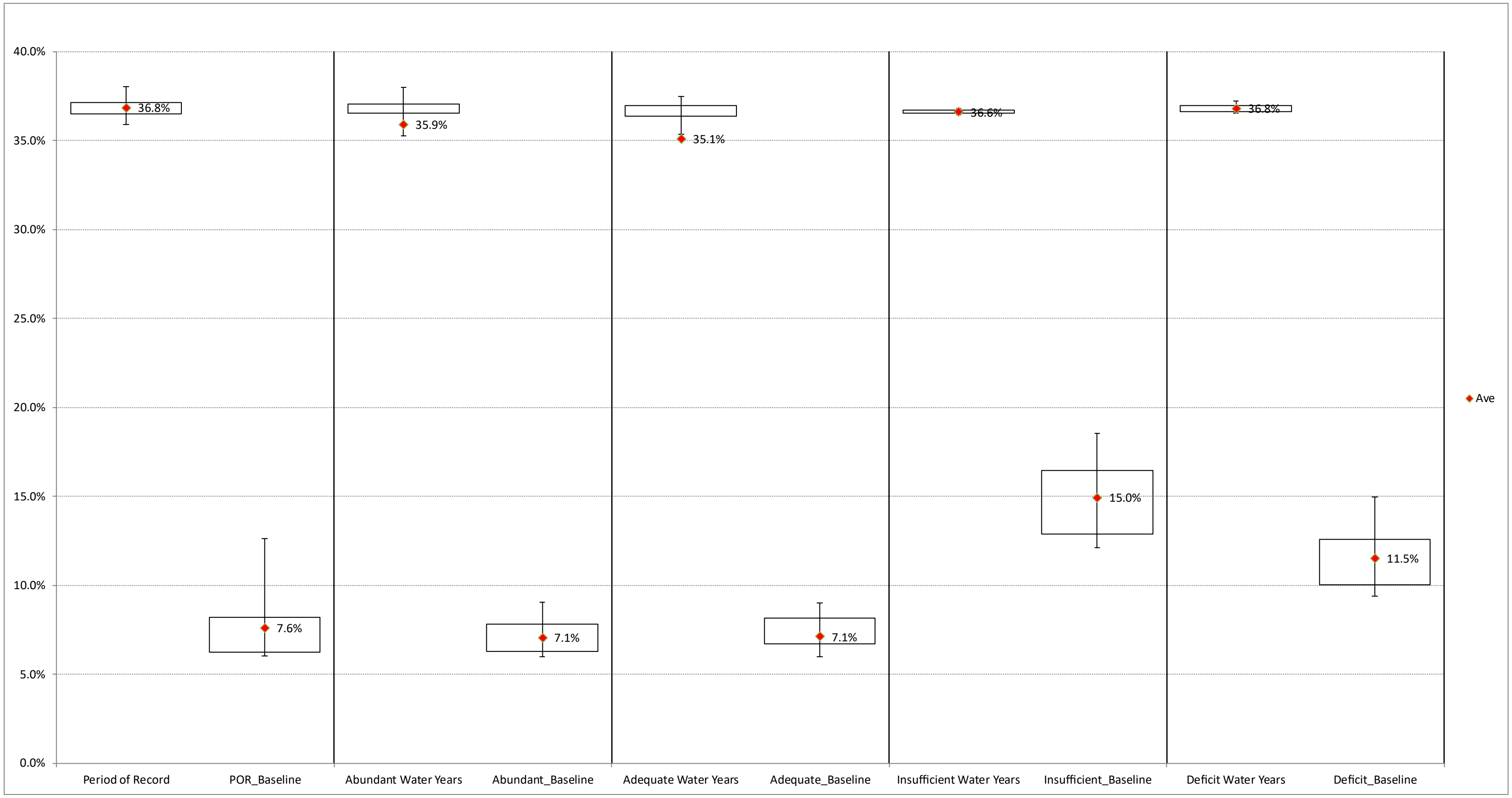


Figure 2-64. Cougar Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Cougar for juvenile spring Chinook fry under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period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

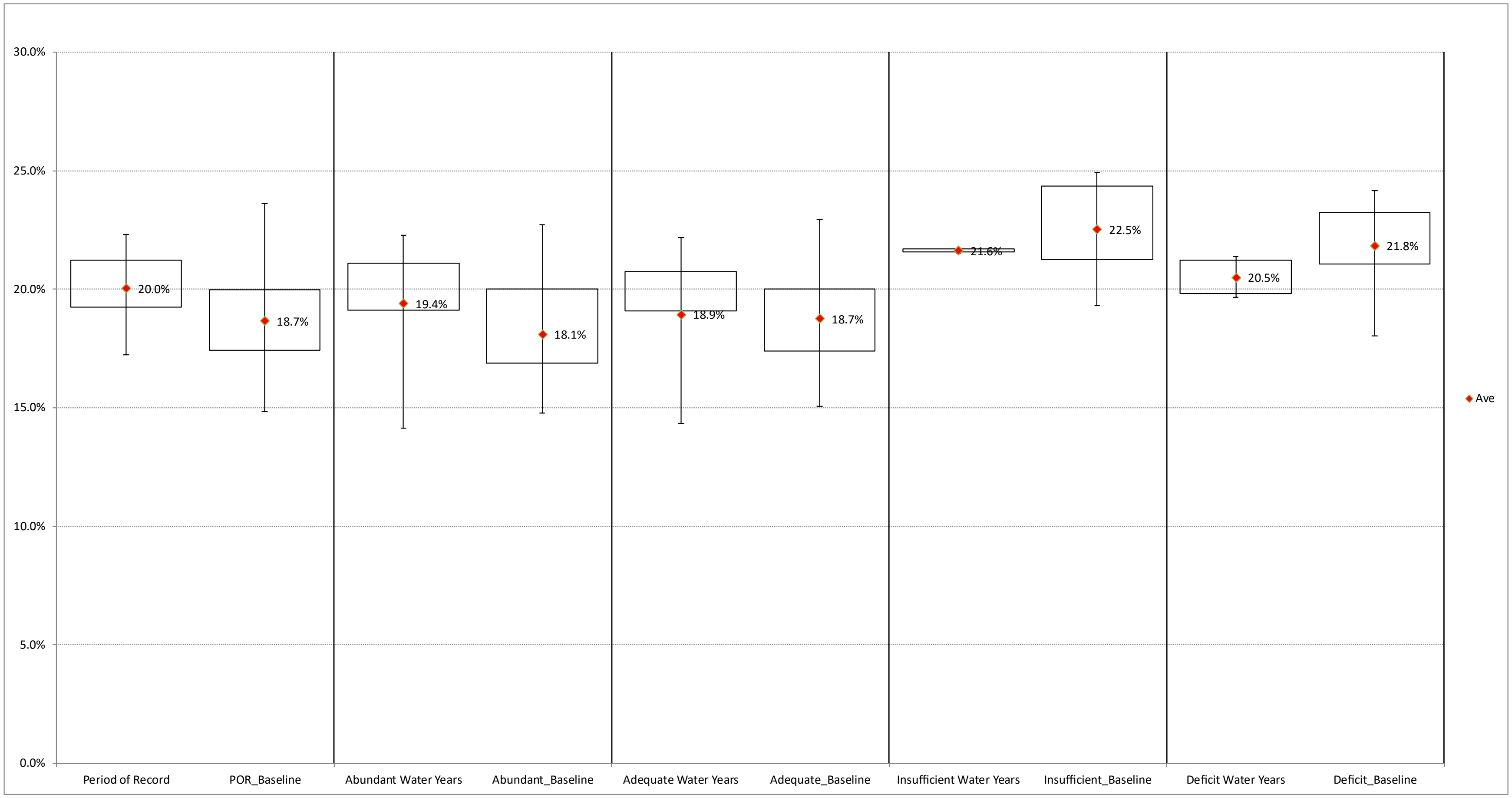


Figure 2-65. Cougar Juvenile Spring Chinook Sub-Yearlings Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Cougar for juvenile spring Chinook sub-yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

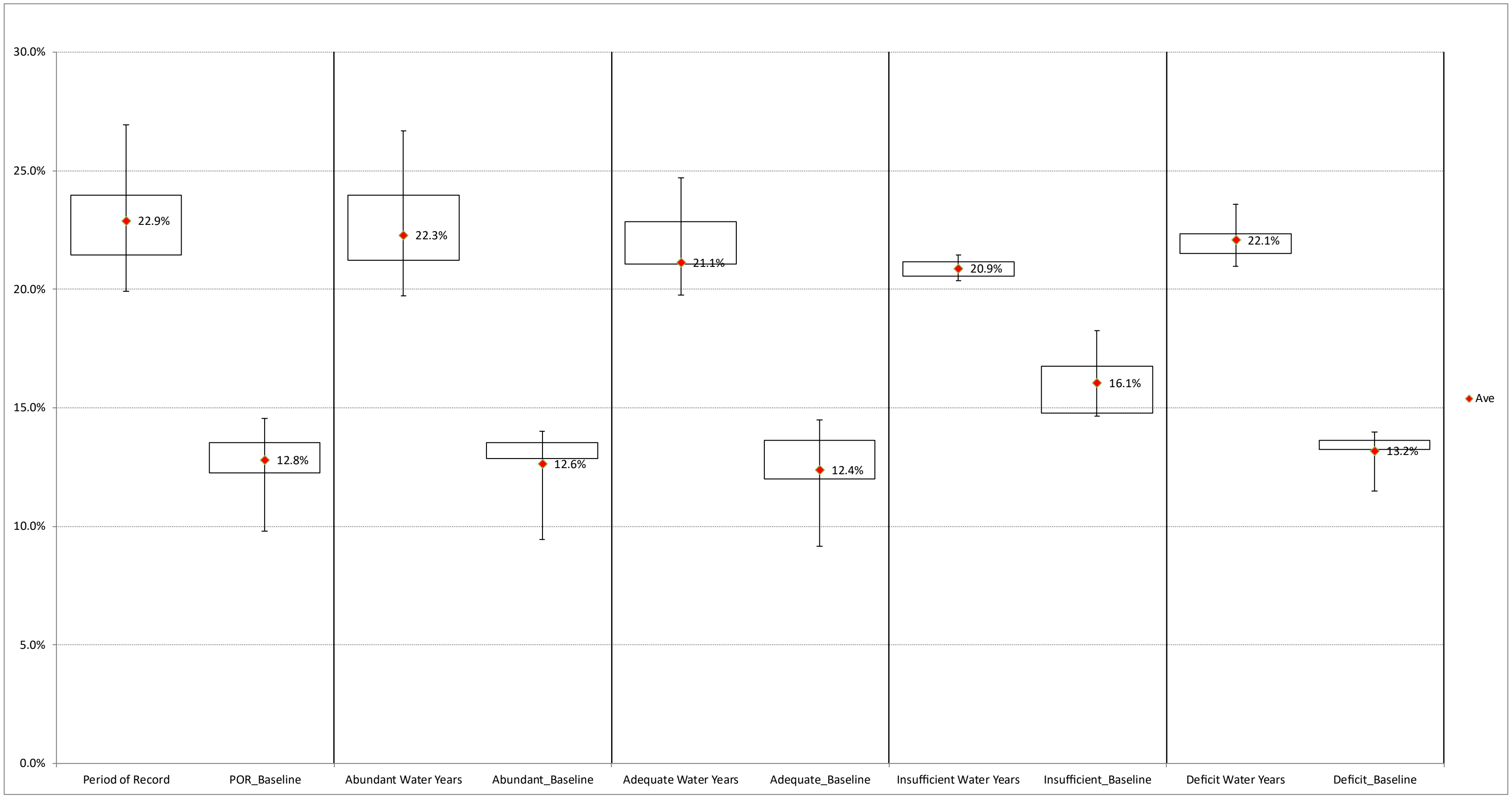


Figure 2-66. Cougar Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Cougar for juvenile spring Chinook yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

2.5.5 Middle Fork – Lookout Point

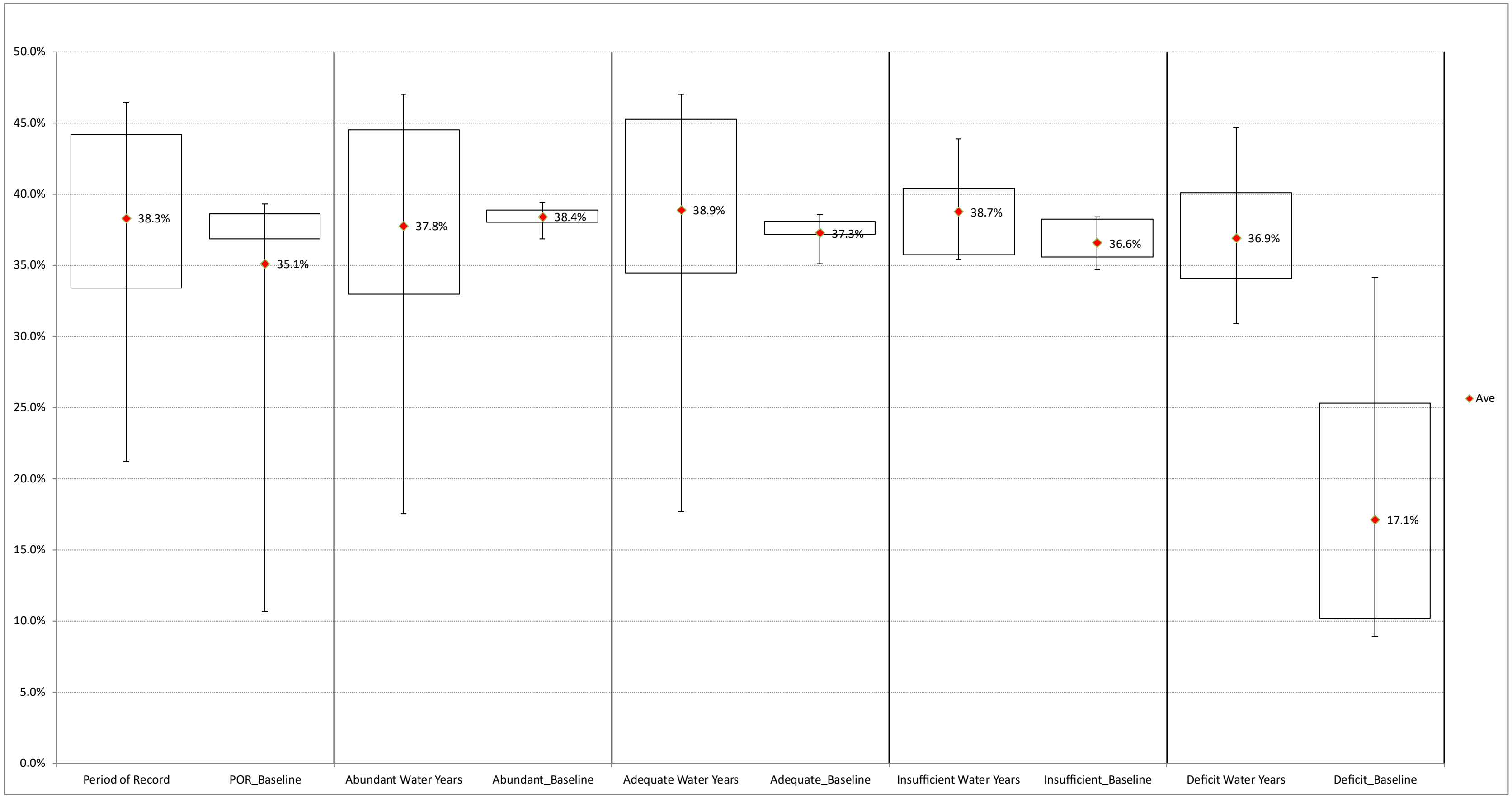


Figure 2-67. Lookout Point Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook fry under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for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

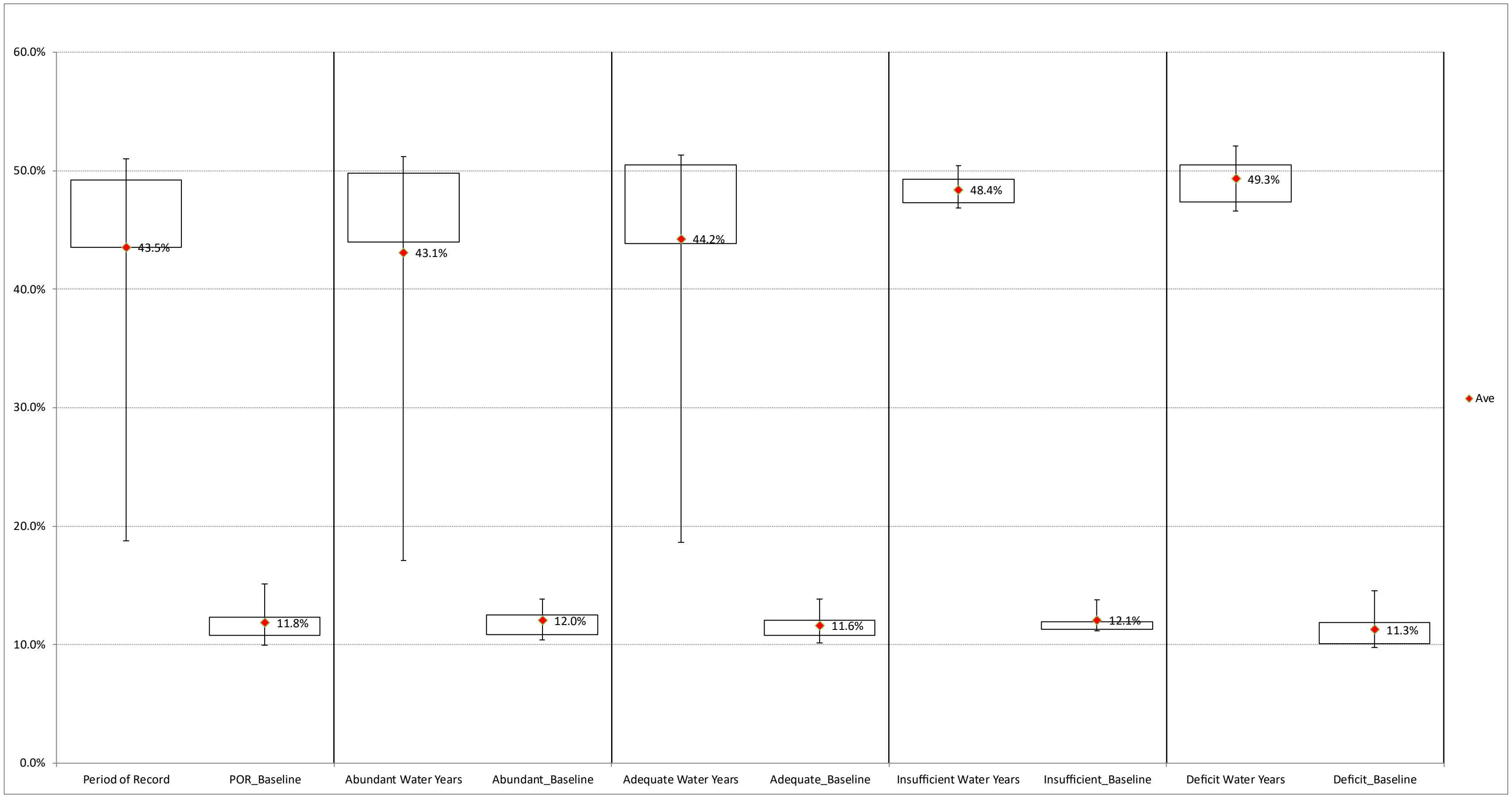


Figure 2-68. Lookout Point Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 3a.
Downstream dam passage survival at Lookout Point for juvenile spring Chinook sub-yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities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

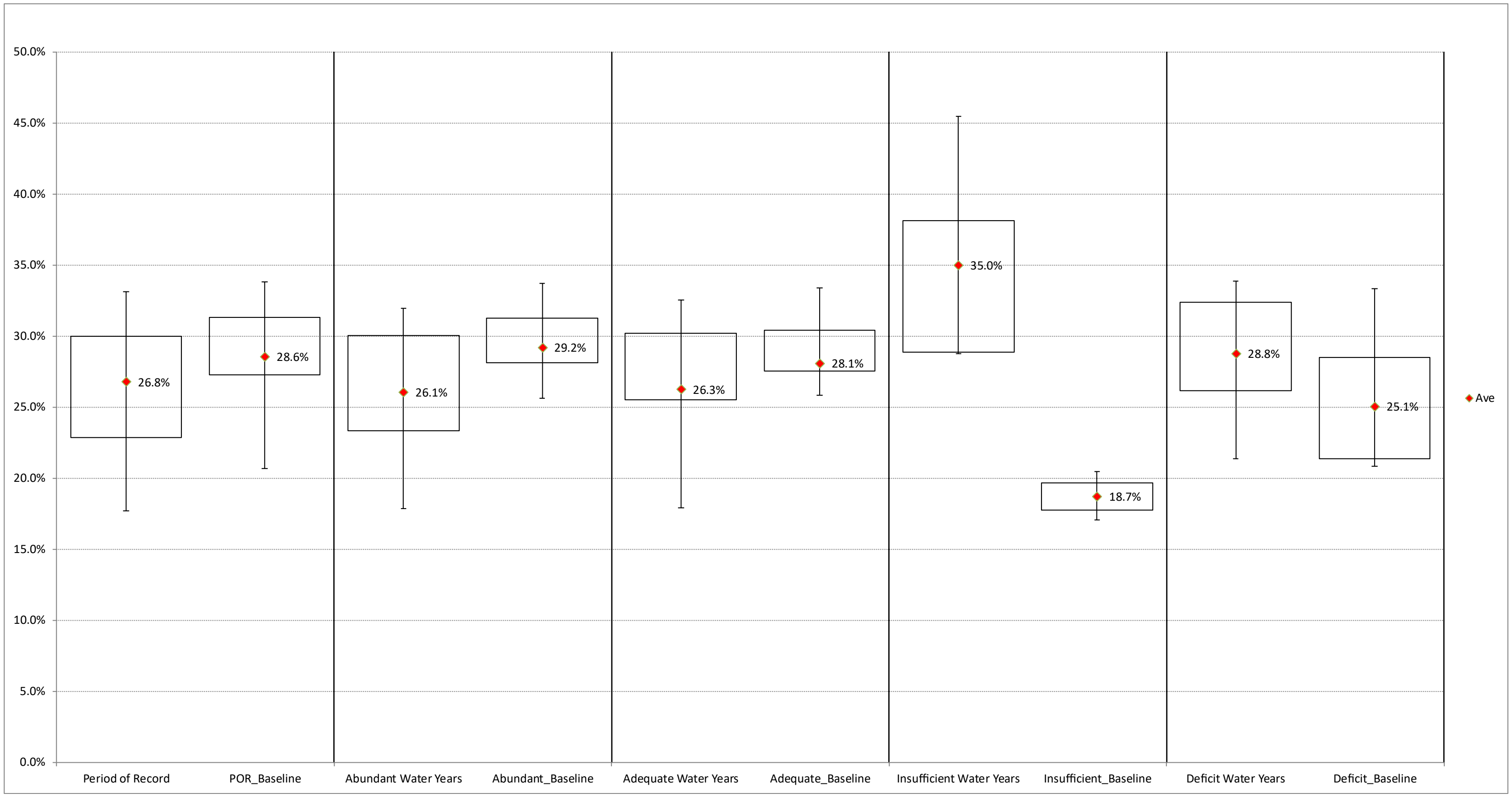


Figure 2-69. Lookout Point Juvenile Spring Chinook Yearlings Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities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

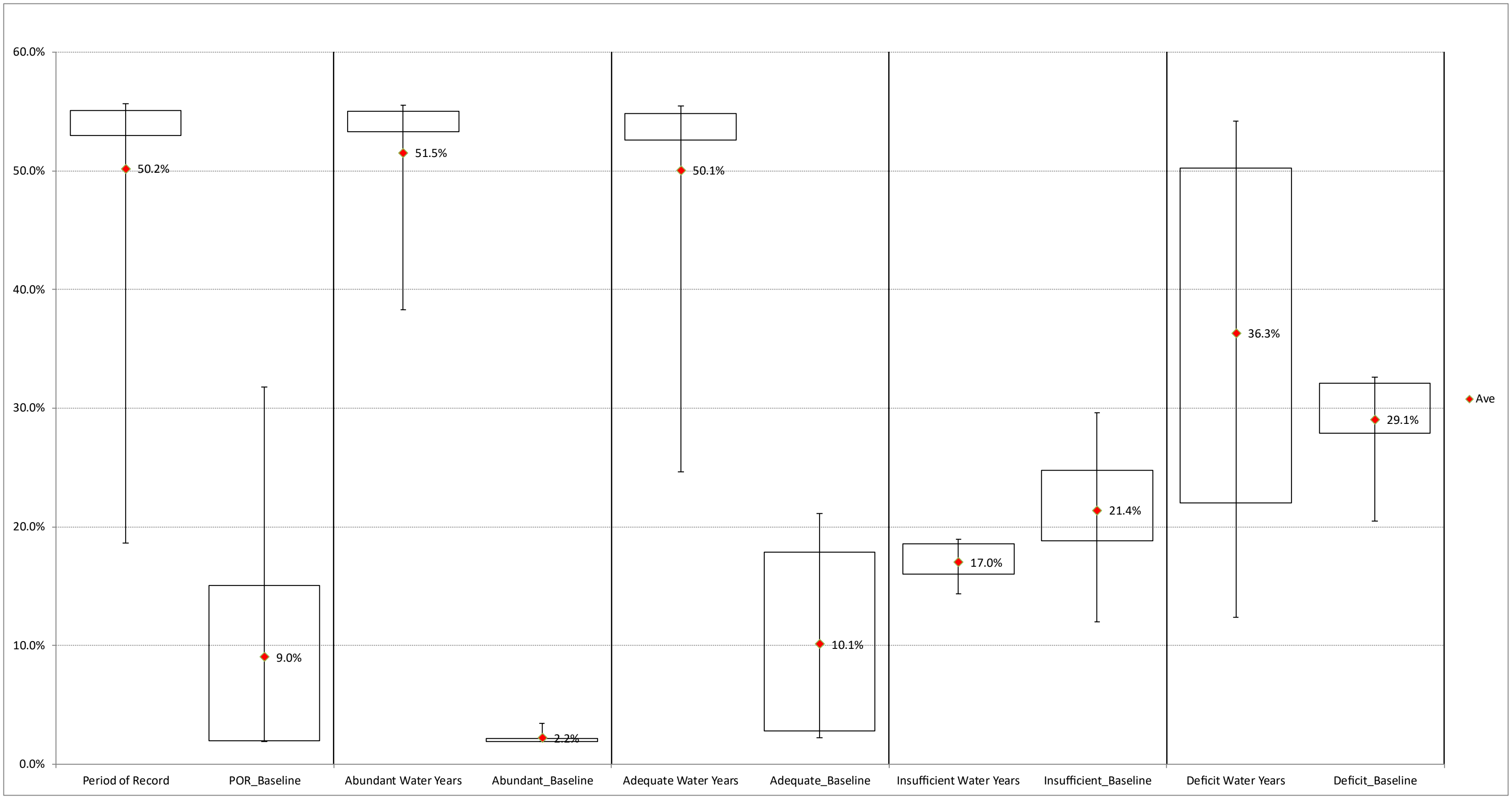


Figure 2-70. Hills Creek Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook fry under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given for the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

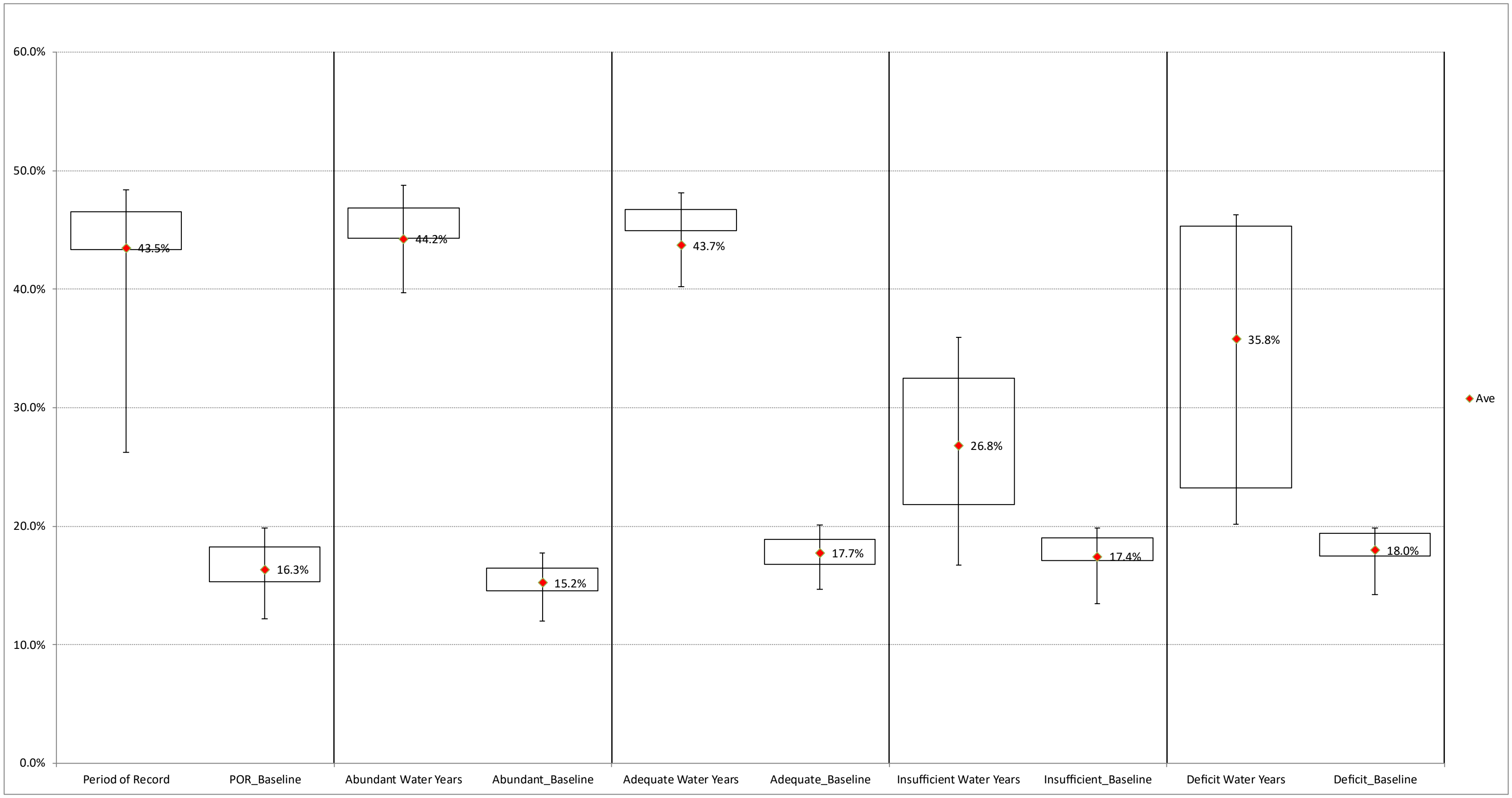


Figure 2-71. Hills Creek Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook sub-yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities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

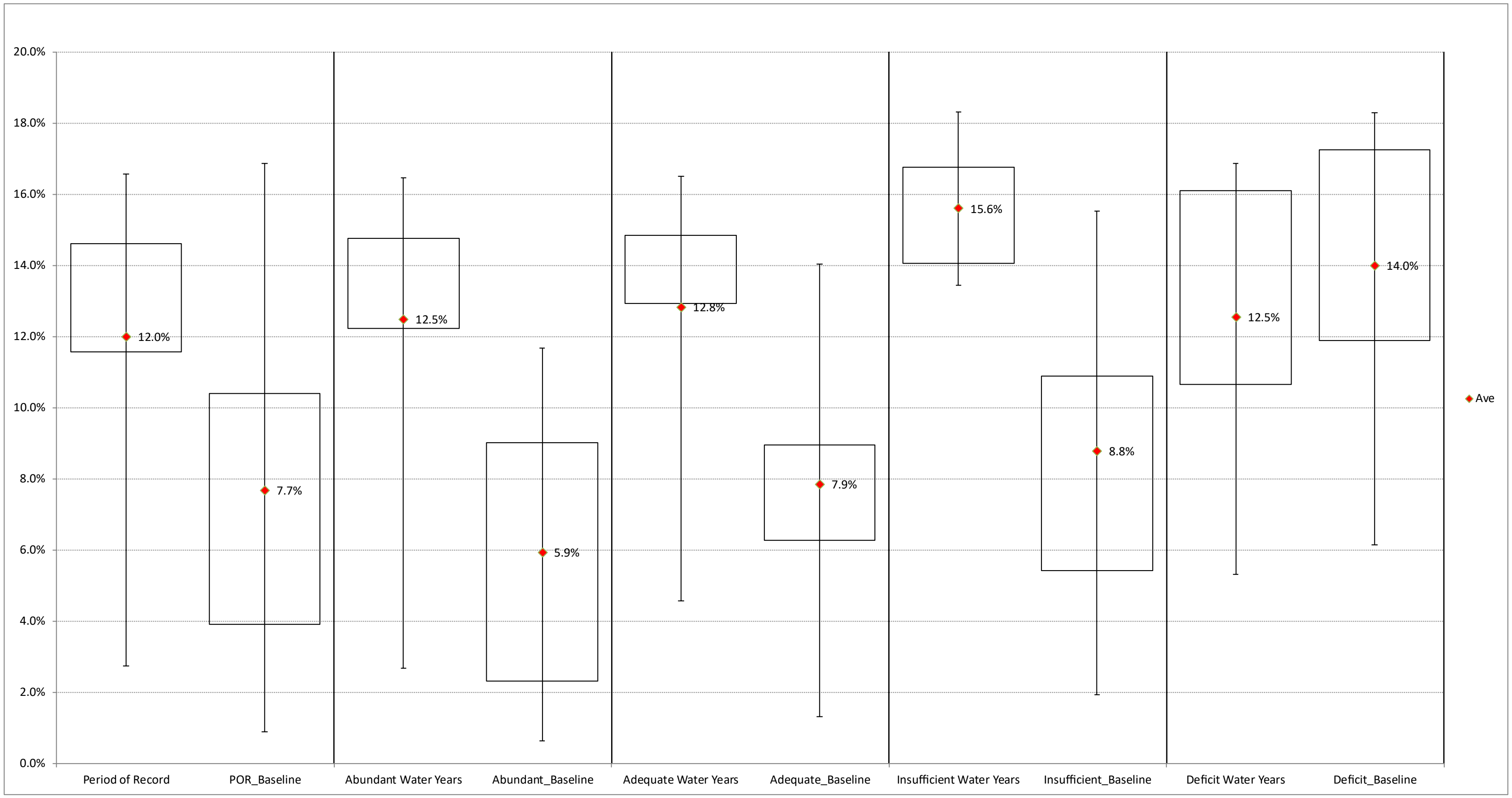


Figure 2-72. Downstream dam passage survival at Hills Creek for juvenile spring Chinook yearlings under Alternative 3a. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities 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

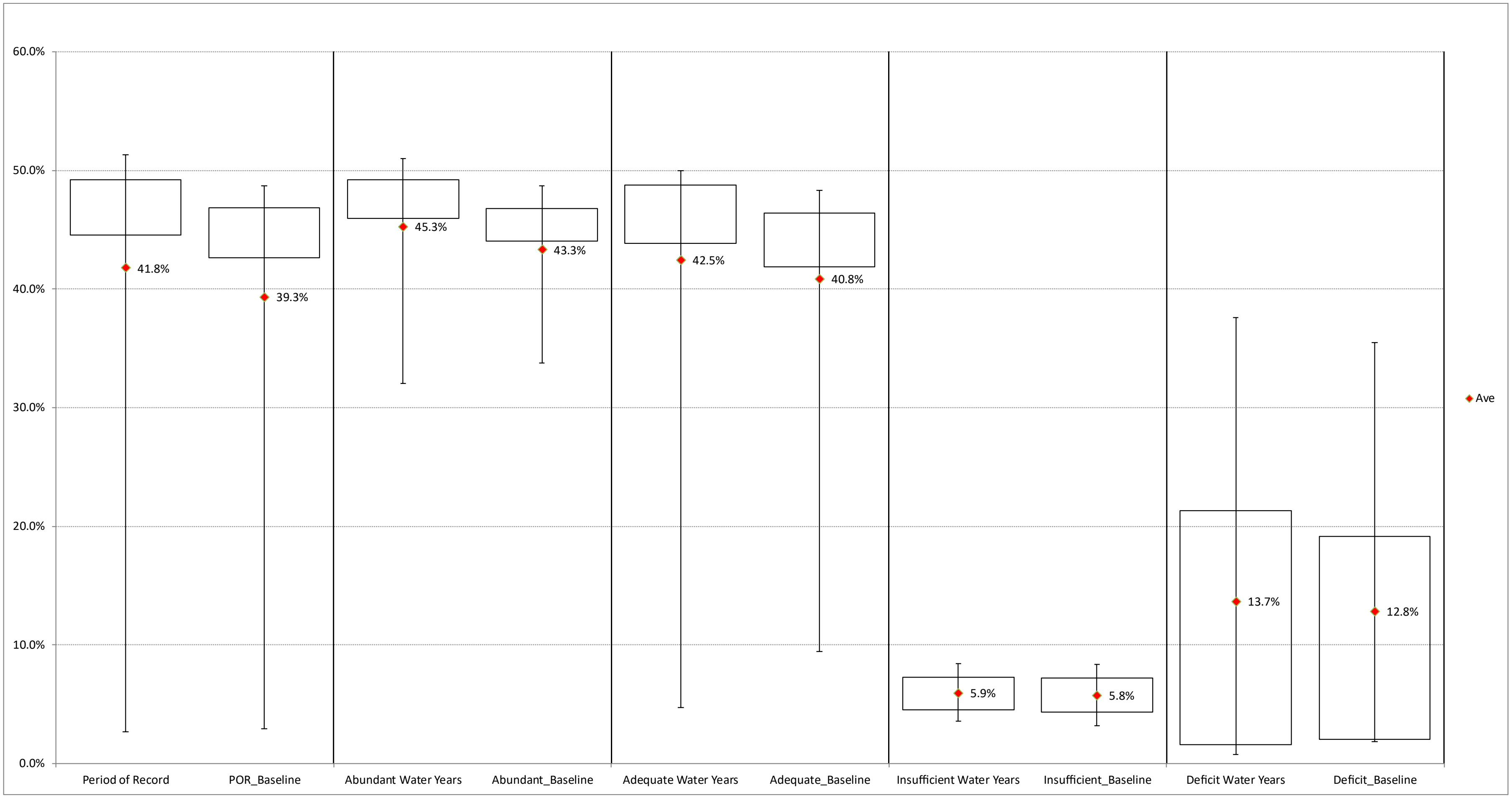


Figure 2-73. Detroit Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Detroit for juvenile spring Chinook fry under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period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

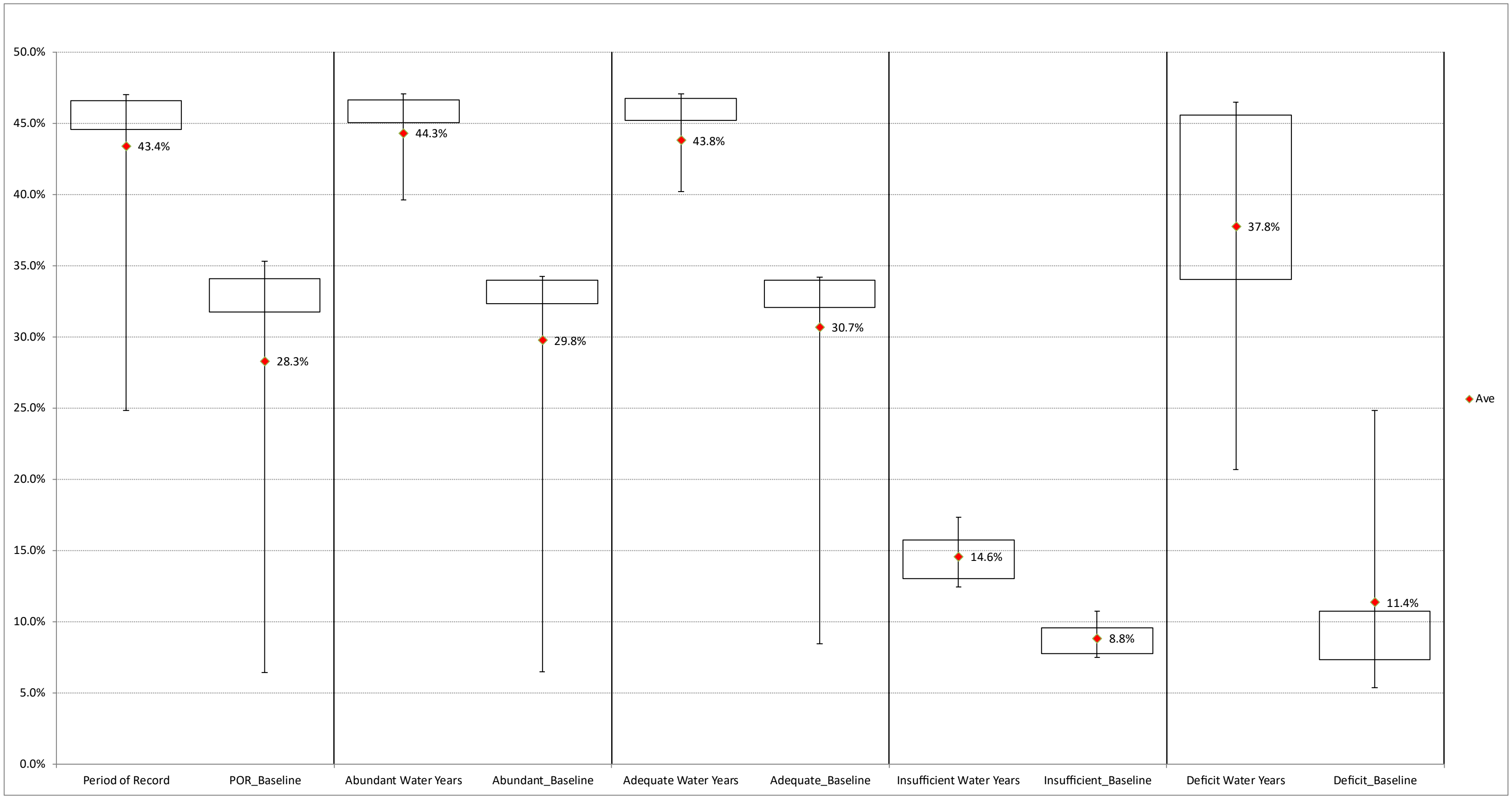


Figure 2-74. Detroit Juvenile Spring Chinook Sub-Yearlings Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Detroit for juvenile spring Chinook sub-yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are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

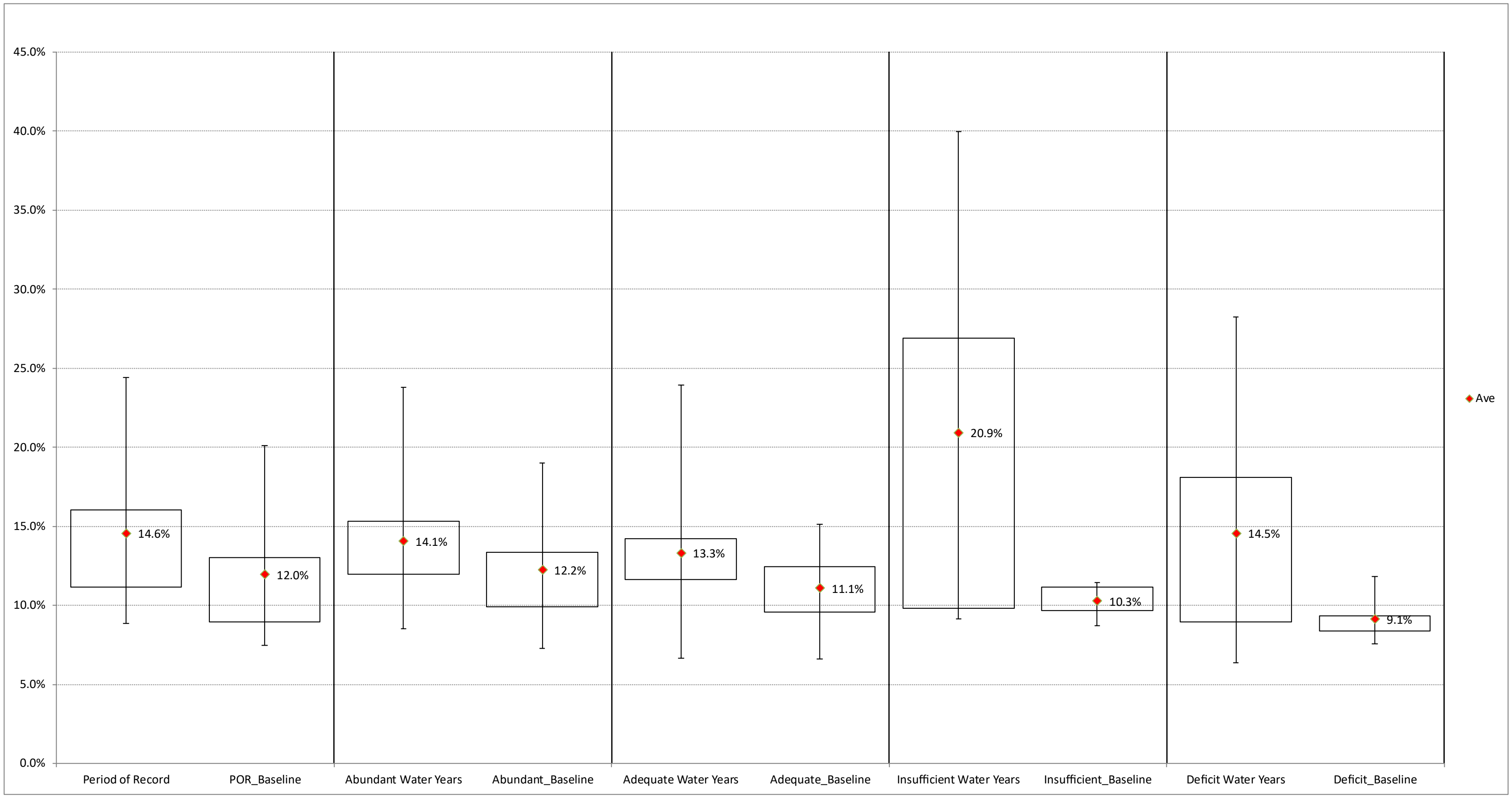


Figure 2-75. Detroit Juvenile Spring Chinook Yearlings Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Detroit for juvenile spring Chinook yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for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

2.6.2 South Santiam – Foster

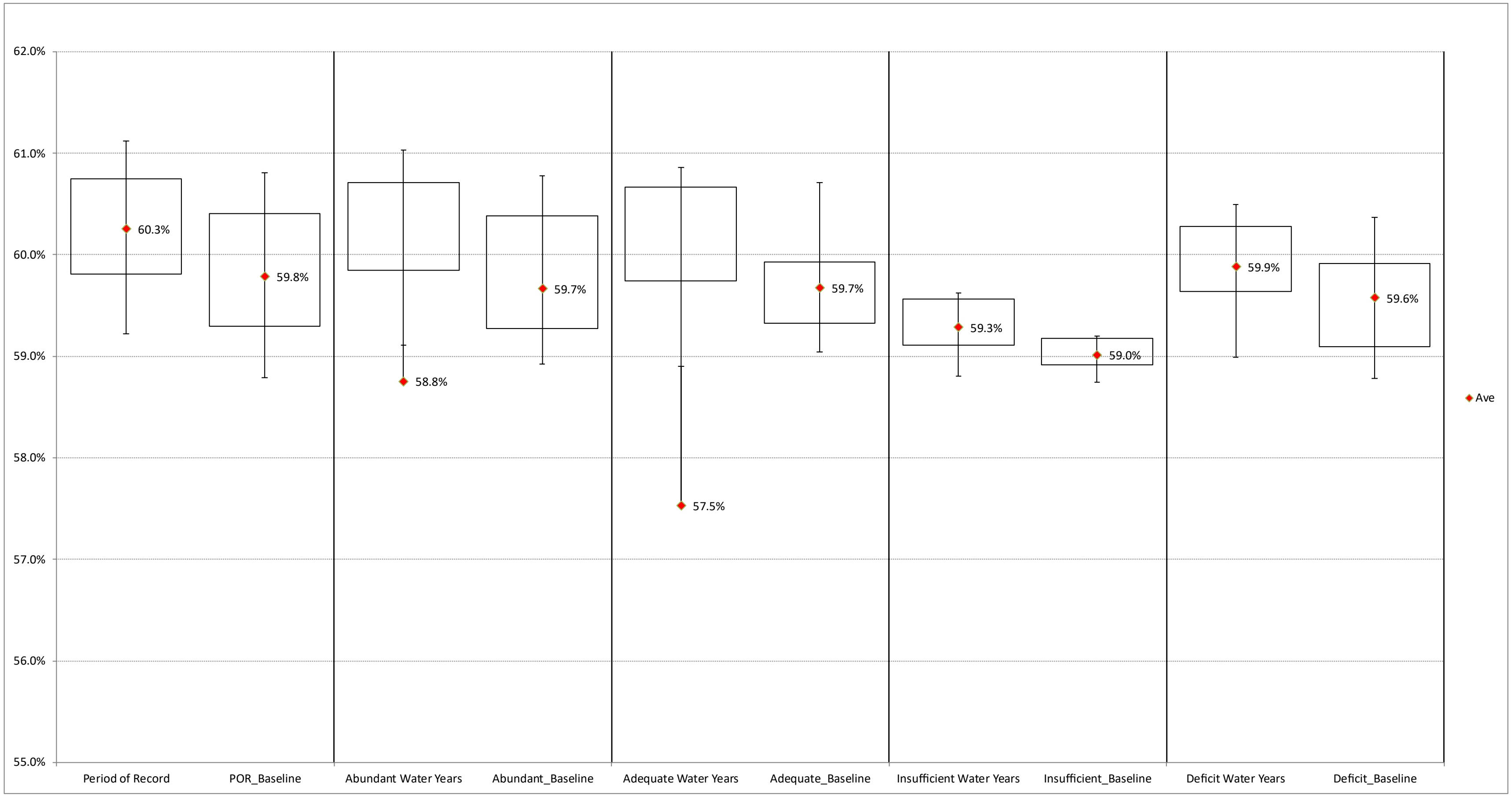


Figure 2-76. Foster Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Foster for juvenile spring Chinook fry under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period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

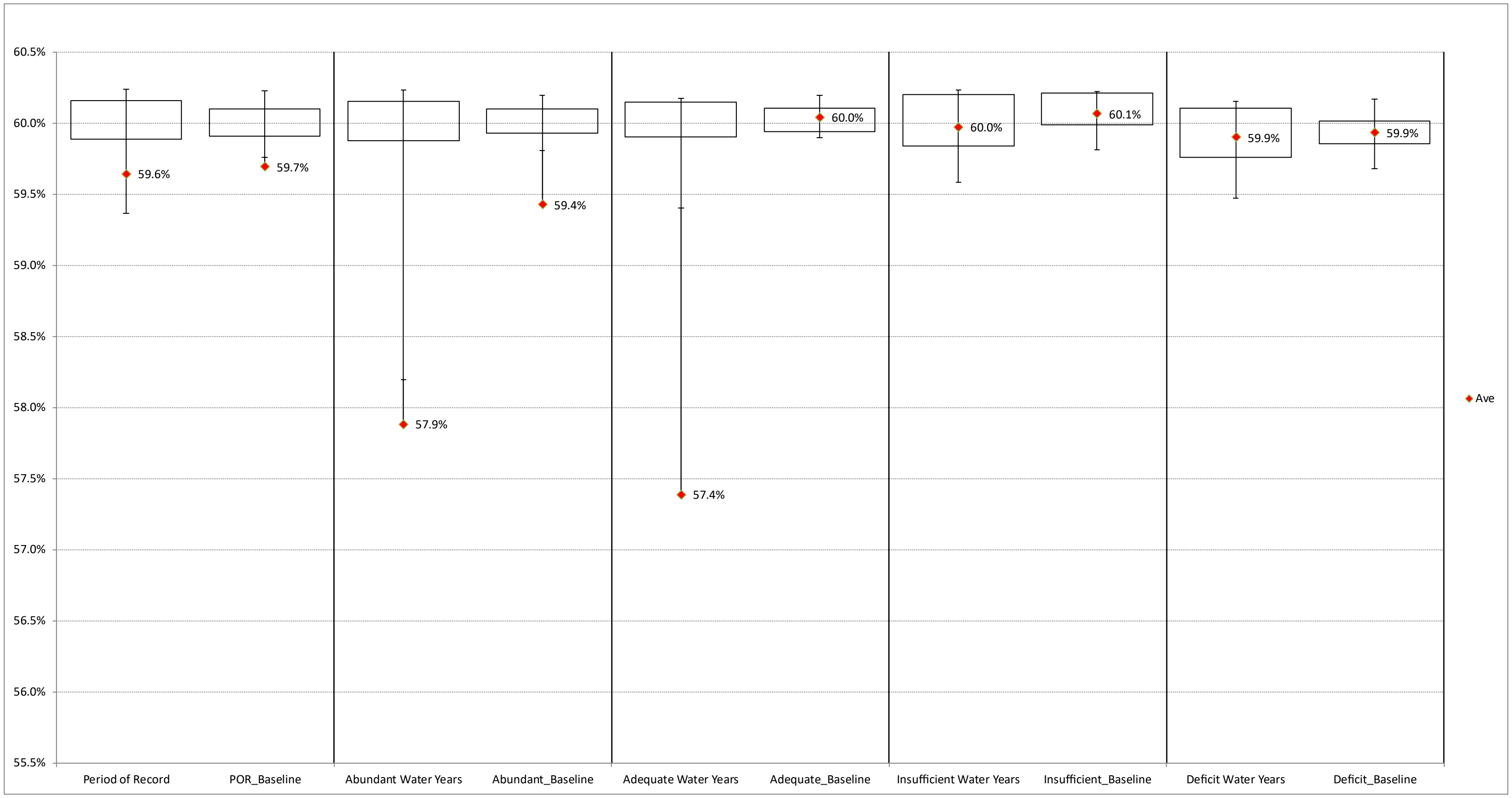


Figure 2-77. Foster Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Foster for juvenile spring Chinook sub-yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given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

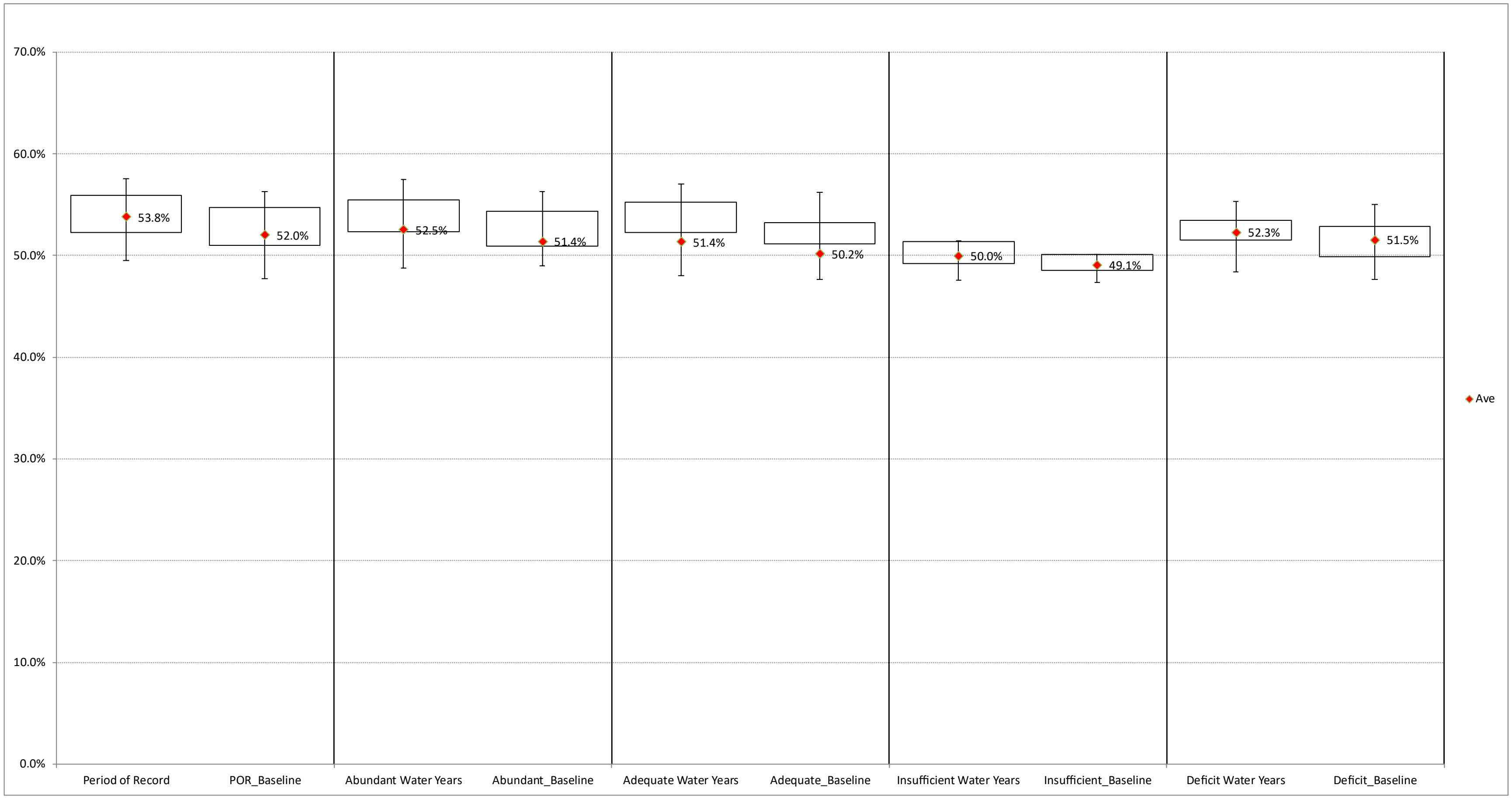


Figure 2-78. Downstream dam passage survival at Foster for juvenile spring Chinook yearlings under Alternative 3b. *Downstream dam passage survival at Foster for juvenile spring Chinook yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given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

2.6.3 McKenzie – Cougar

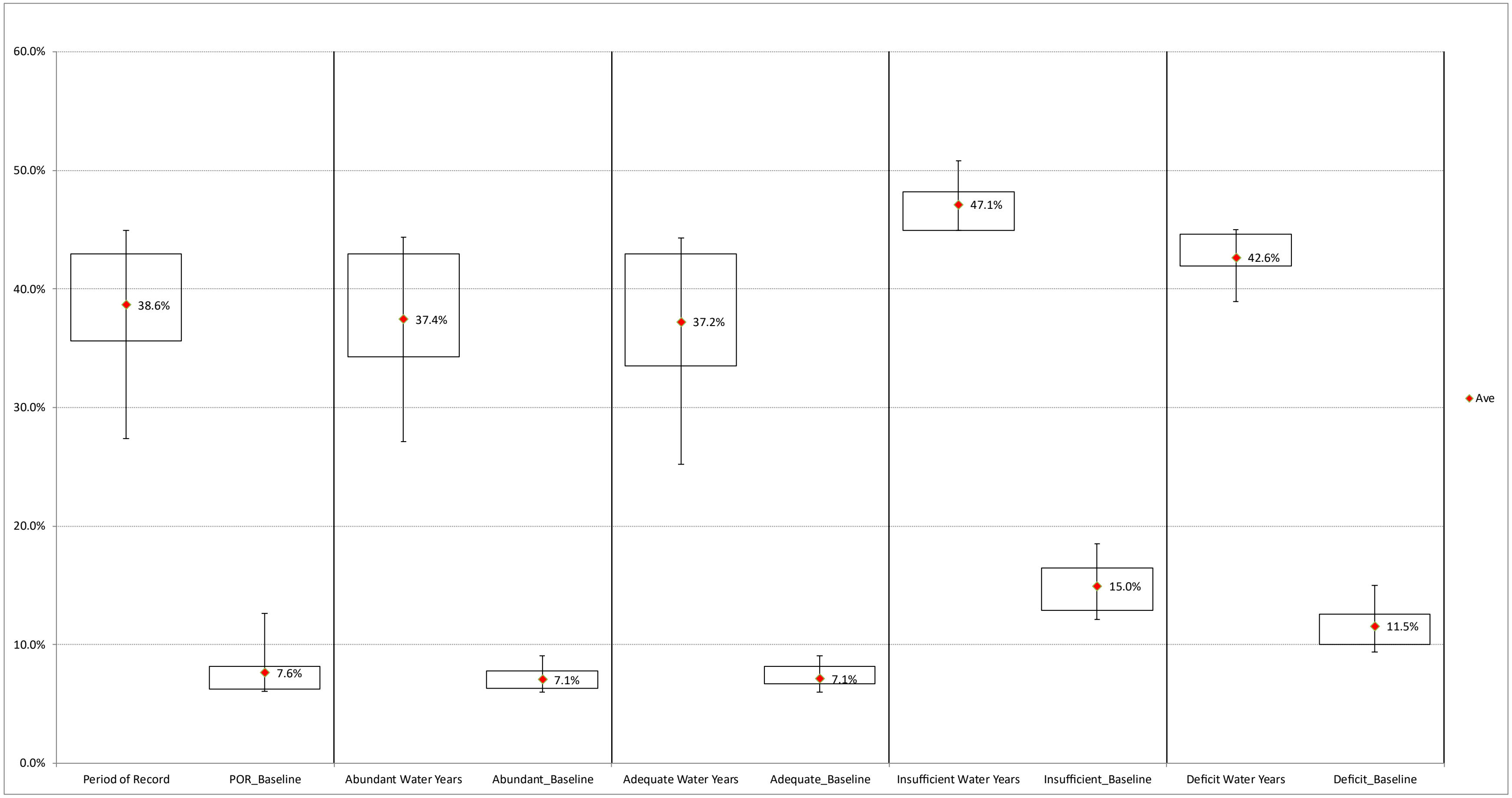


Figure 2-79. Cougar Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Cougar for juvenile spring Chinook fry under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period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

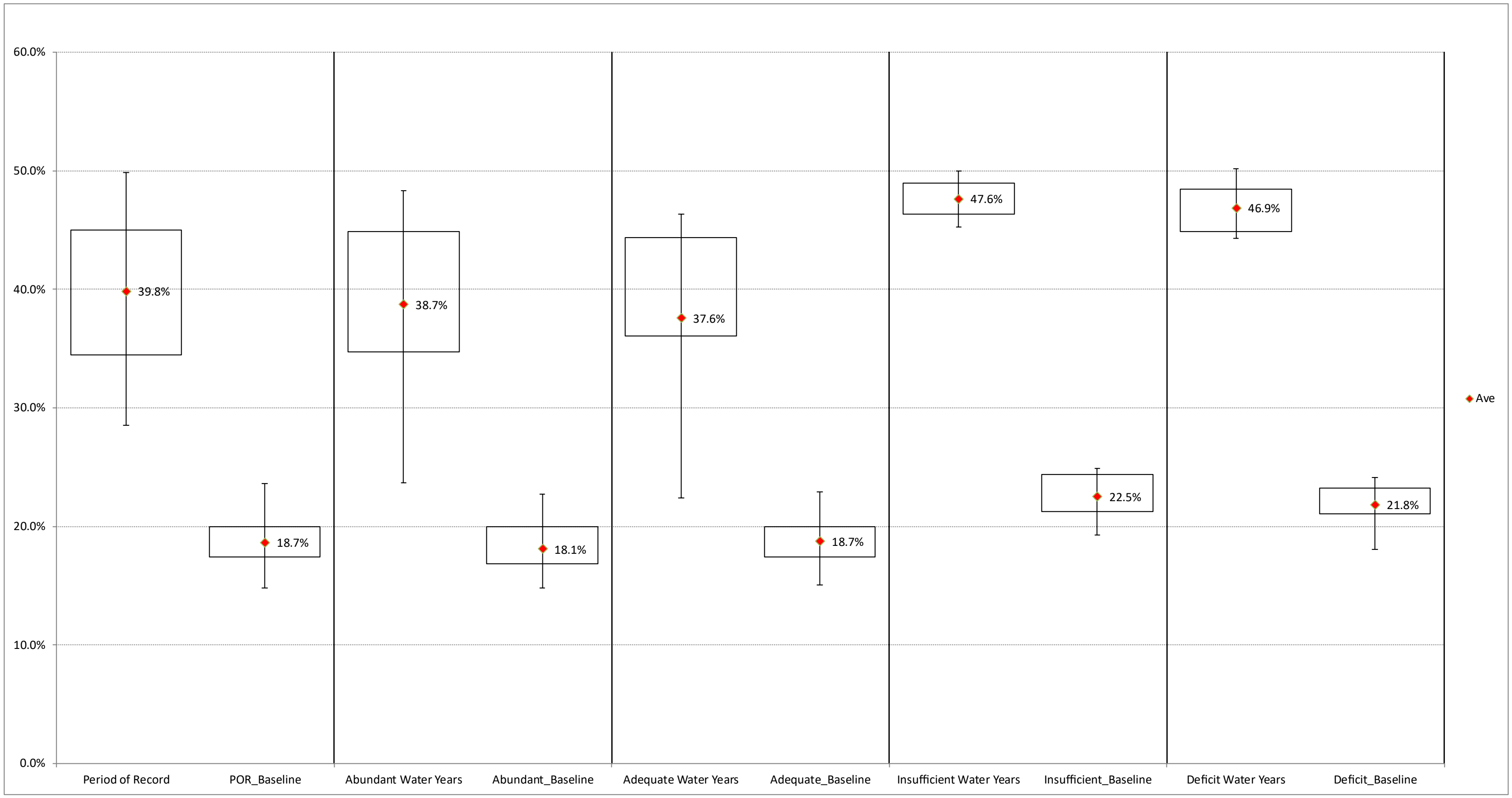


Figure 2-80. Cougar Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Cougar for juvenile spring Chinook sub-yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given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

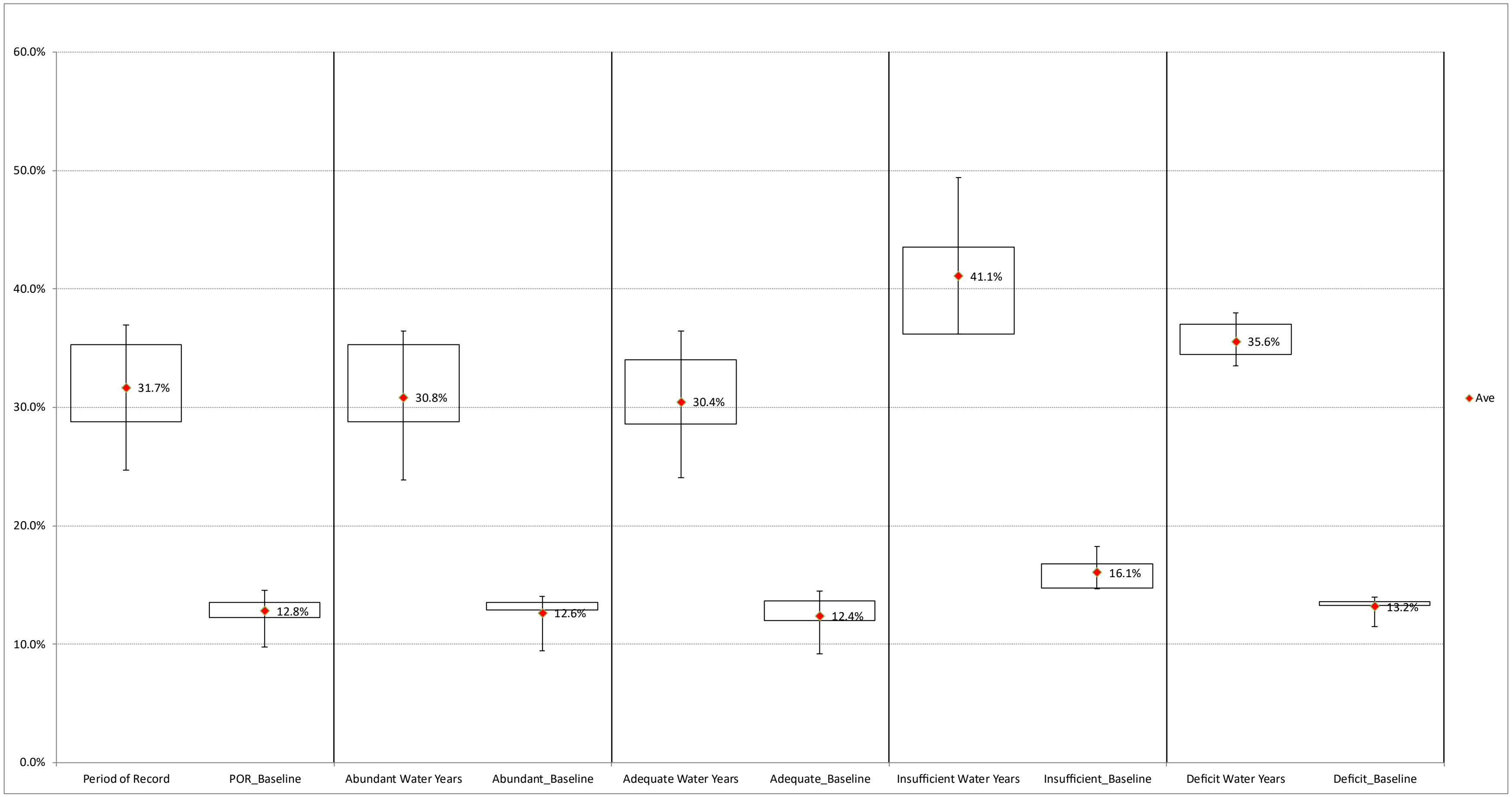


Figure 2-81. Cougar Juvenile Spring Chinook Yearlings Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Cougar for juvenile spring Chinook yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for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

2.6.4 Middle Fork – Lookout Point

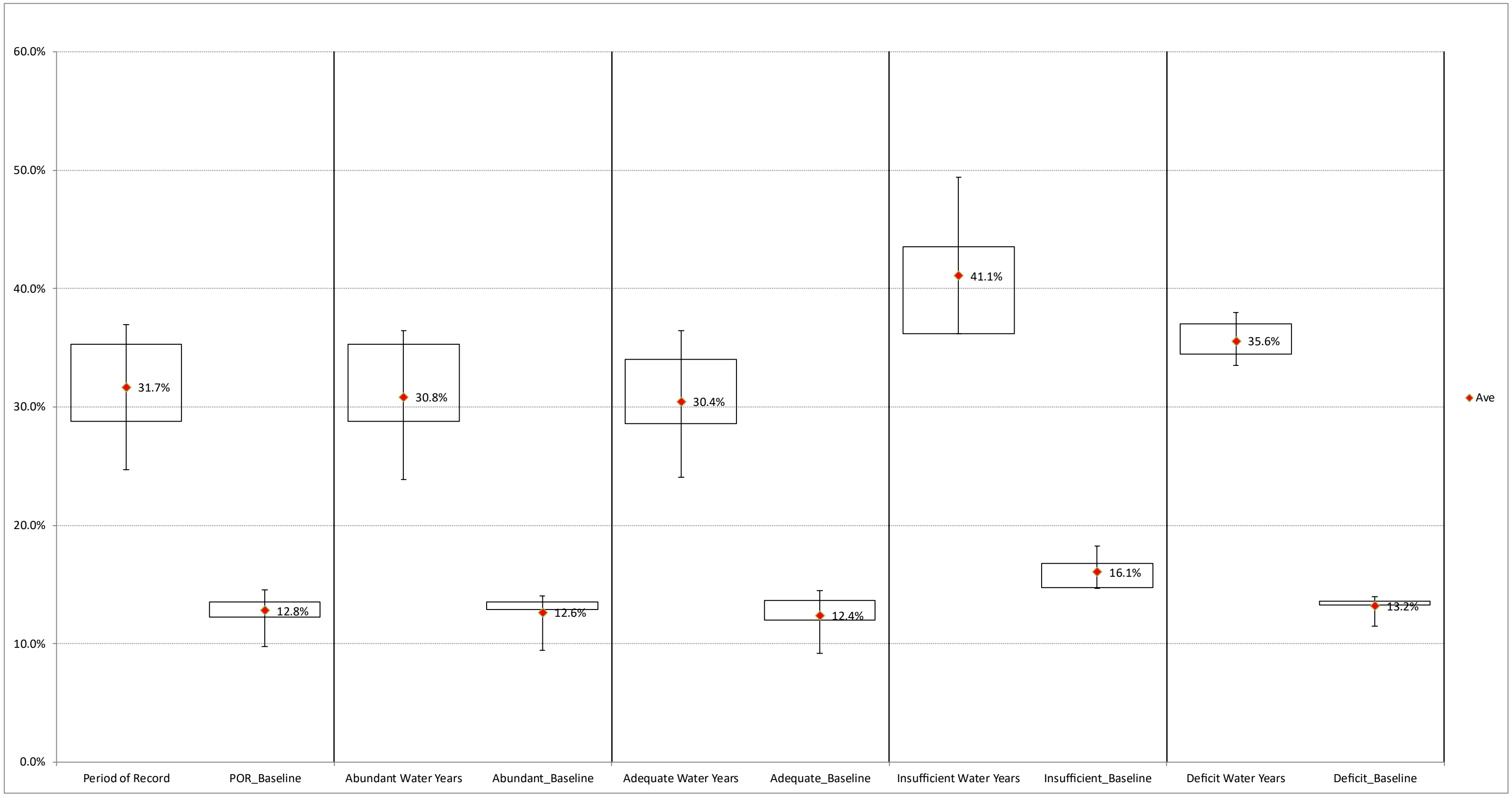


Figure 2-82. Lookout Point Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook fry under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for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

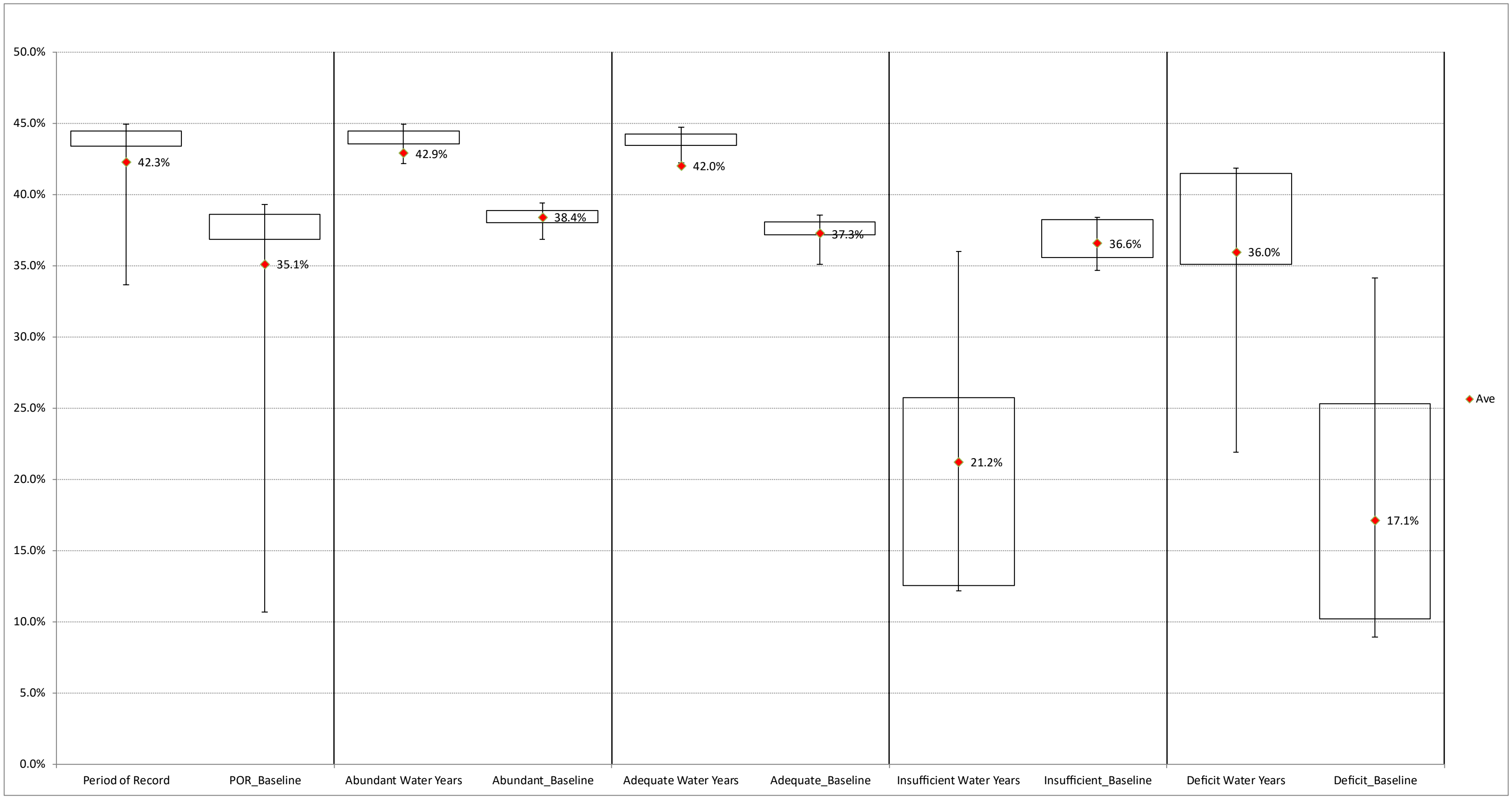


Figure 2-83. Lookout Point Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook sub-yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities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

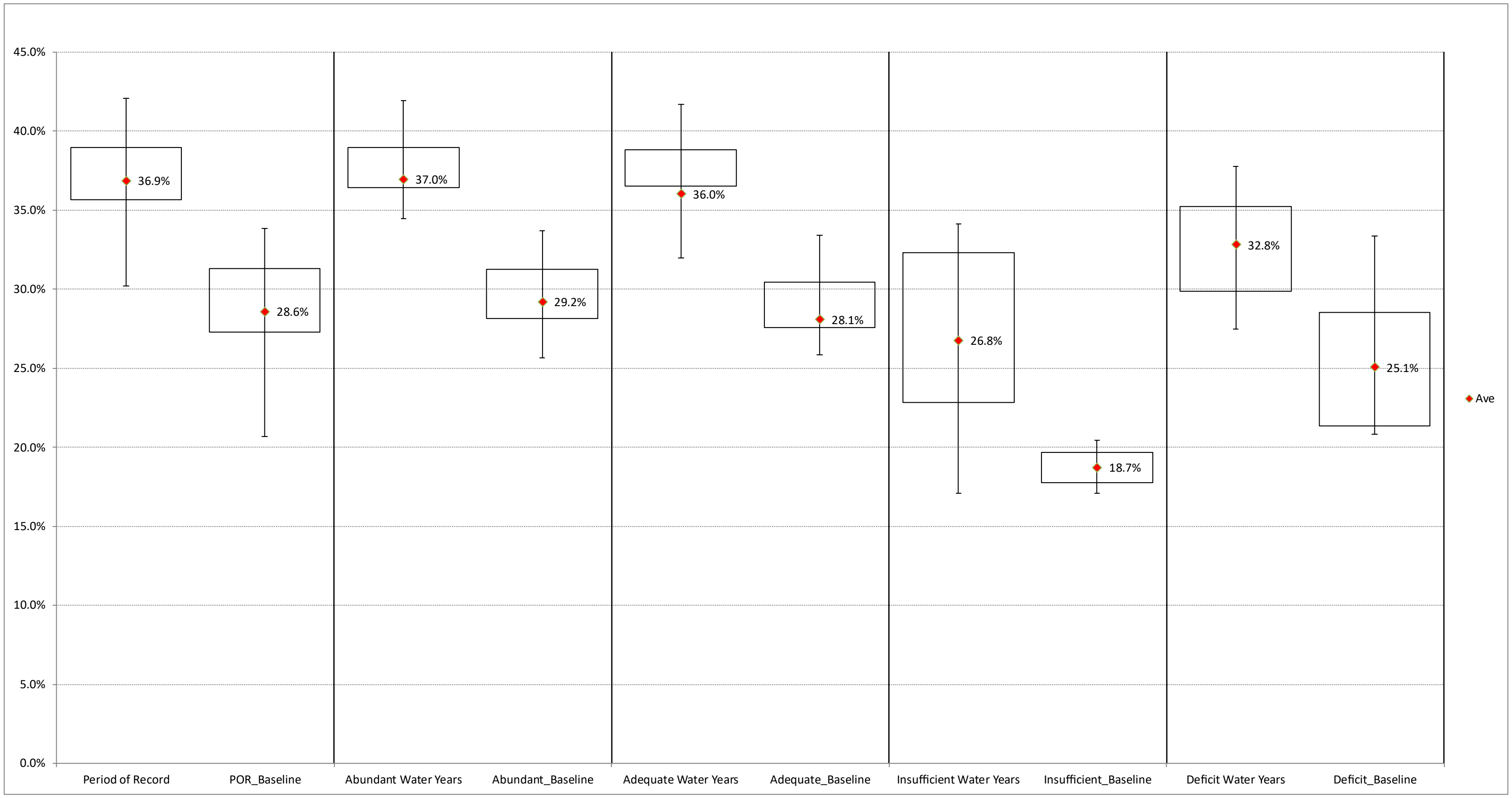


Figure 2-84. Lookout Point for juvenile spring Chinook yearling Downstream dam passage survival under Alternative 3b*.*
Downstream dam passage survival at Lookout Point for juvenile spring Chinook yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.

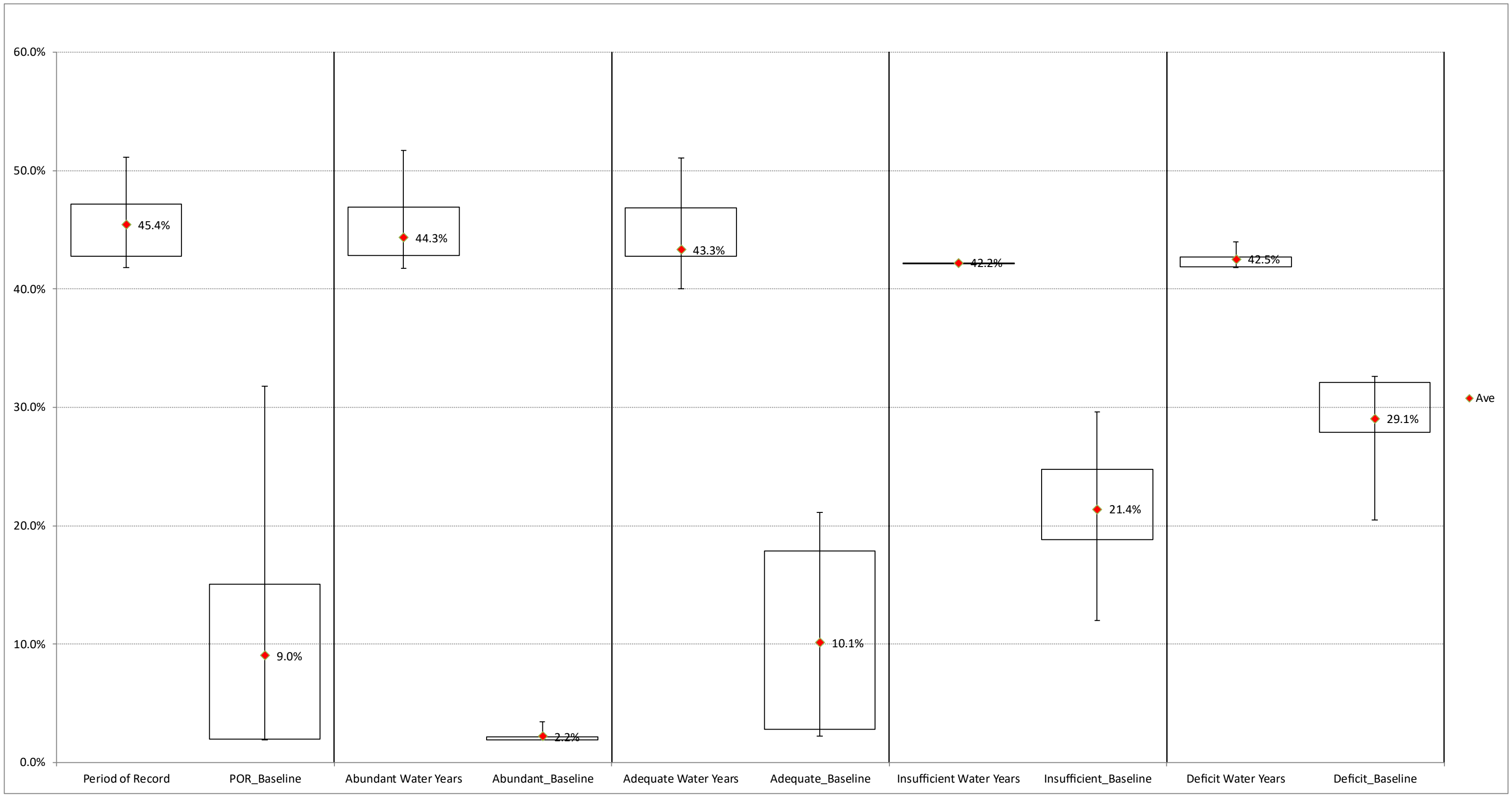


Figure 2-85. Hills Creek Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook fry under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the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

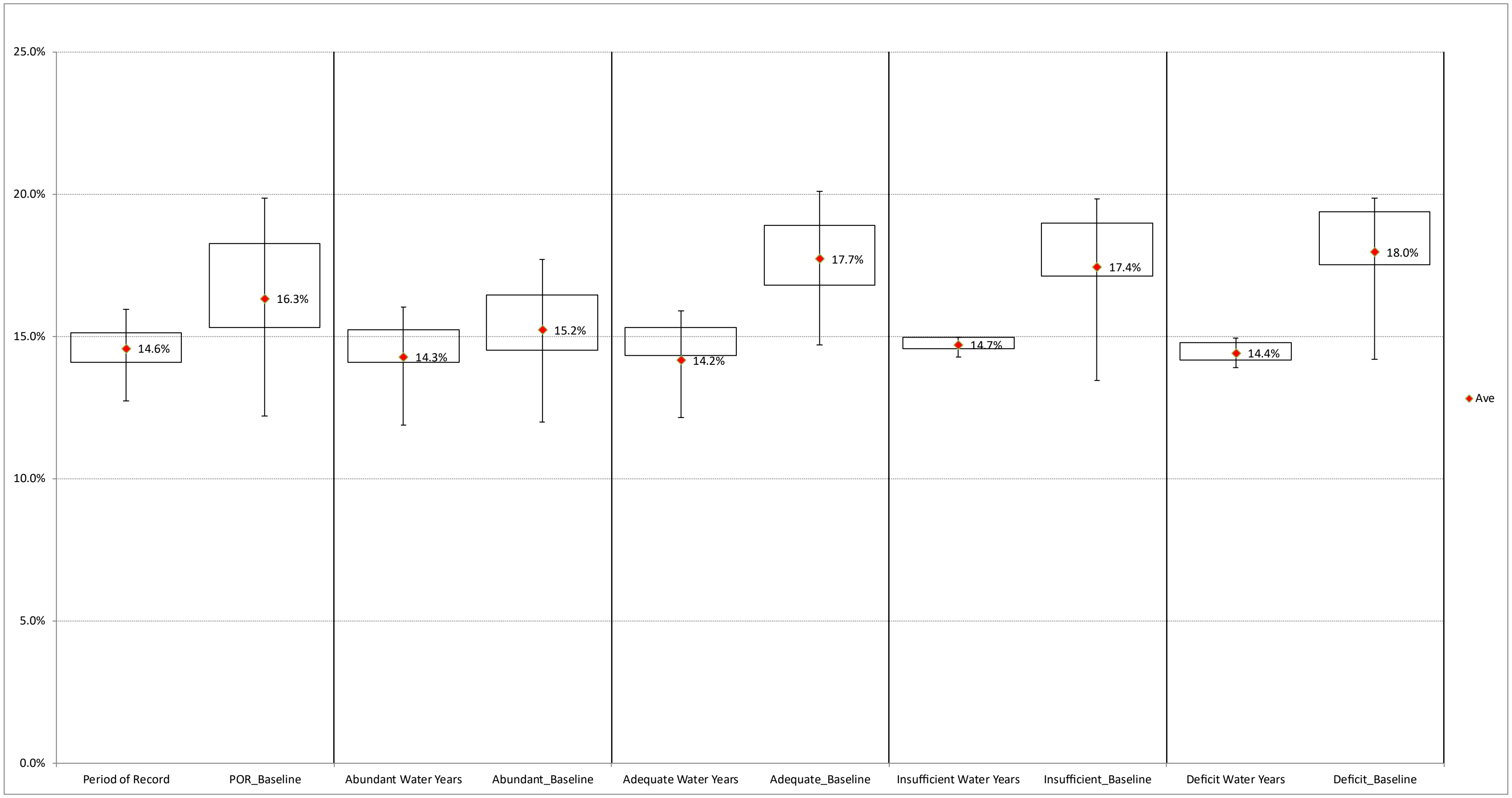


Figure 2-86. Hills Creek For Juvenile Spring Chinook Sub-Yearlings Downstream Dam Passage Survival At Under Alternative 3b. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook sub-yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

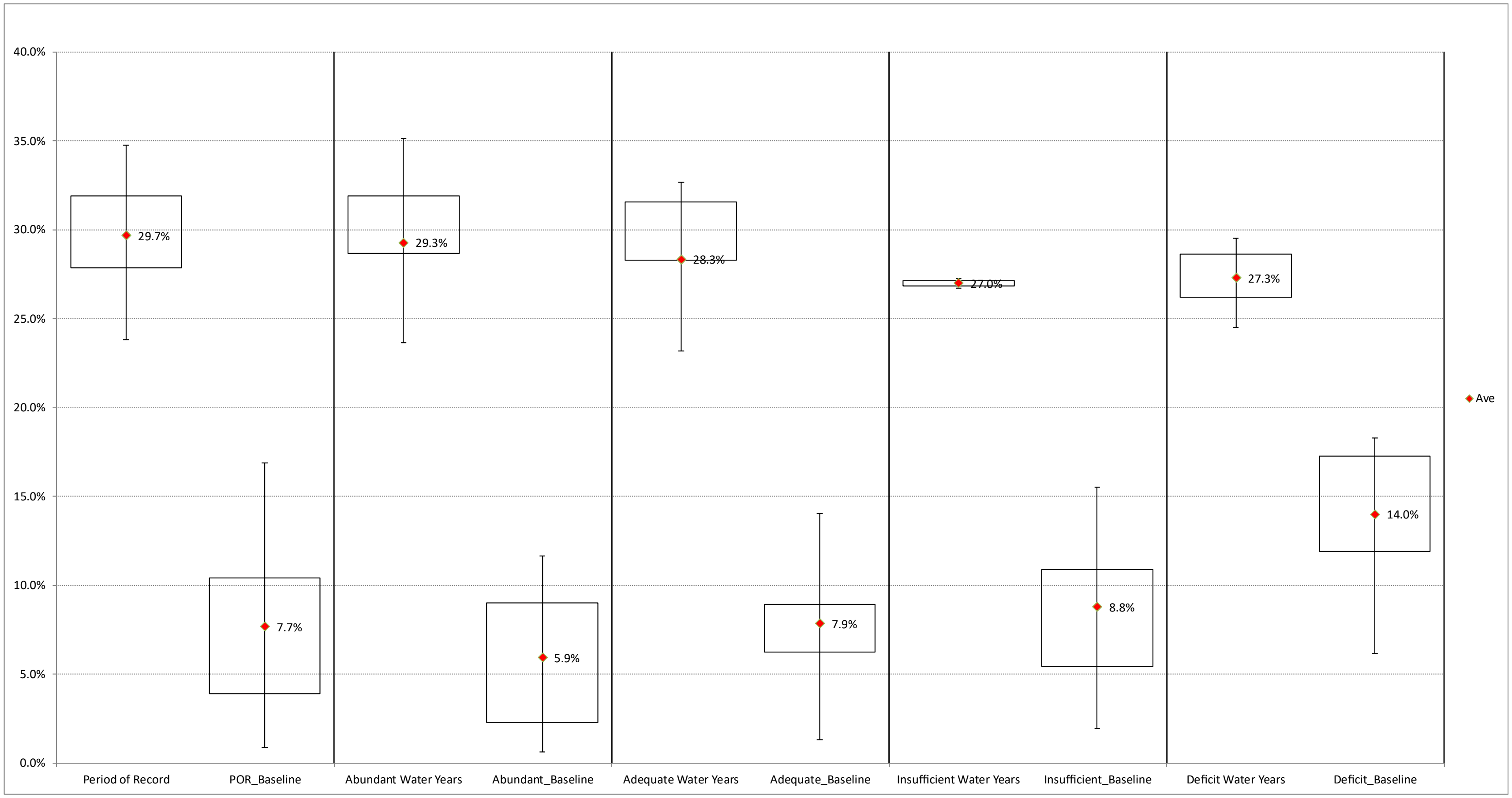


Figure 2-87. Hills Creek Juvenile Spring Chinook Yearlings Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are 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

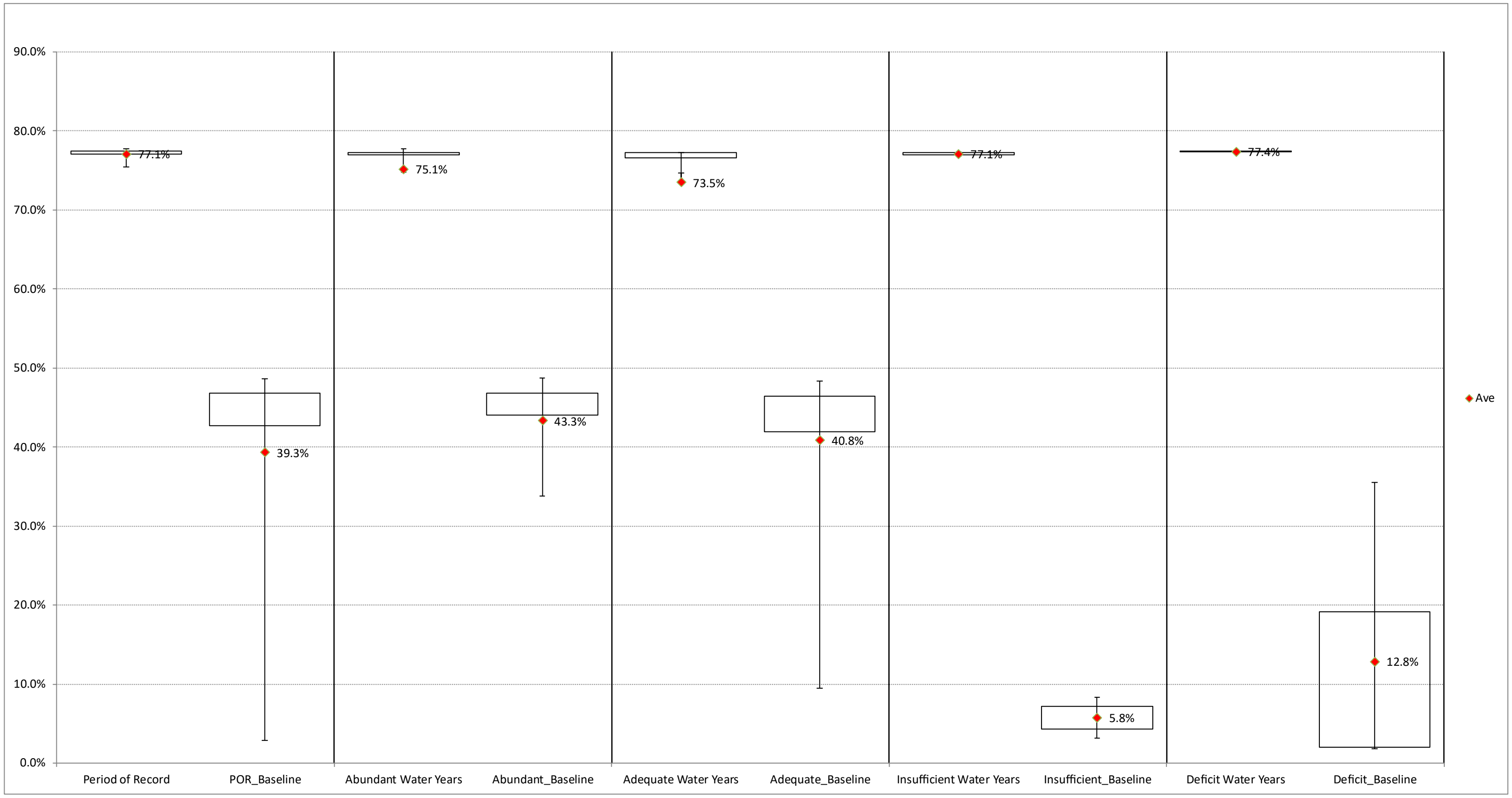


Figure 2-88. Detroit Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Detroit for juvenile spring Chinook fry under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period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

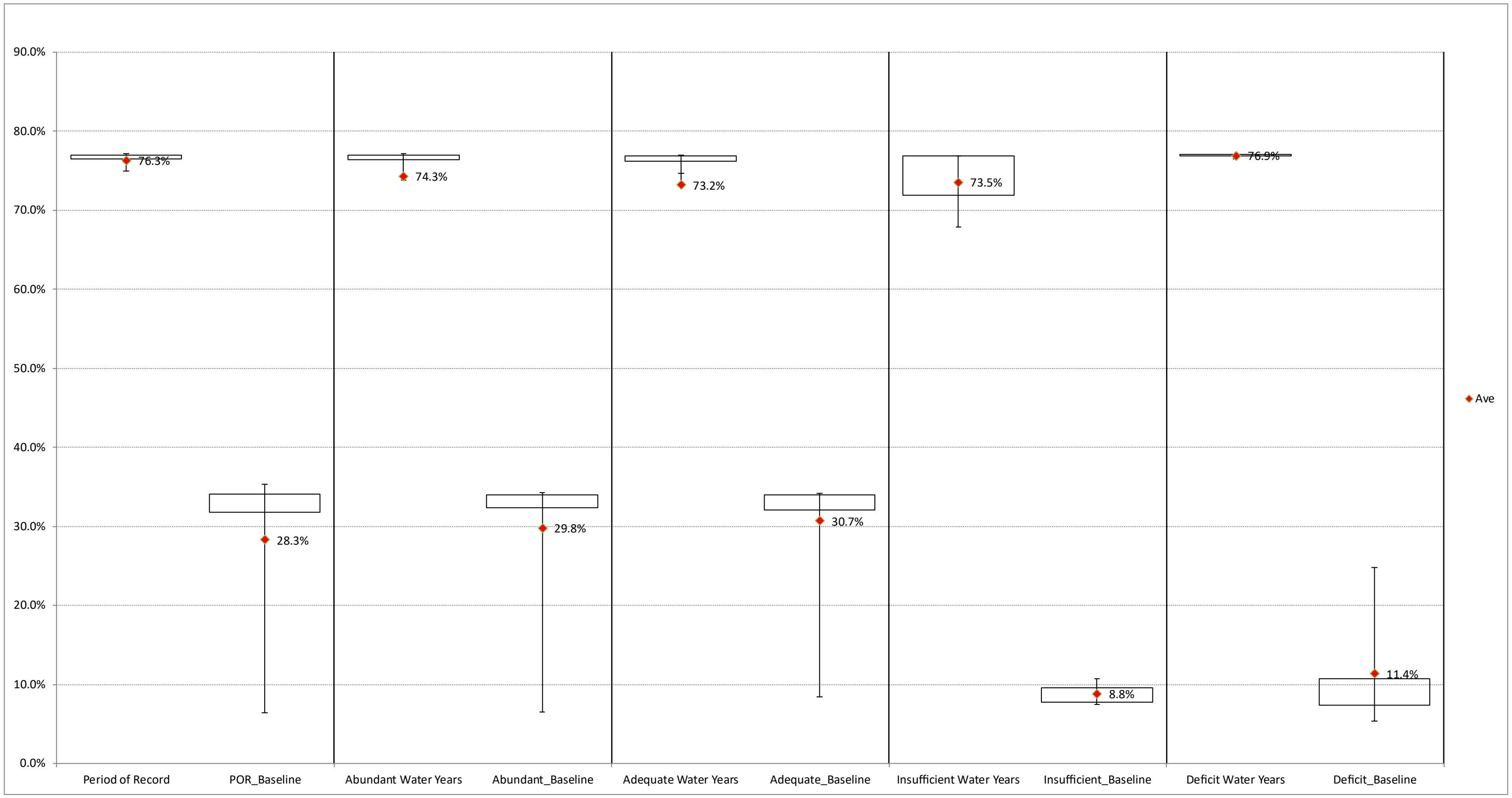


Figure 2-89. Detroit Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Detroit for juvenile spring Chinook sub-yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given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

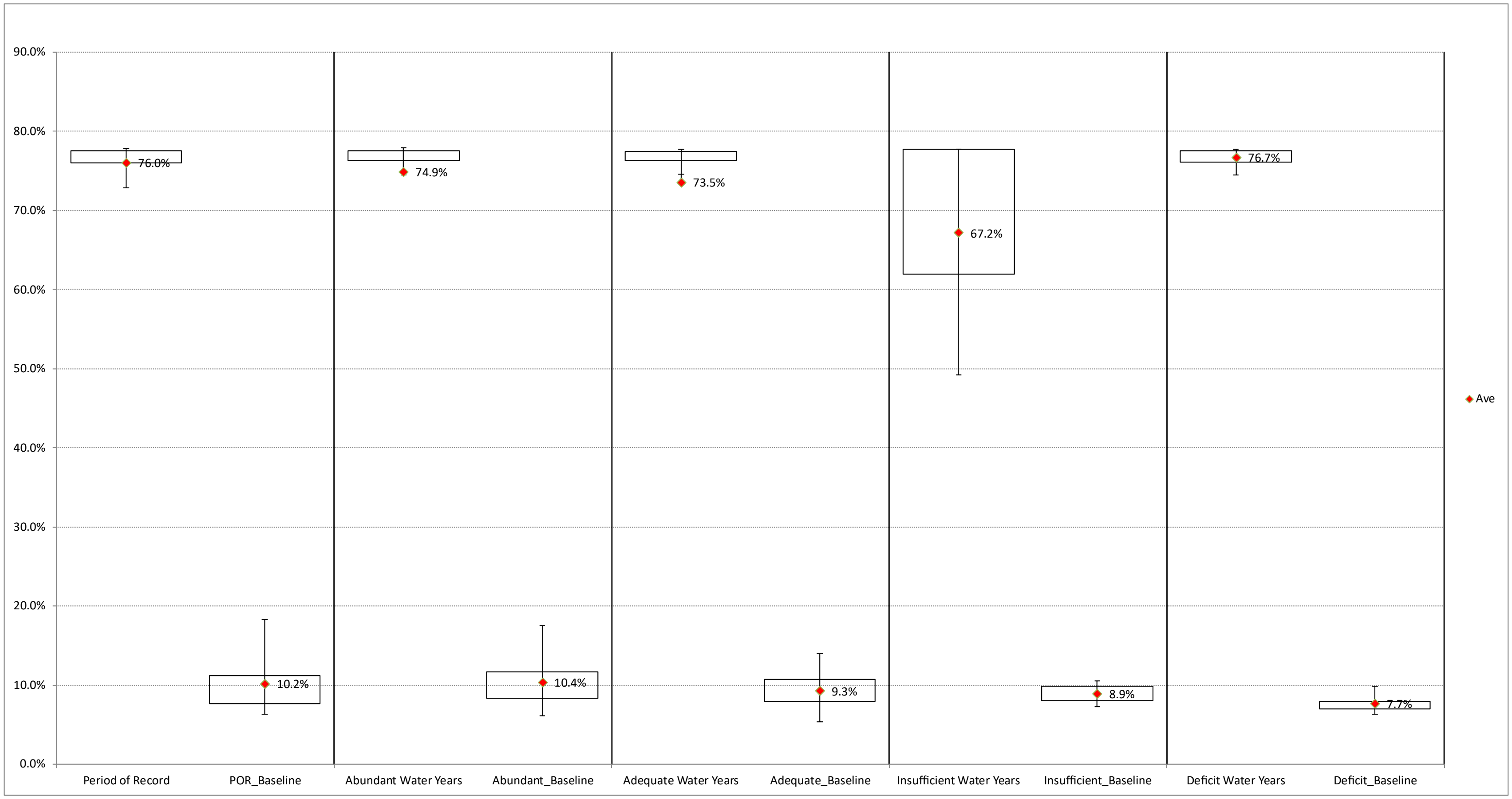


Figure 2-90. Downstream dam passage survival at Detroit for juvenile spring Chinook yearlings under Alternative 4. *Downstream dam passage survival at Detroit for juvenile spring Chinook yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given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

2.7.2 South Santiam – Foster

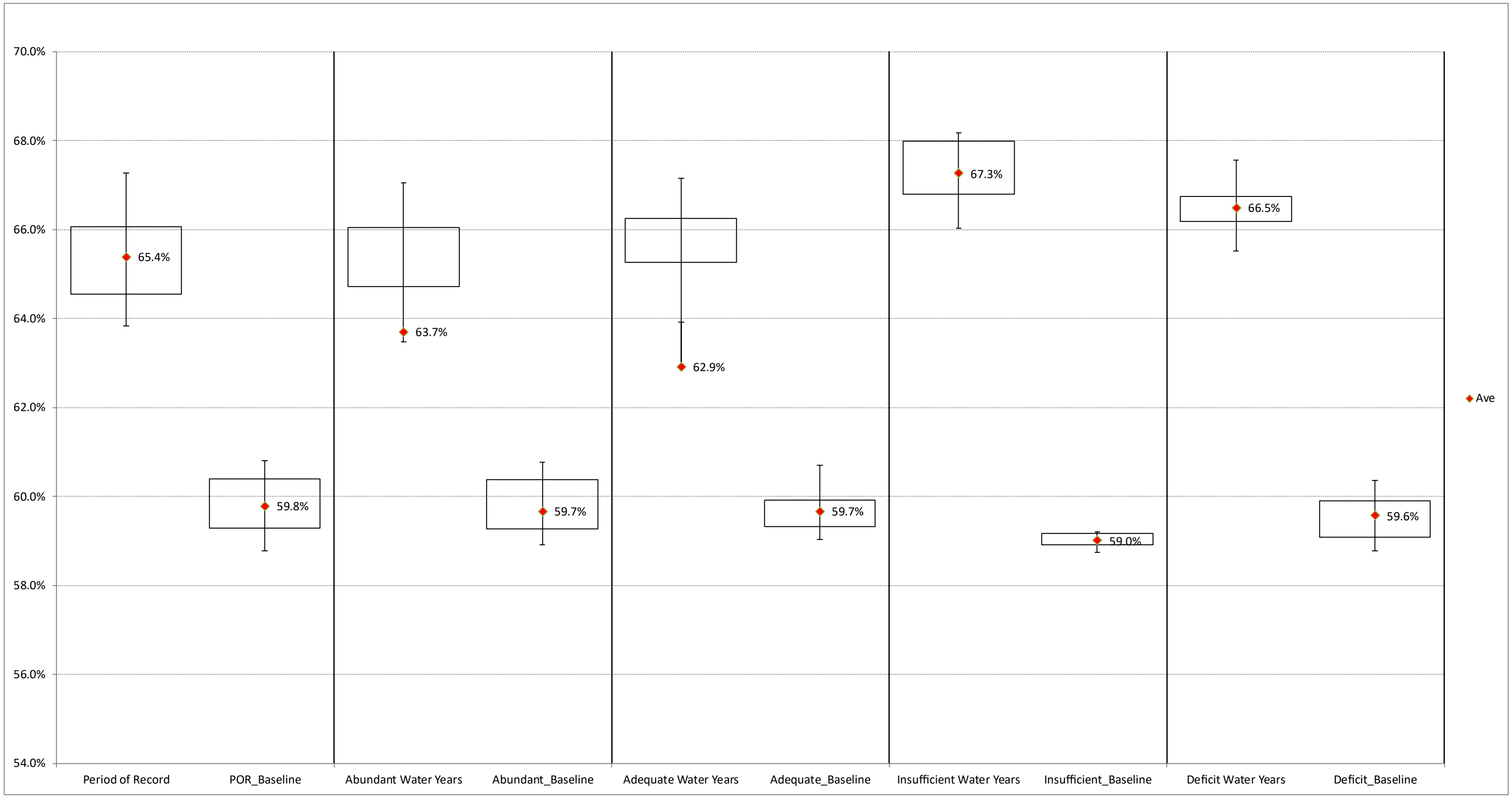


Figure 2-91. Downstream dam passage survival at Foster for juvenile spring Chinook fry under Alternative 4. *Downstream dam passage survival at Foster for juvenile spring Chinook fry under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period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

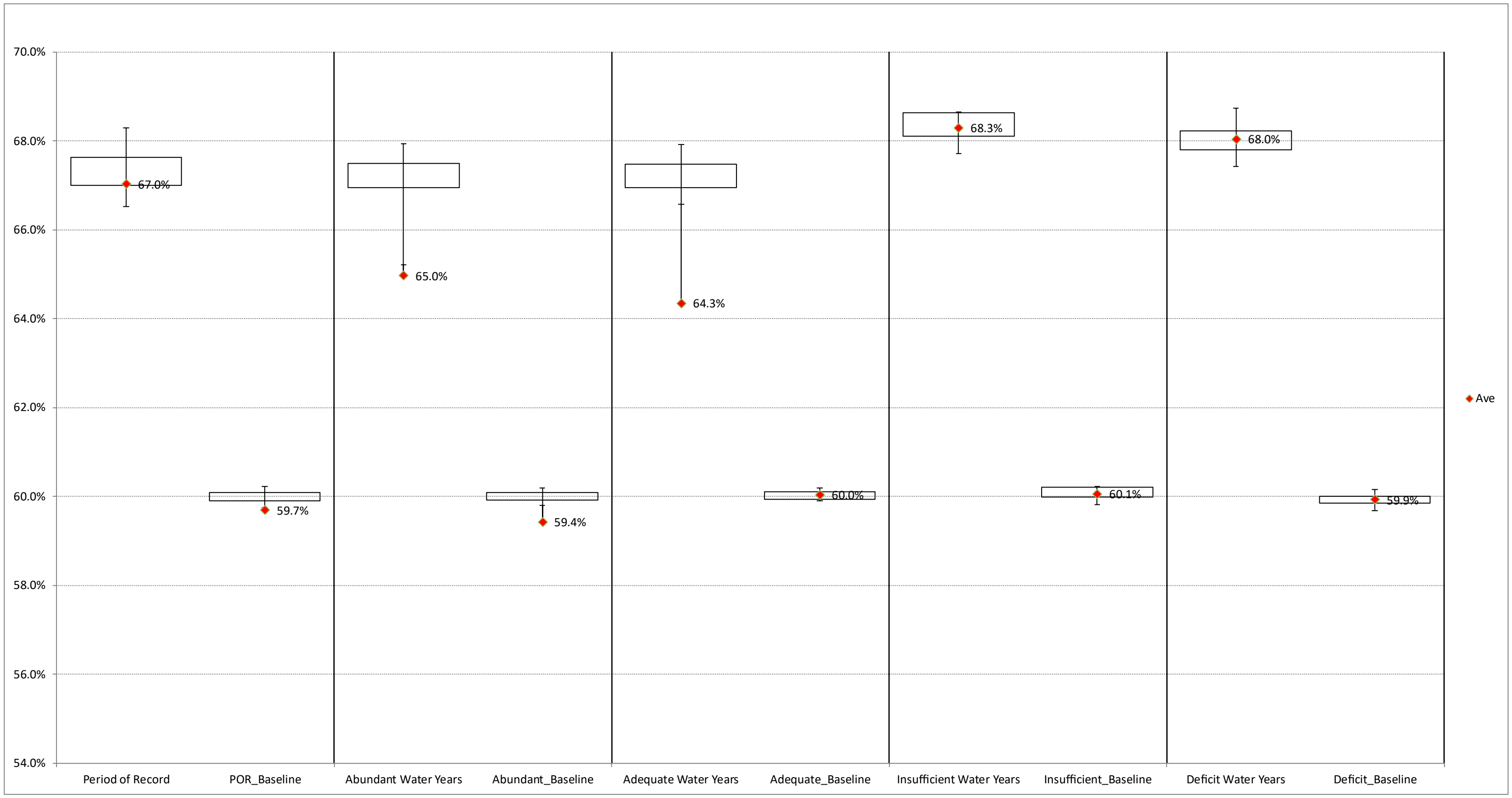


Figure 2-92. Foster Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Foster for juvenile spring Chinook sub-yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given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

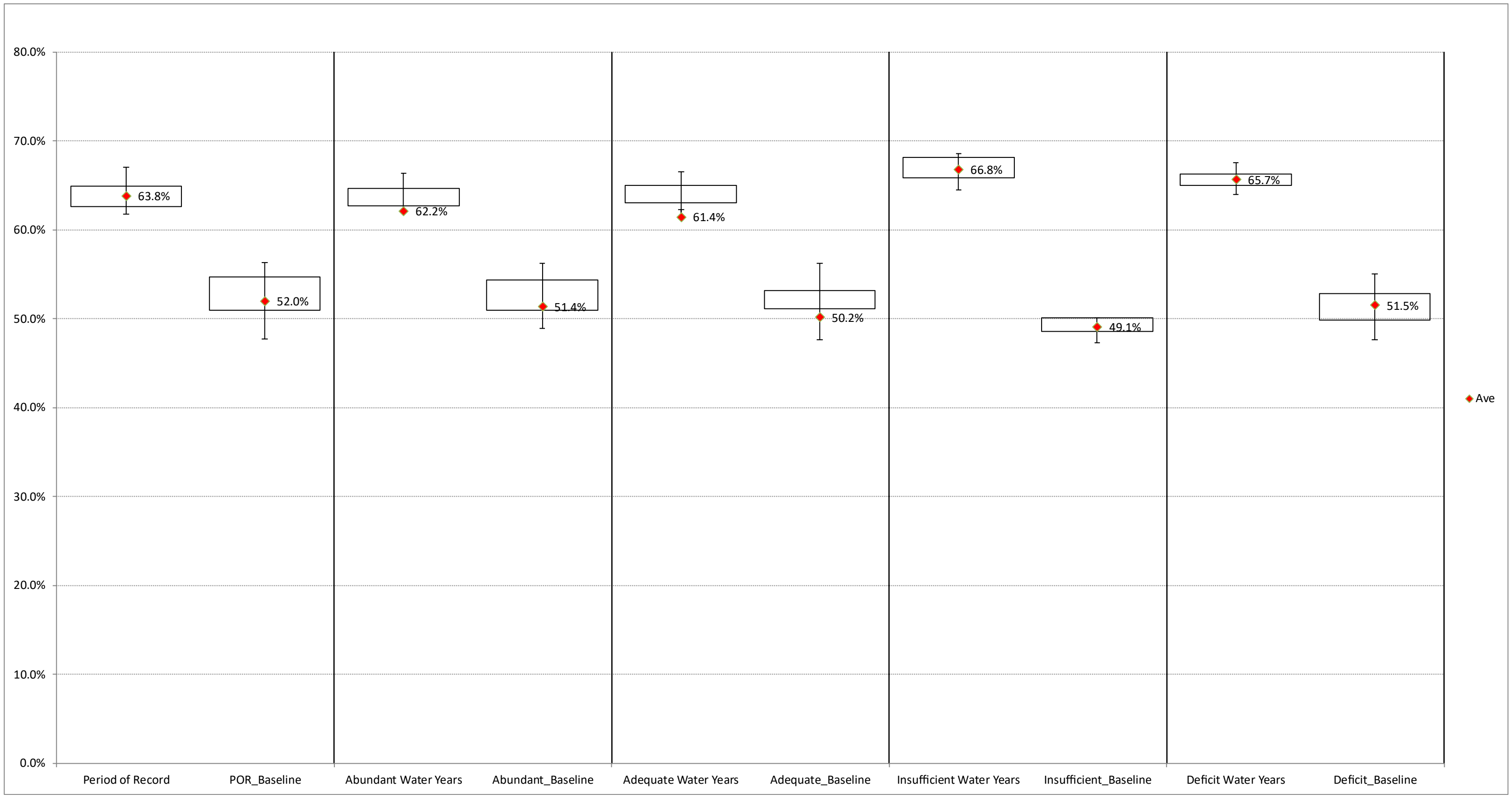


Figure 2-93. Foster Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Foster for juvenile spring Chinook yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the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

2.7.3 South Santiam – Green Peter

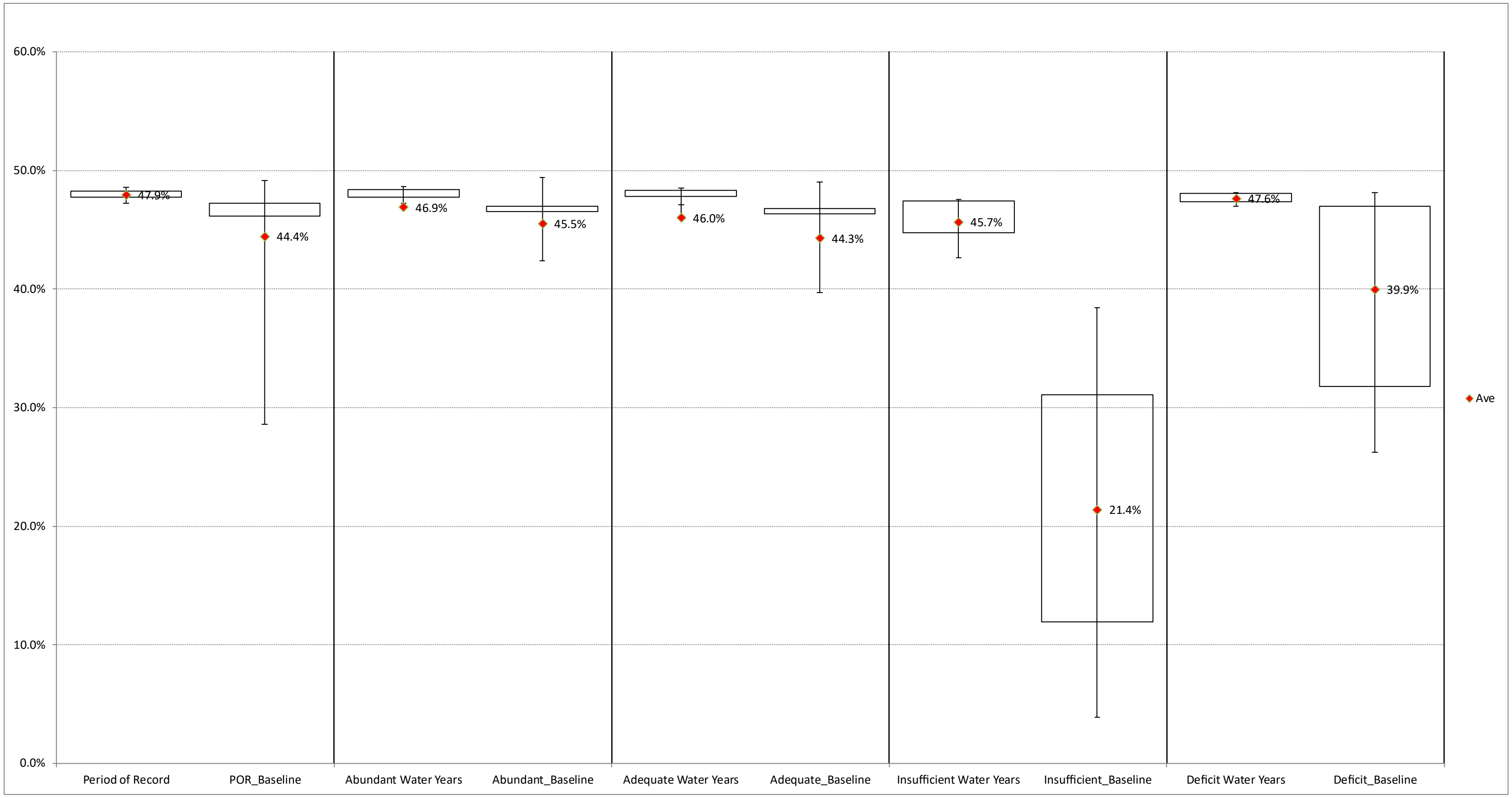


Figure 2-94. Green Peter Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Green Peter for juvenile spring Chinook fry under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the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

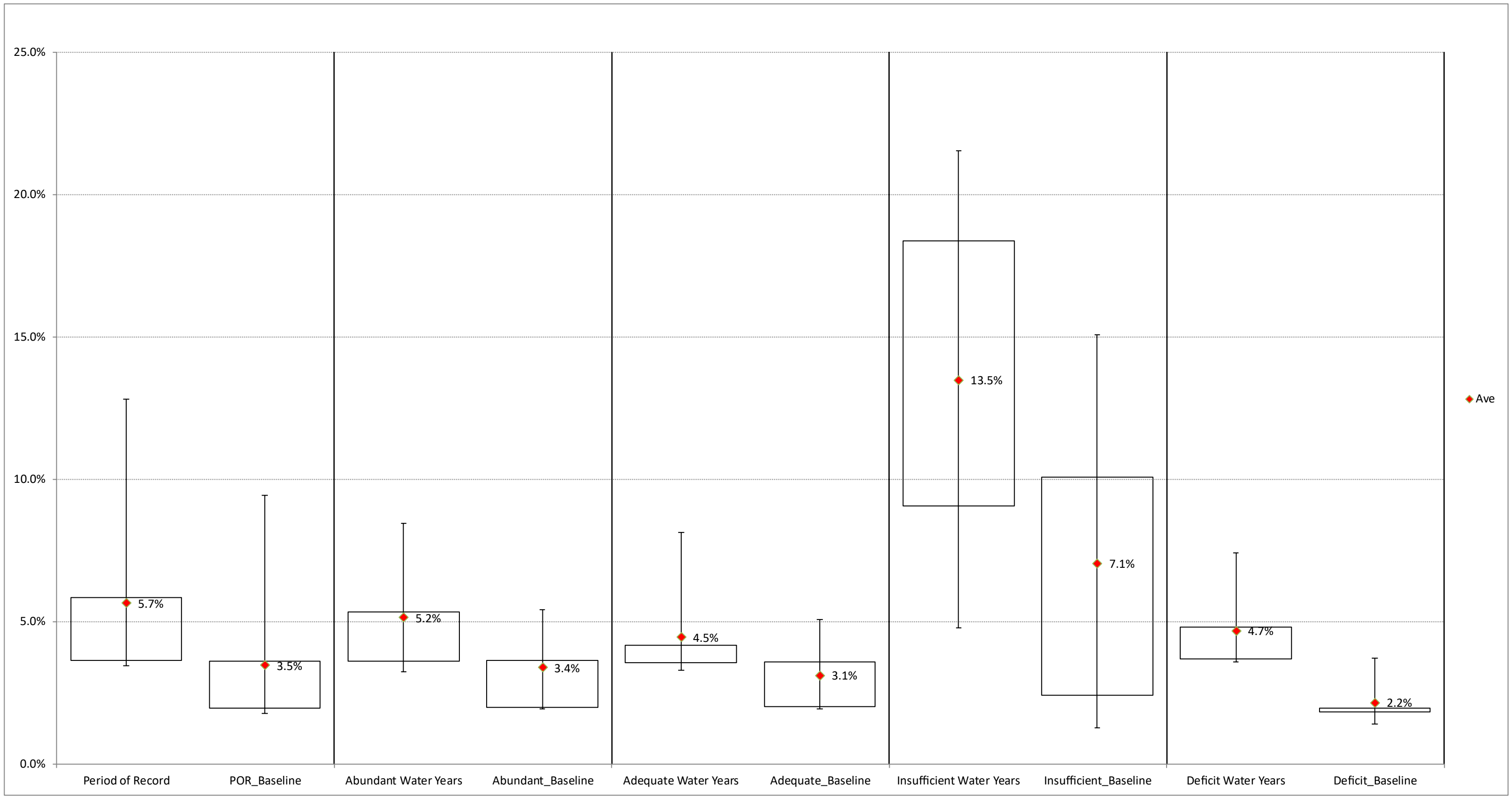


Figure 2-95. Downstream dam passage survival at Green Peter for juvenile spring Chinook sub-yearlings under Alternative 4. *Downstream dam passage survival at Green Peter for juvenile spring Chinook sub-yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities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

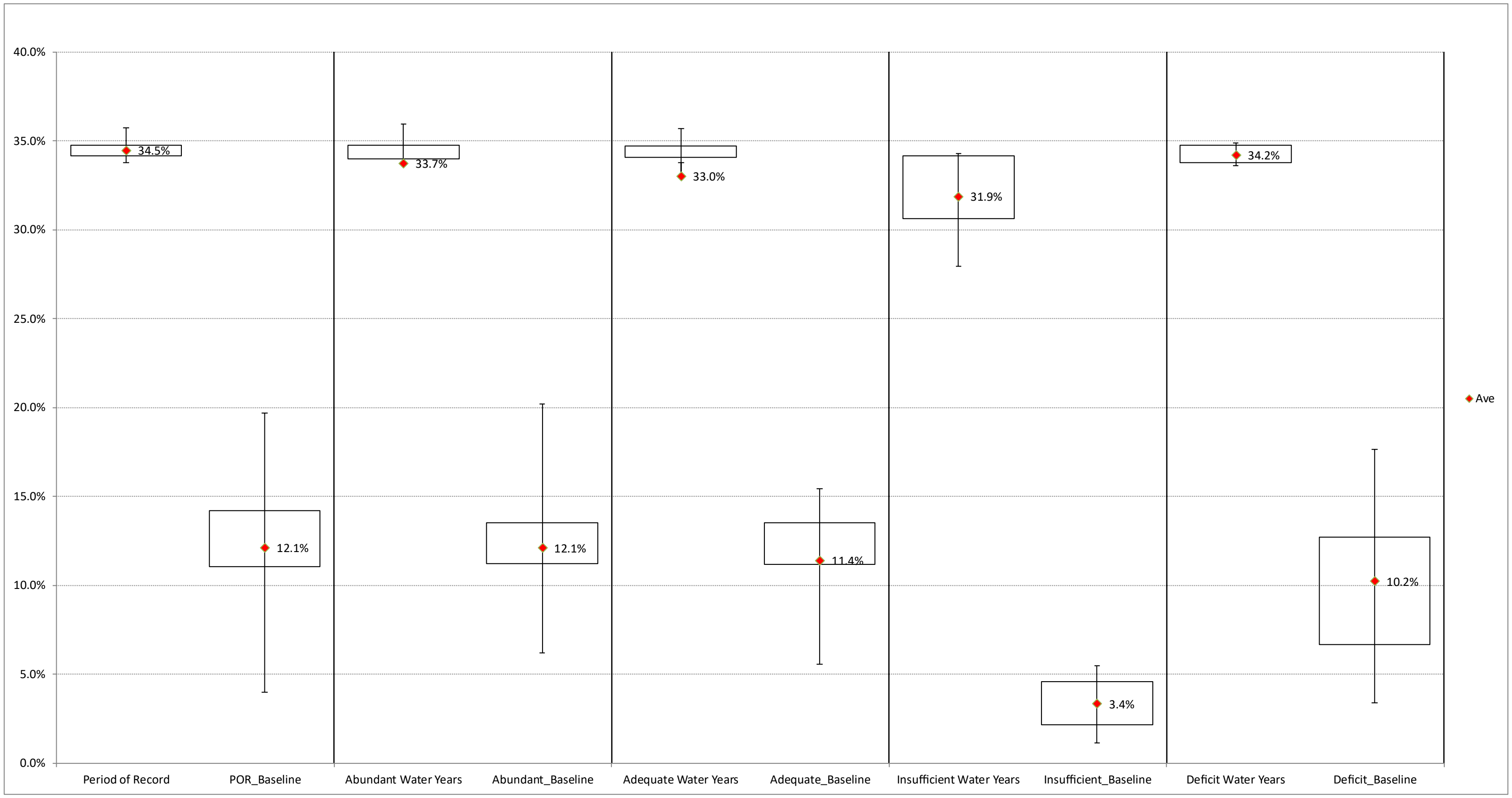


Figure 2-96. Green Peter Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Green Peter for juvenile spring Chinook sub-yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities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

2.7.4 McKenzie - Cougar

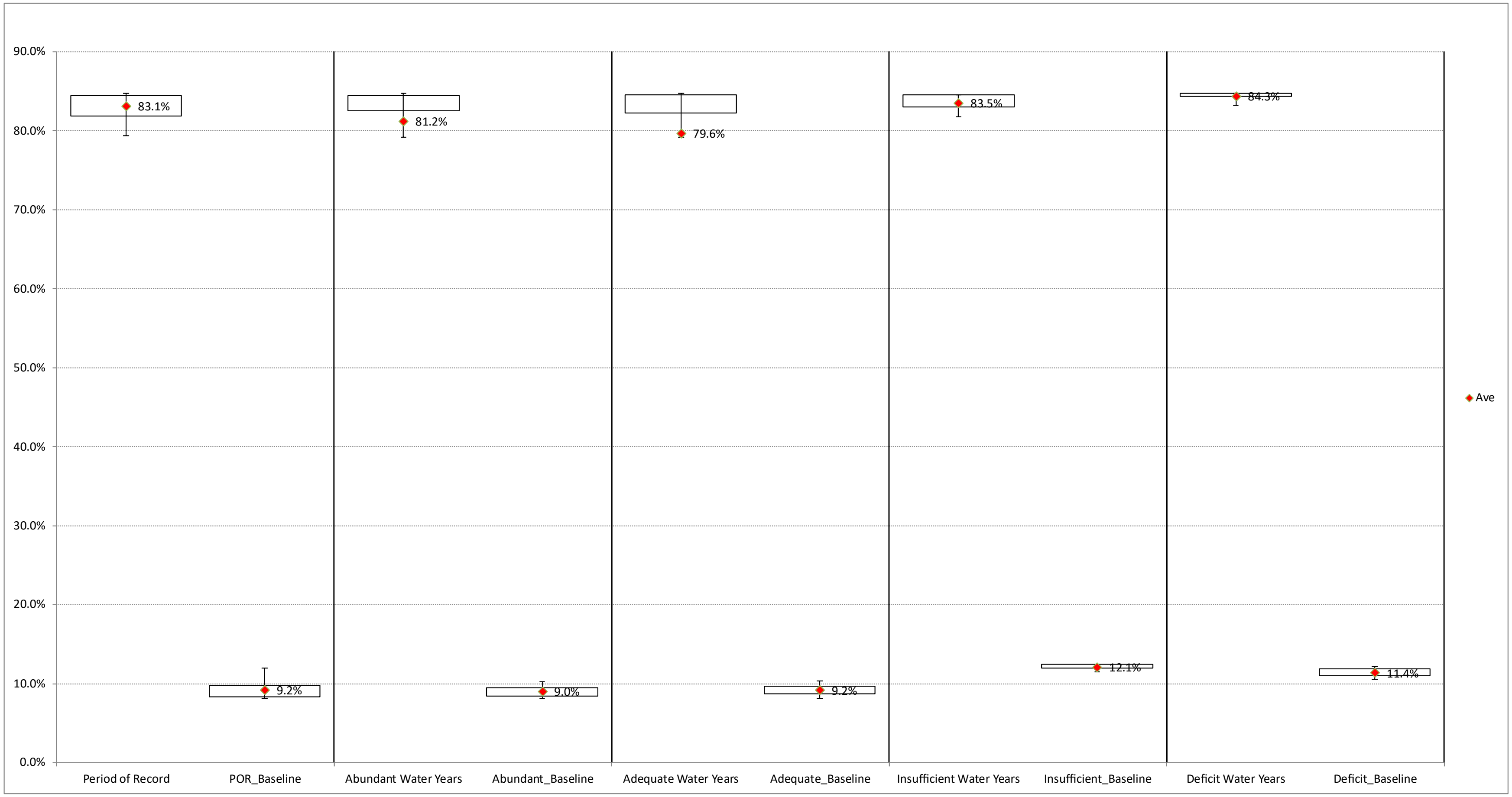


Figure 2-97. Cougar Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Cougar for juvenile spring Chinook fry under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of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

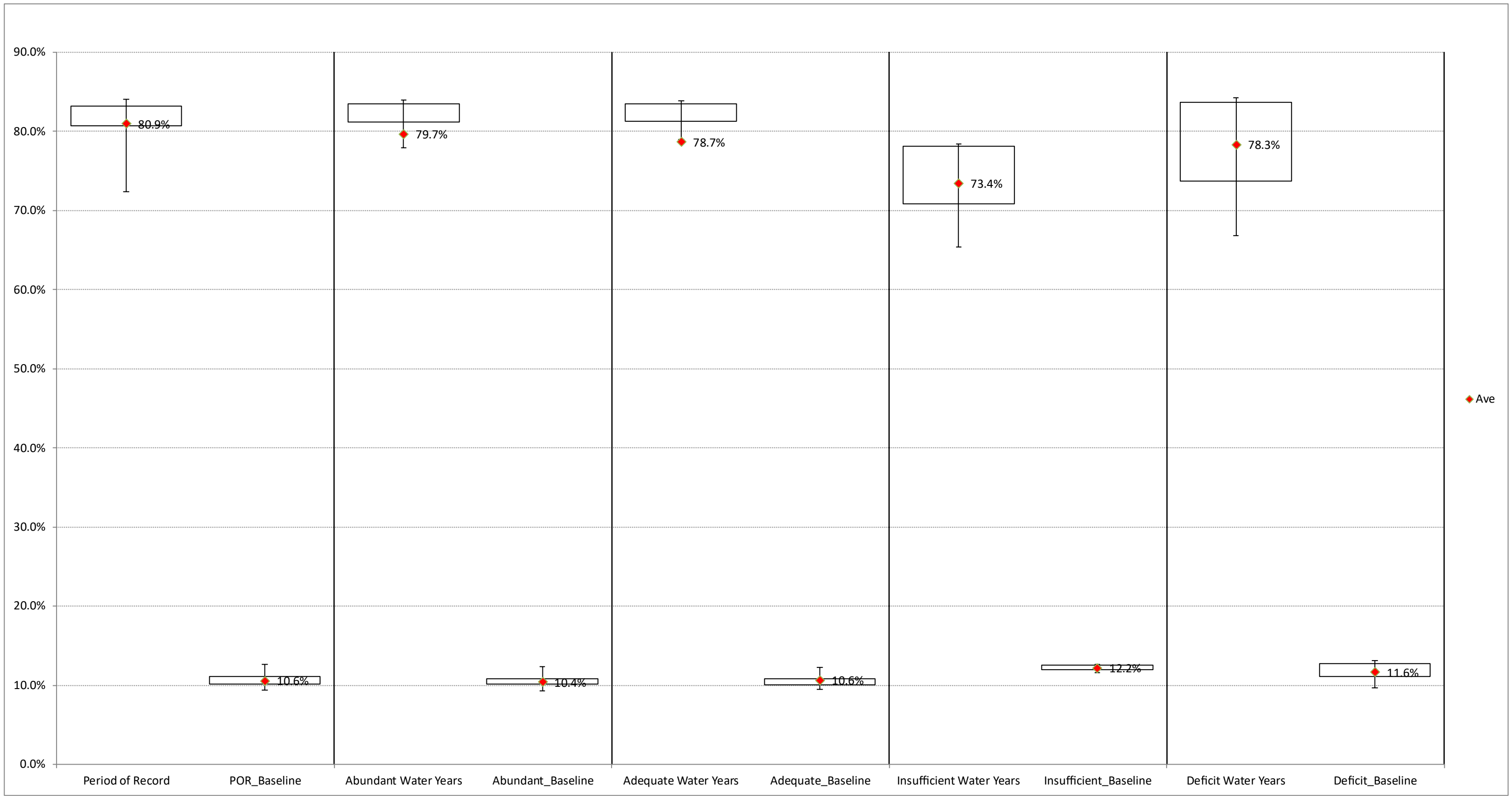


Figure 2-98. Cougar Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Cougar for juvenile spring Chinook sub-yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given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

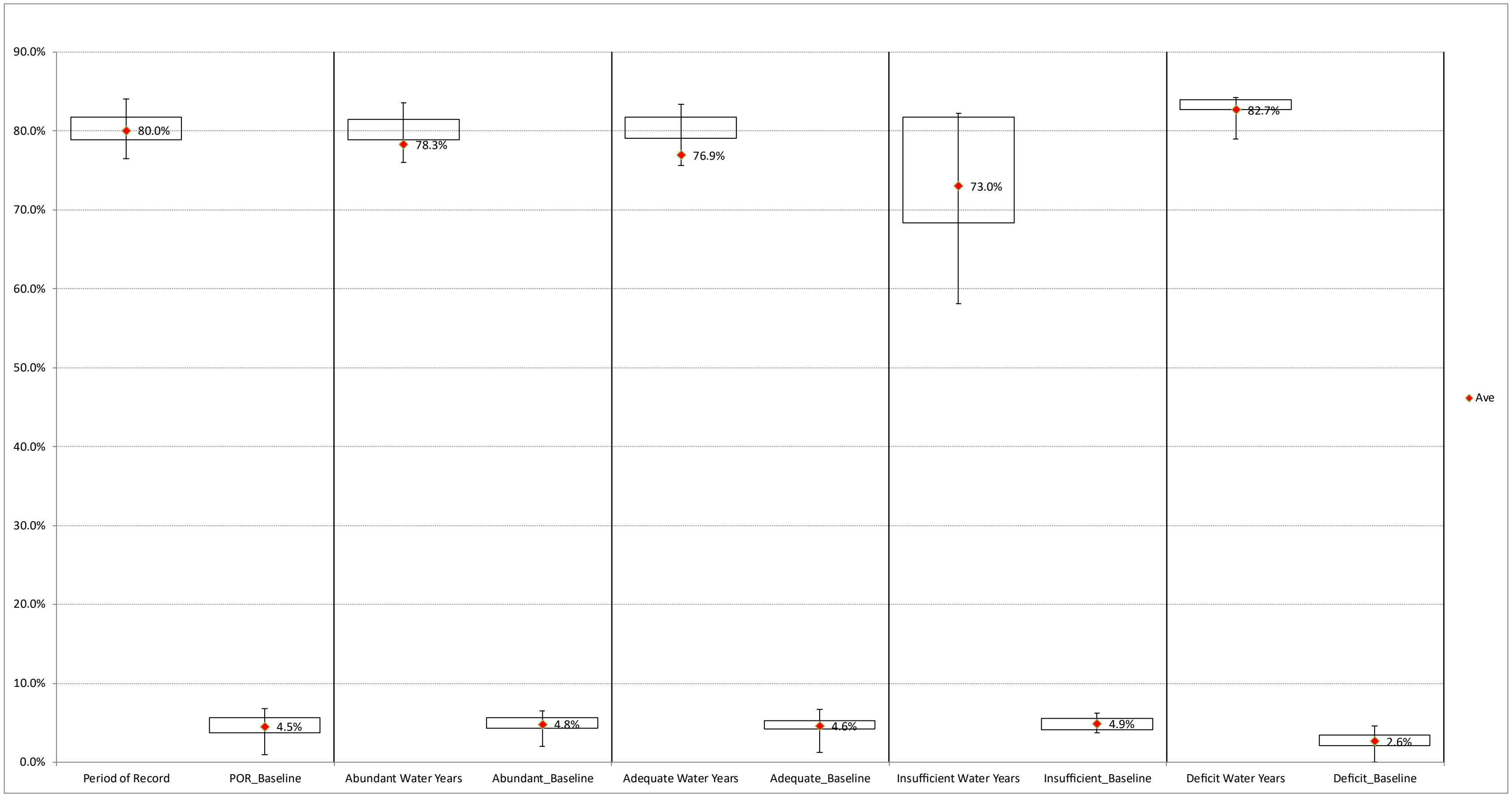


Figure 2-99. Cougar Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Cougar for juvenile spring Chinook yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the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

2.7.5 Middle Fork – Lookout Point

Figure 2-100. 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.*

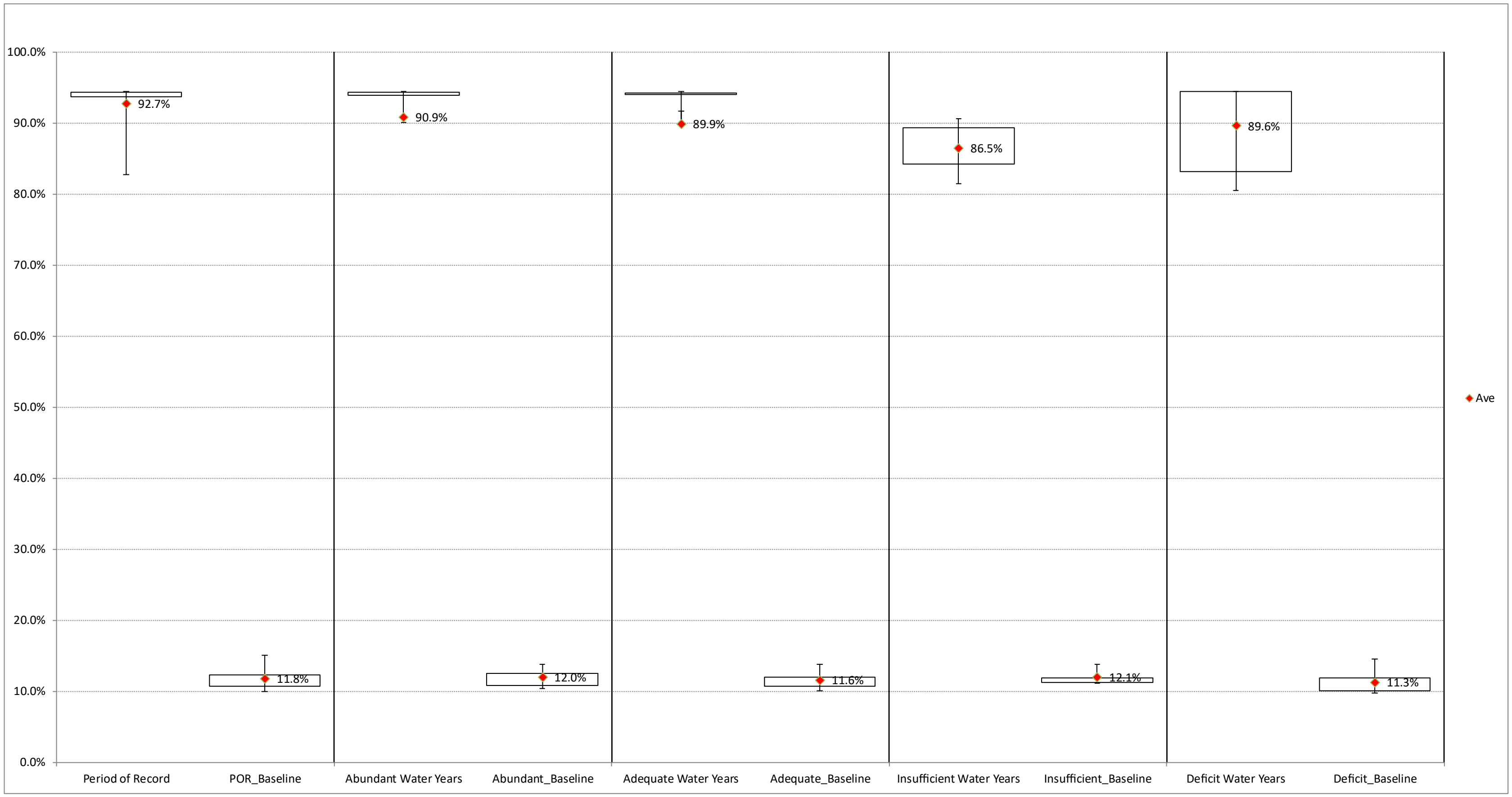


Figure 2-101. Lookout Point Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Lookout Point for juvenile spring Chinook sub-yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities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

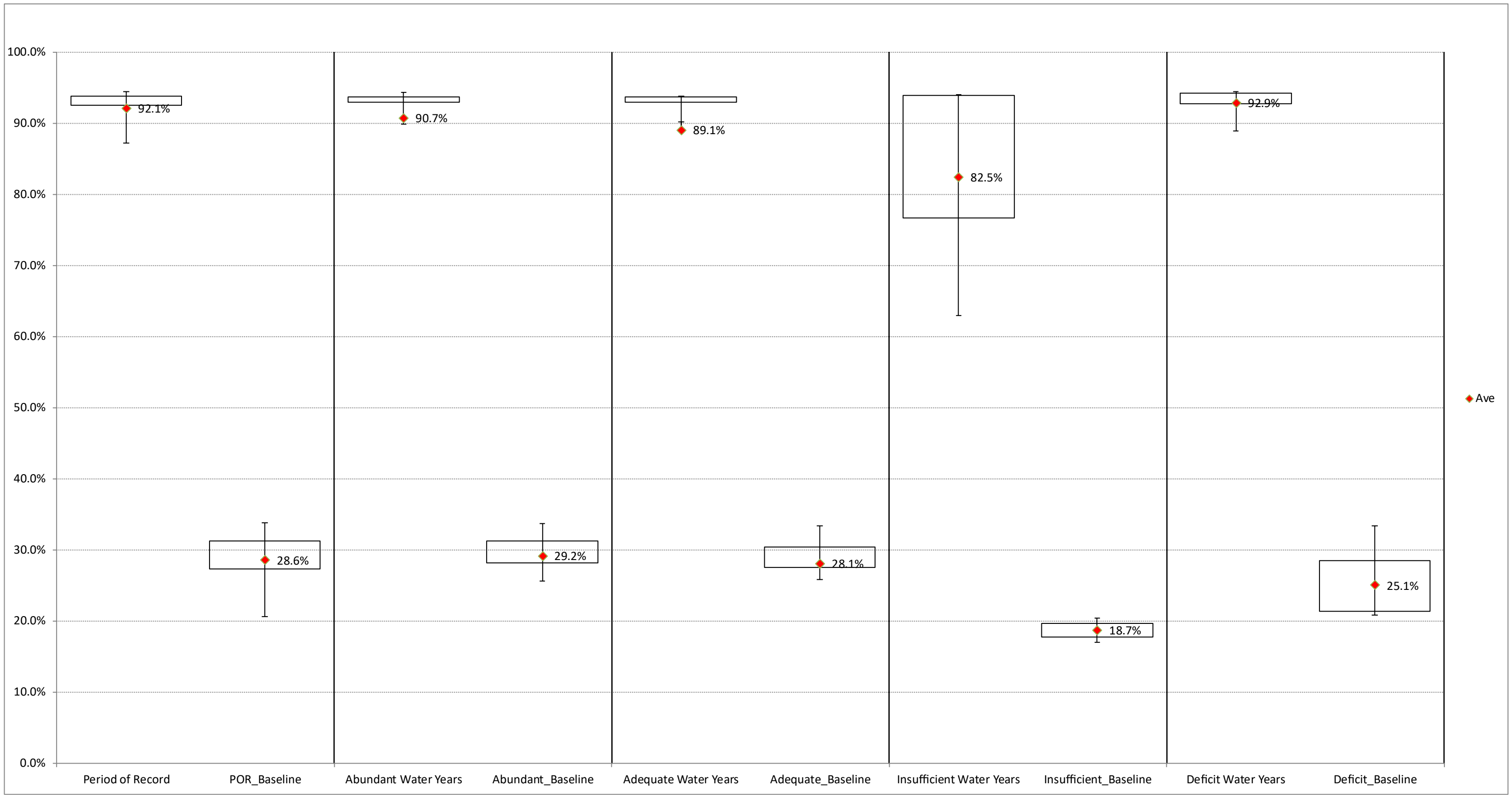


Figure 2-102. Lookout Point Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 4.
Downstream dam passage survival at Lookout Point for juvenile spring Chinook yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are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

2.7.6 Middle Fork – Hills Creek

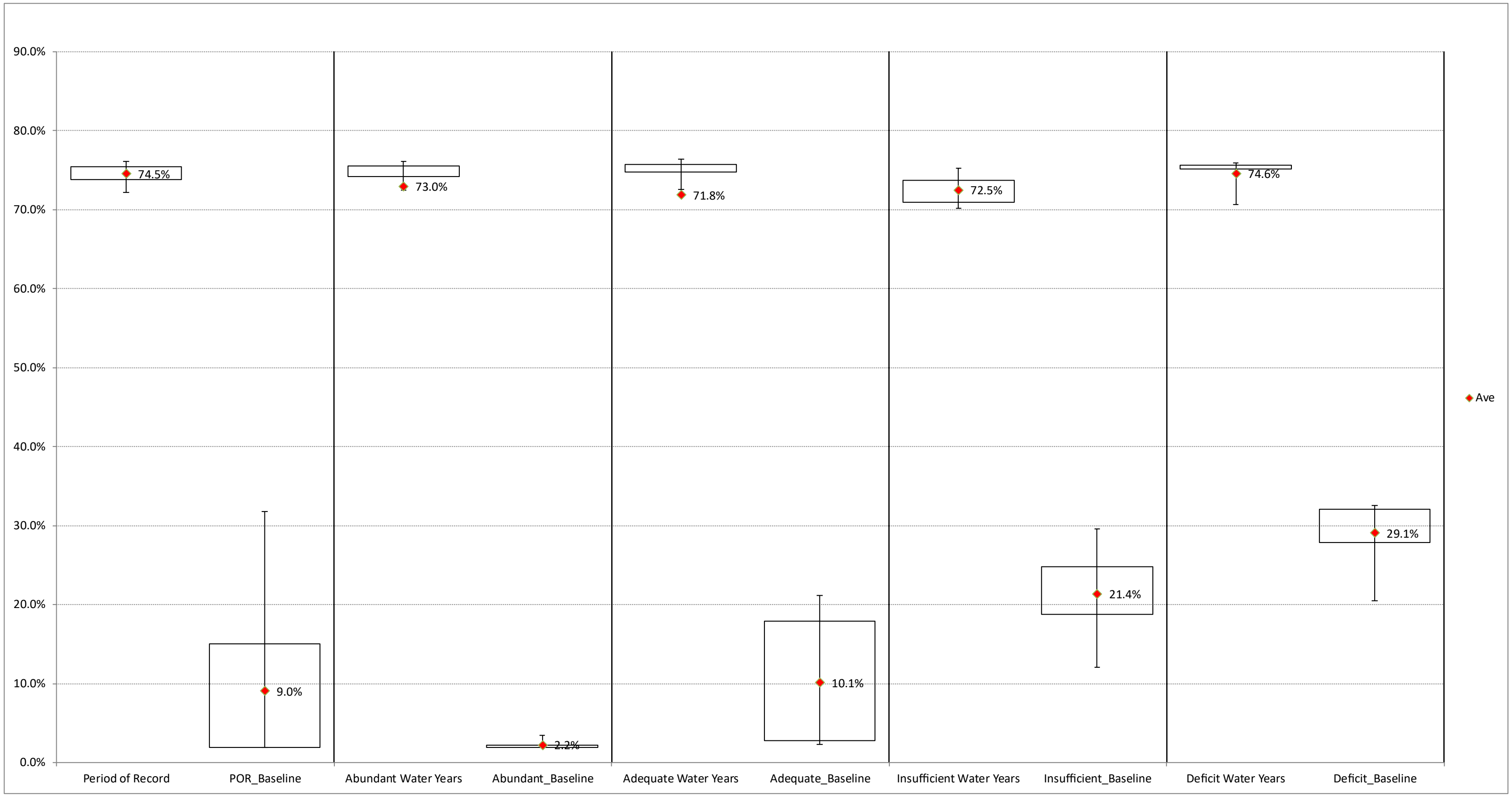


Figure 2-103. Hills Creek Juvenile Spring Chinook Fry Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook fry under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the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

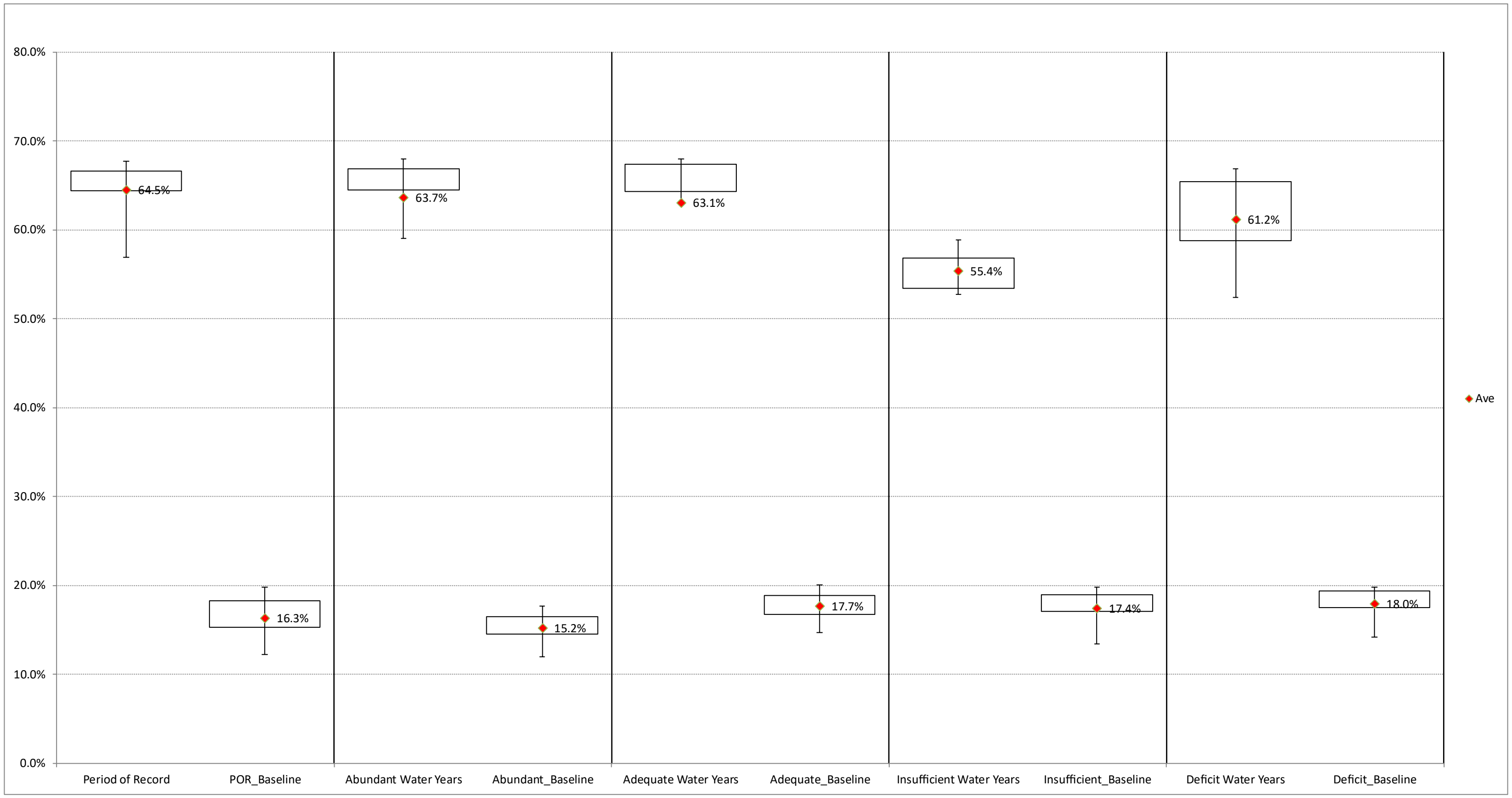


Figure 2-104. Hills Creek Juvenile Spring Chinook Sub-Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook sub-yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

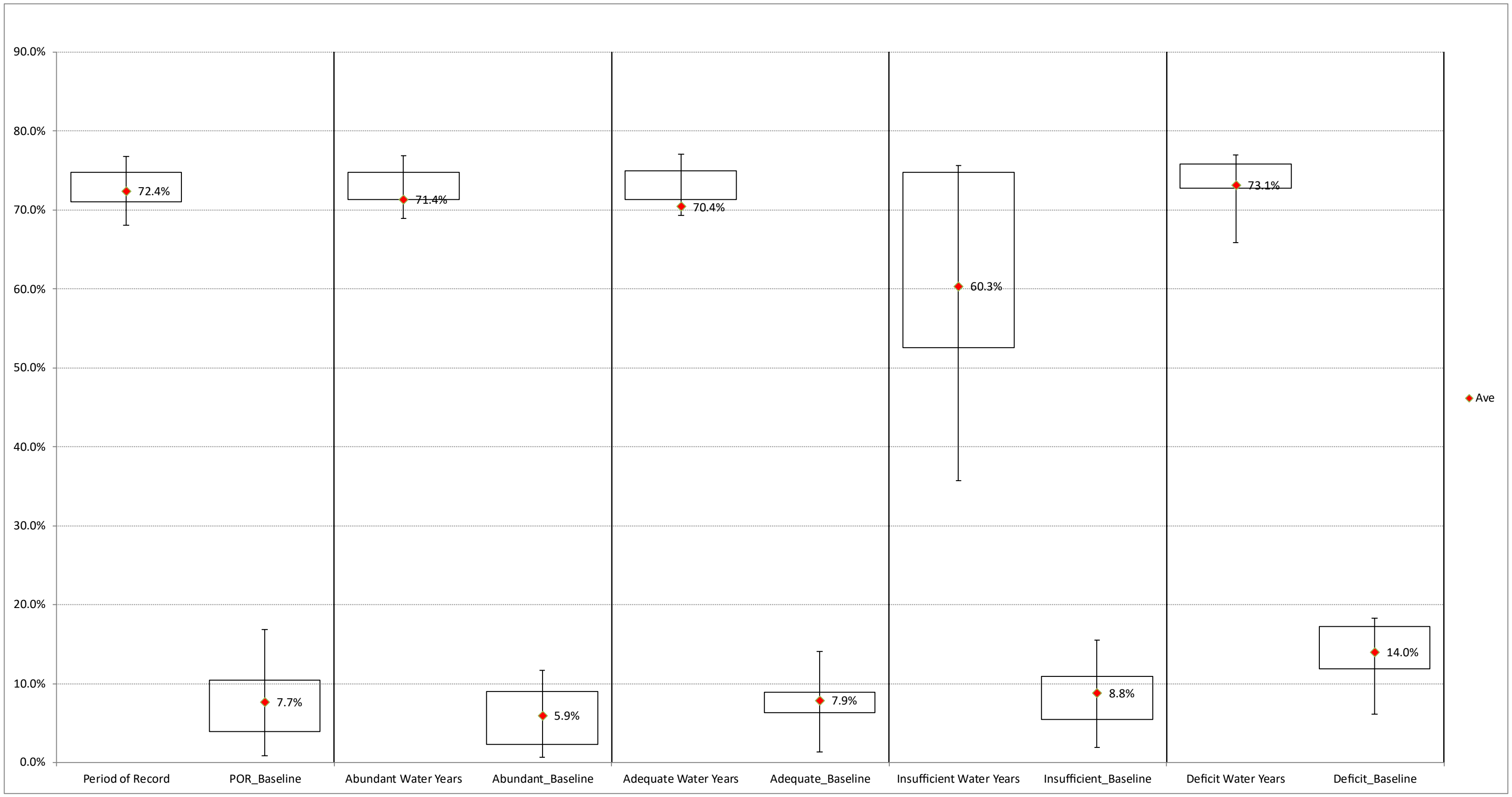


Figure 2-105. Hills Creek Juvenile Spring Chinook Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Hills Creek for juvenile spring Chinook yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given 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)

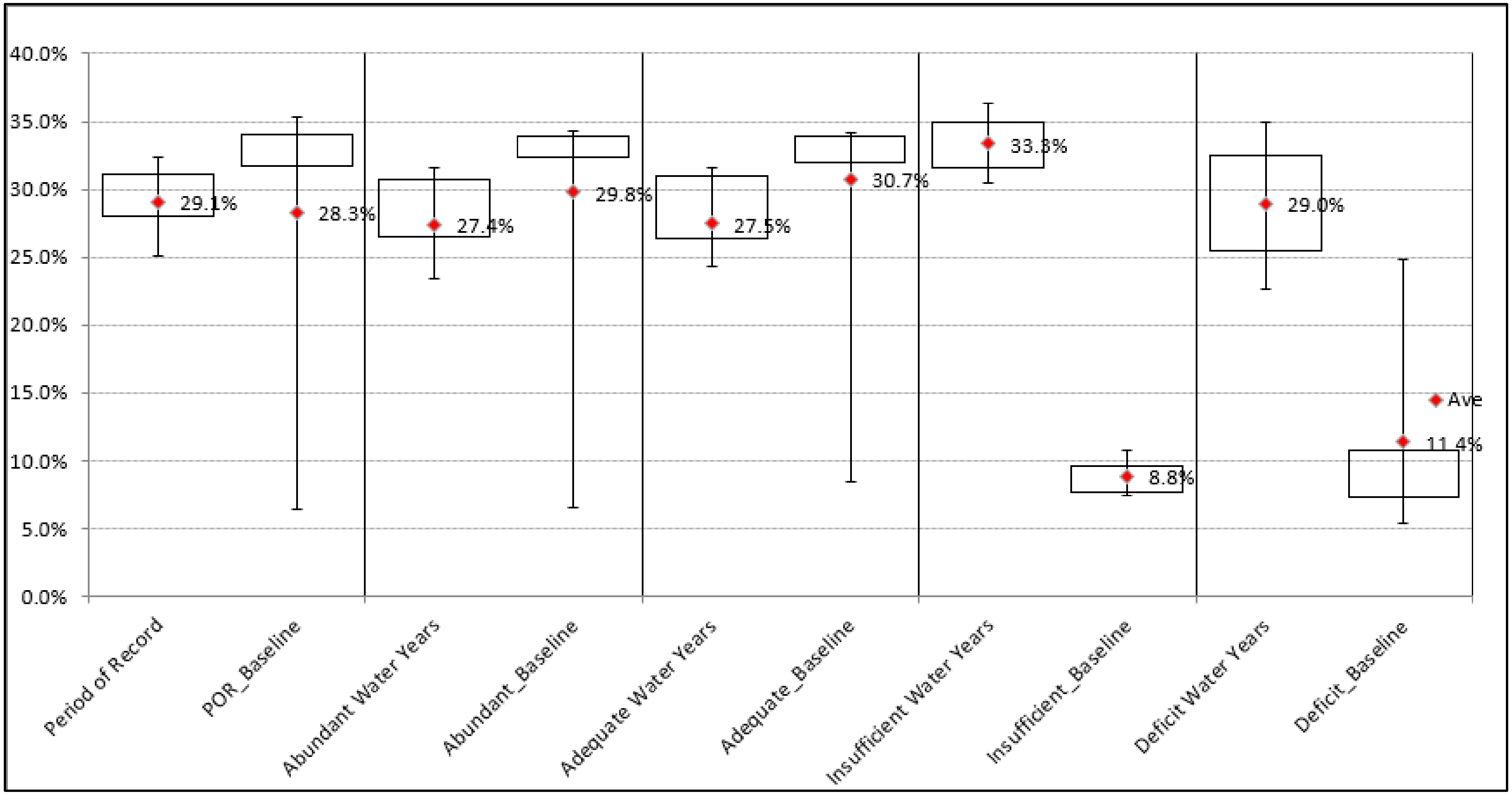


Figure 2-106. Detroit Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under the NAA. *Downstream dam passage survival at Detroit for juvenile winter steelhead sub-yearlings under the NAA. The mean is given by the point estimate (filled dot). Survival probabilities are given for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

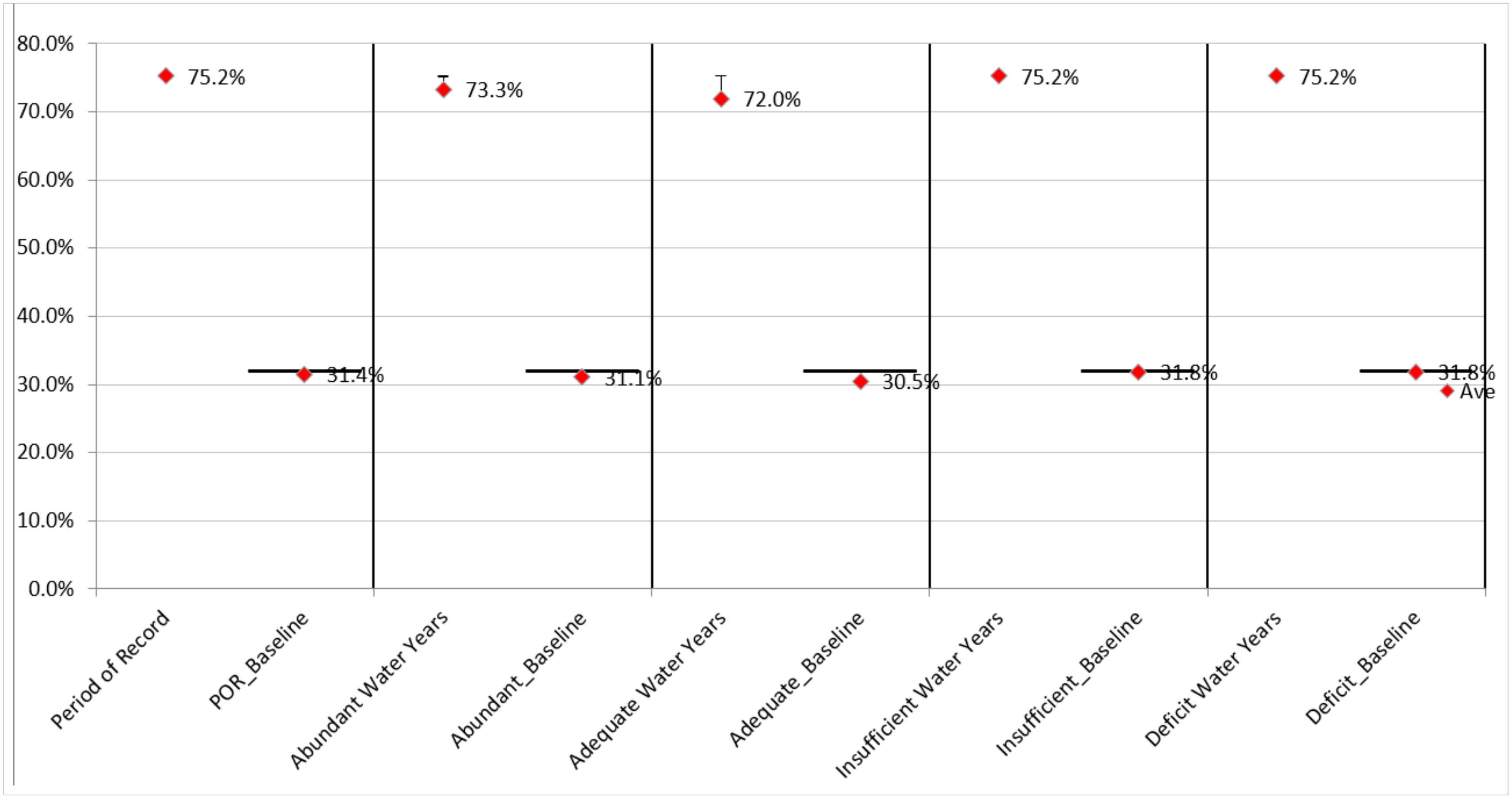


Figure 2-107. Detroit Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under the NAA. *The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

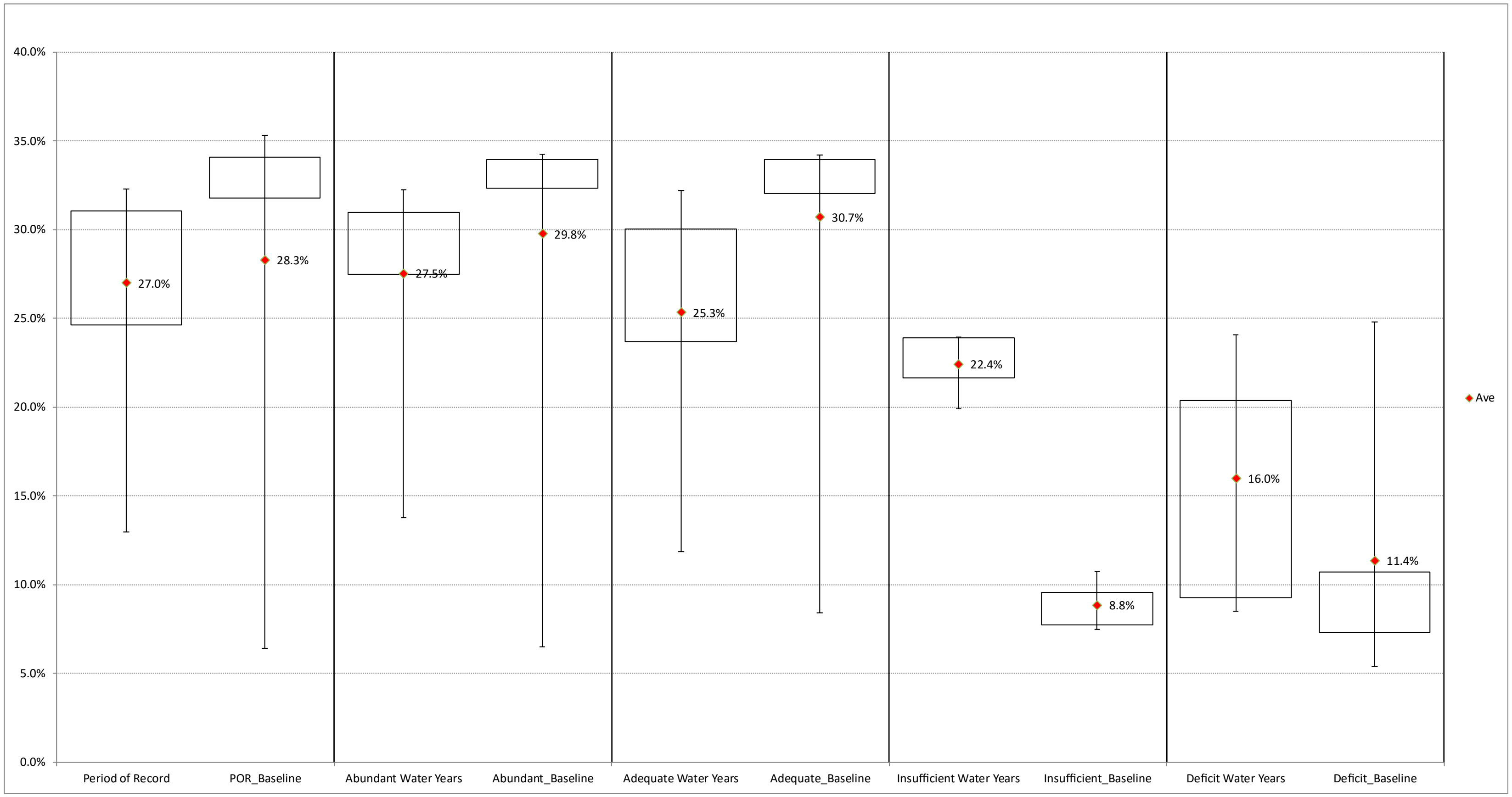


Figure 2-108. Detroit For 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival At Under the NAA. *Downstream dam passage survival at Detroit for juvenile winter steelhead 2 year olds under the NAA. The mean is given by the point estimate (filled dot). Survival probabilities are given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

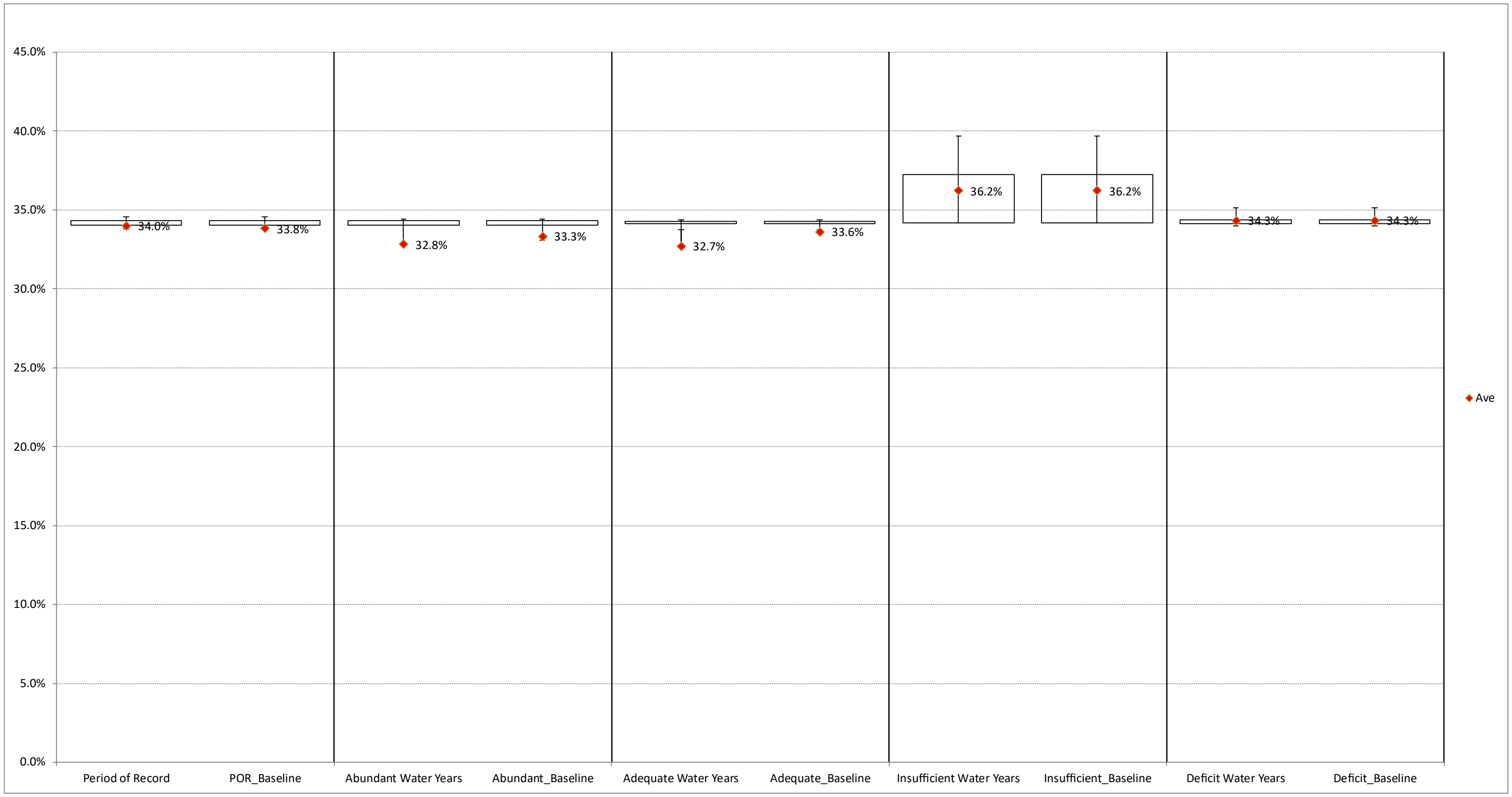


Figure 2-109. Foster Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under the NAA. *Downstream dam passage survival at Foster for juvenile winter steelhead sub-yearlings under the NAA. The mean is given by the point estimate (filled dot). Survival probabilities are given for the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

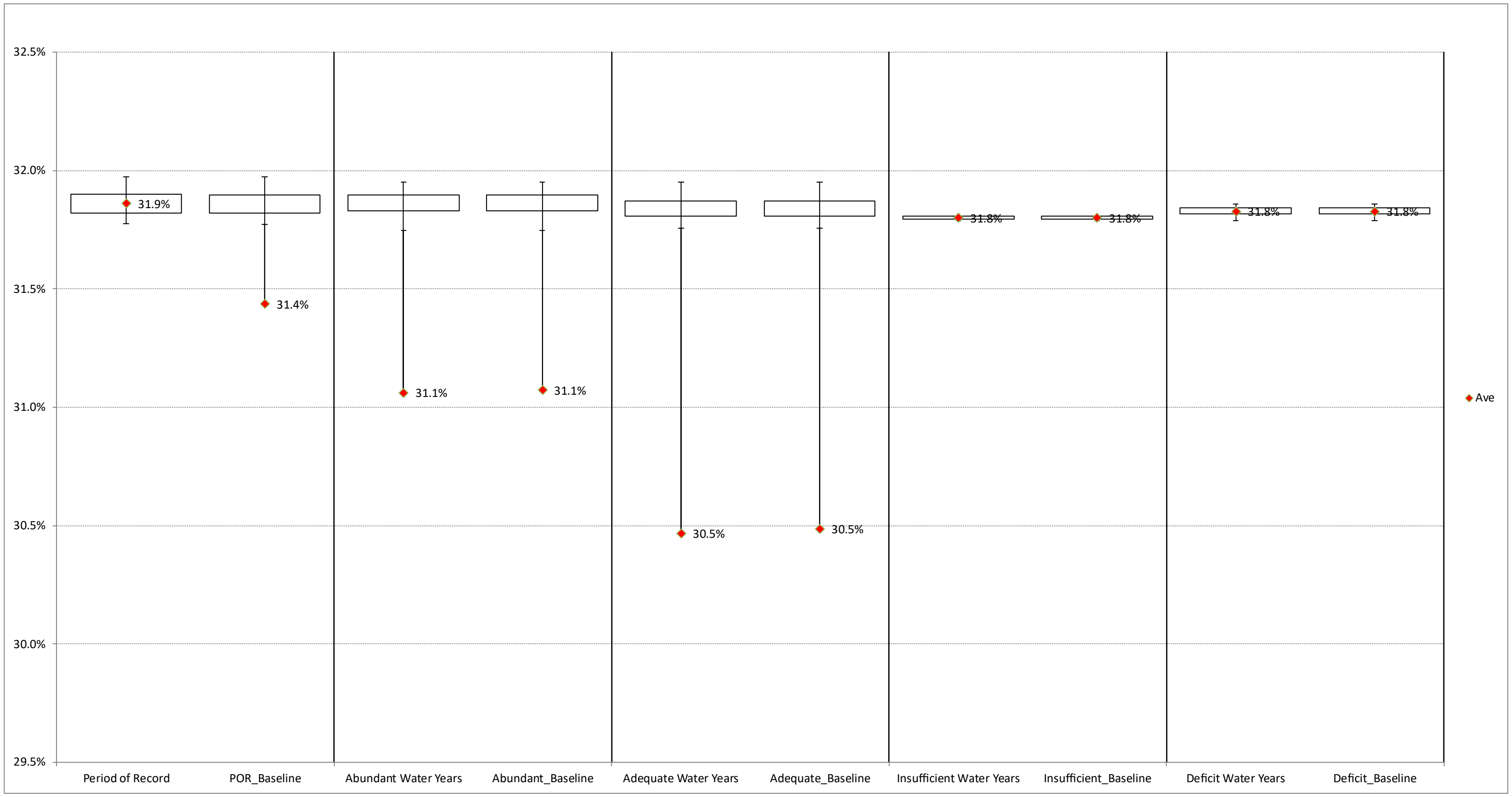


Figure 2-110. Foster Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under the NAA. *Downstream dam passage survival at Foster for juvenile winter steelhead yearlings under the NAA. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period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

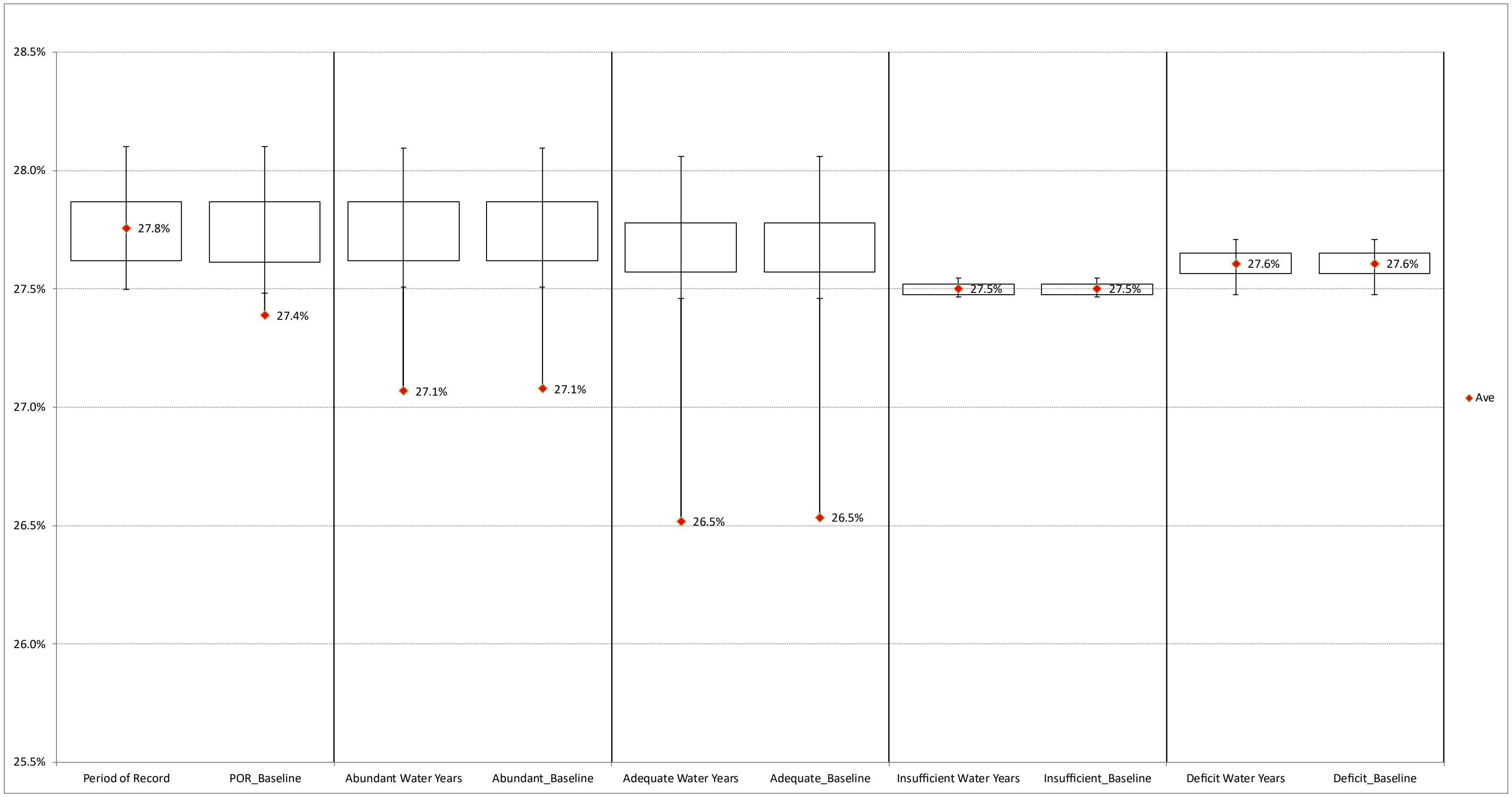


Figure 2-111. Foster 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival Under the NAA. *Downstream dam passage survival at Foster for juvenile winter steelhead 2 year olds under the NAA. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period 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 2-112. 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.*

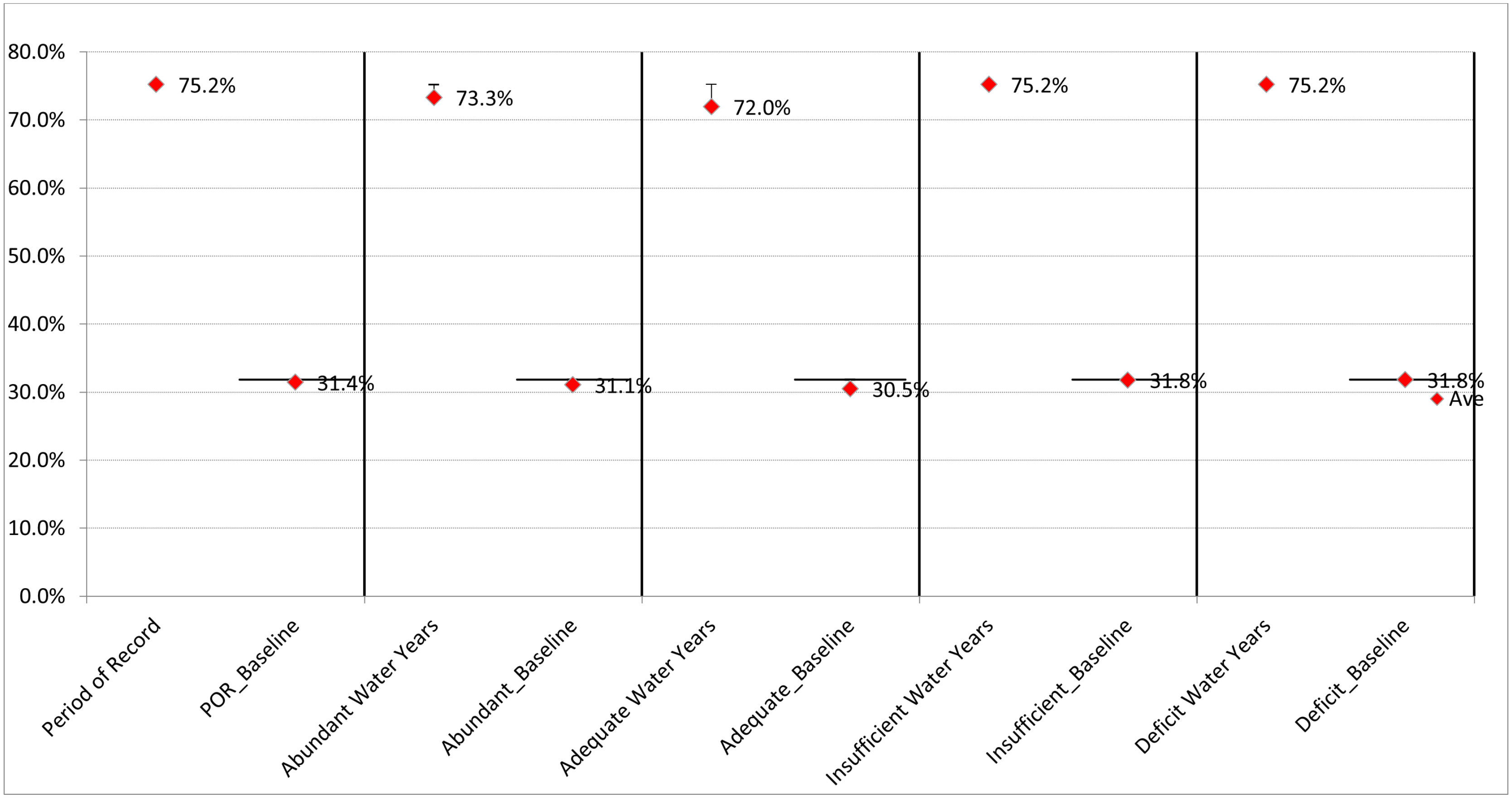


Figure 2-113. Foster Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Foster for juvenile winter steelhead yearlings under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for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

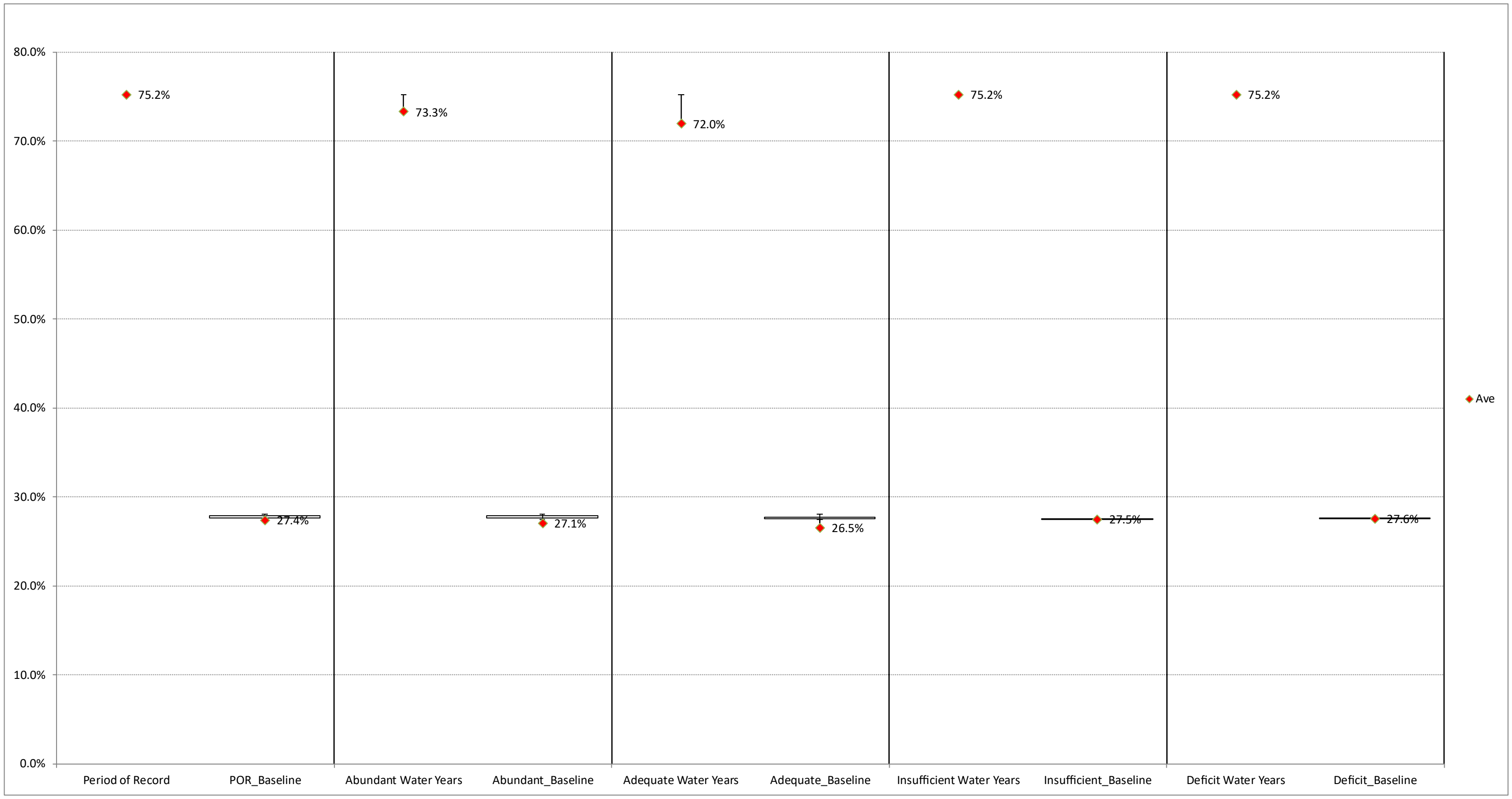


Figure 2-114. Foster 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Foster for juvenile winter steelhead 2 year olds under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given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

2.9.2 South Santiam – Green Peter

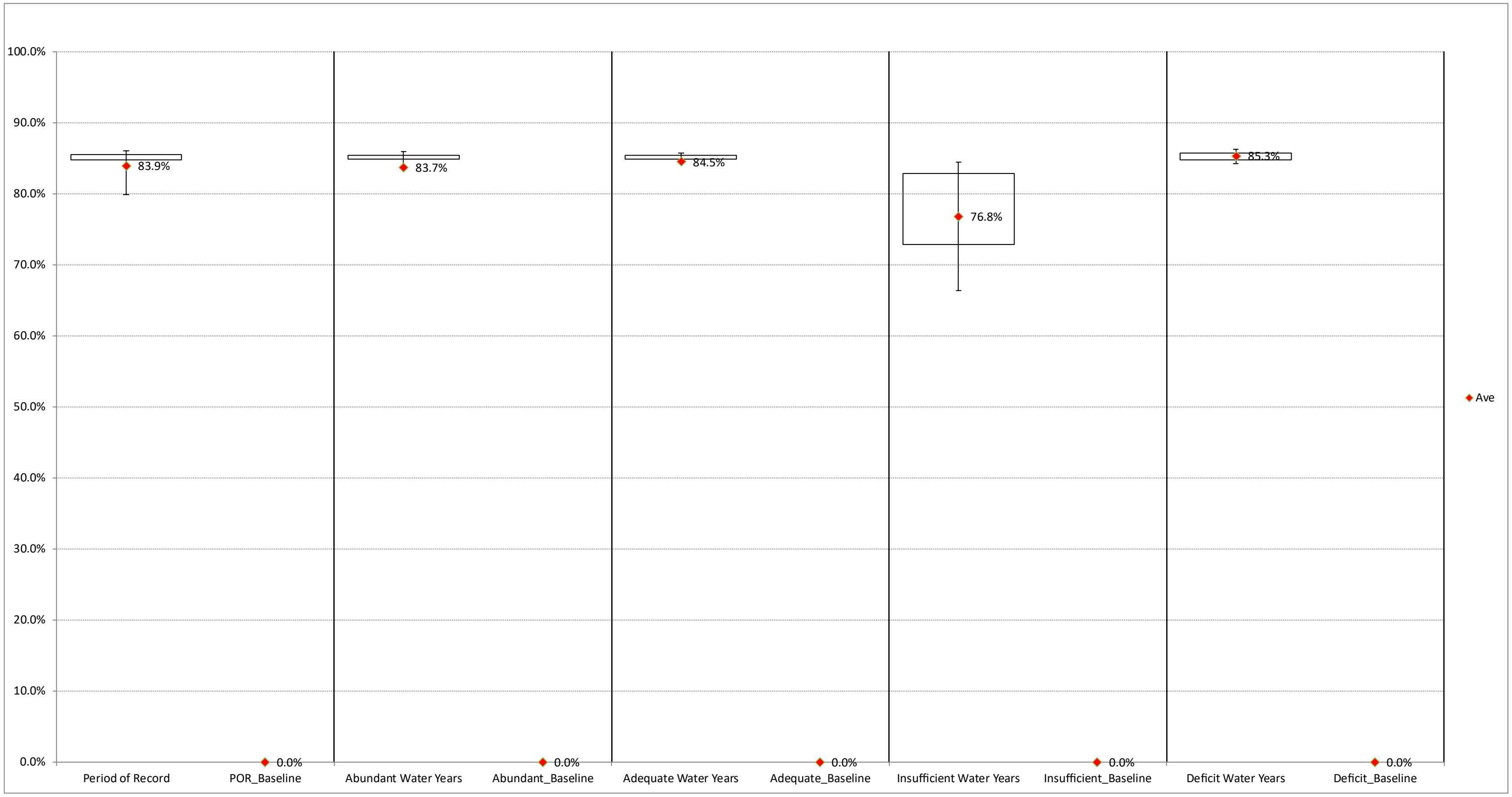


Figure 2-115. Green Peter Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Green Peter for juvenile winter steelhead sub-yearlings under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities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

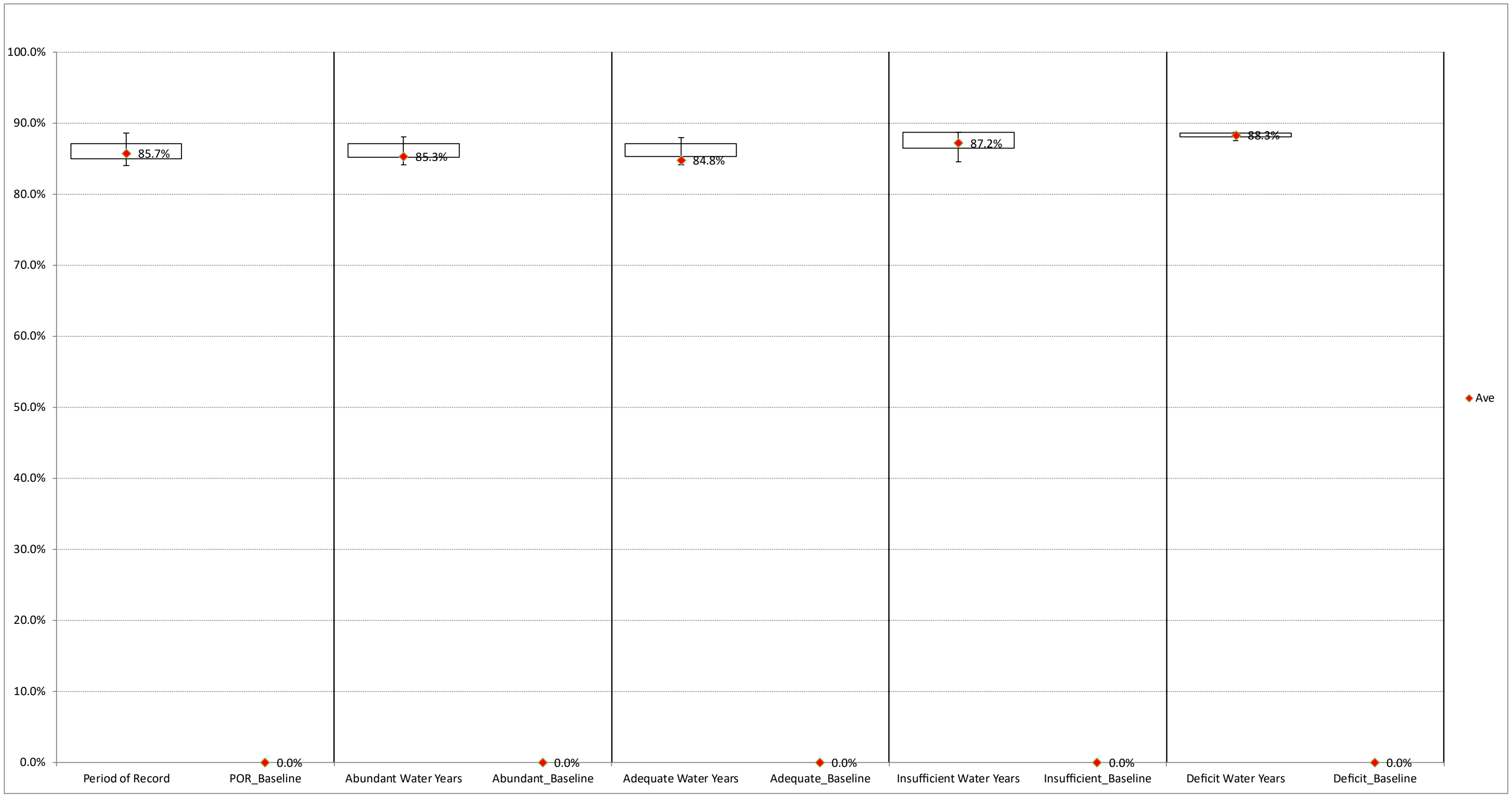


Figure 2-116. Green Peter Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Green Peter for juvenile winter steelhead yearlings under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

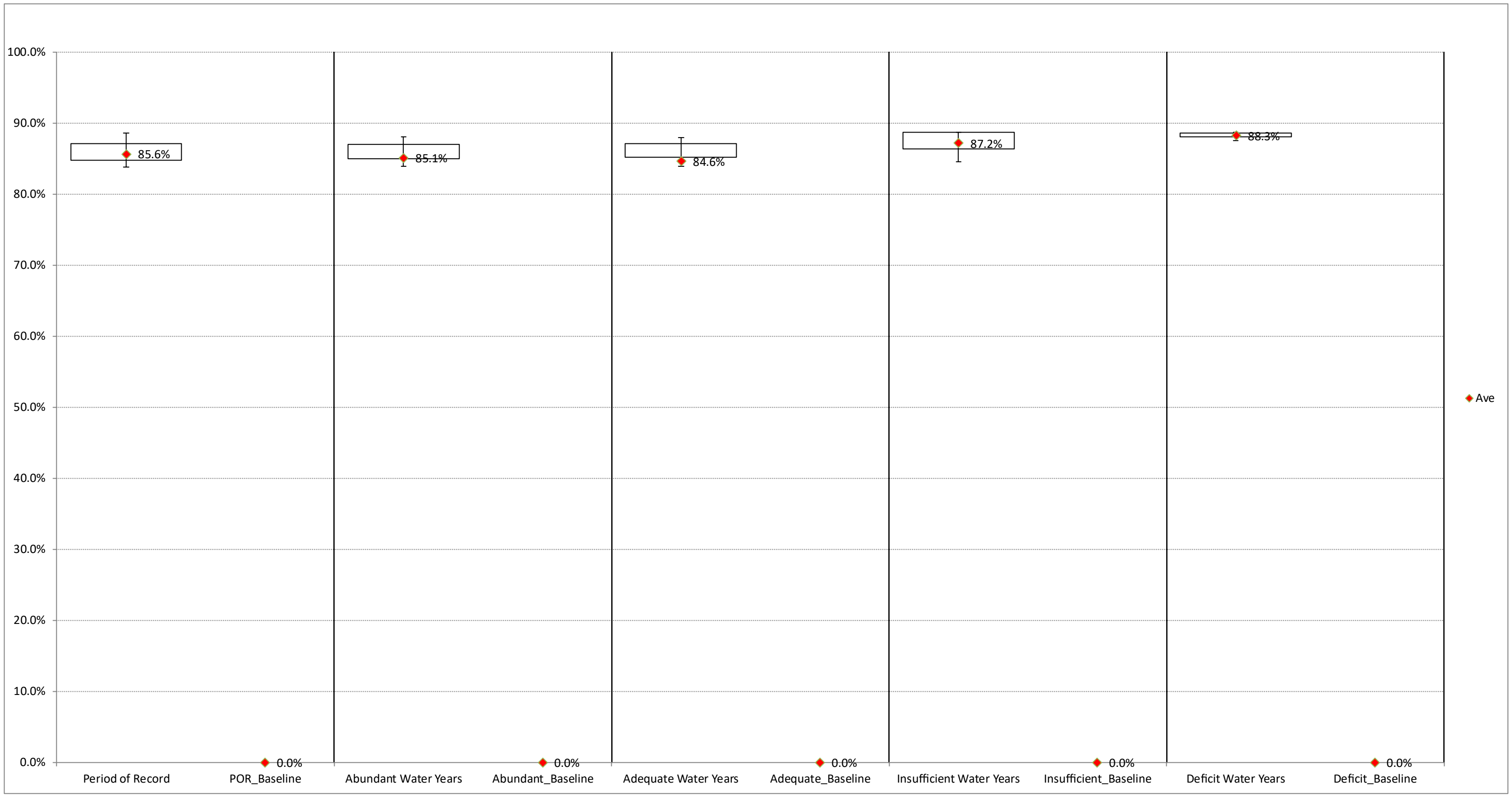


Figure 2-117. Green Peter 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival Under Alternative 1. *Downstream dam passage survival at Green Peter for juvenile winter steelhead 2 year olds under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities 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

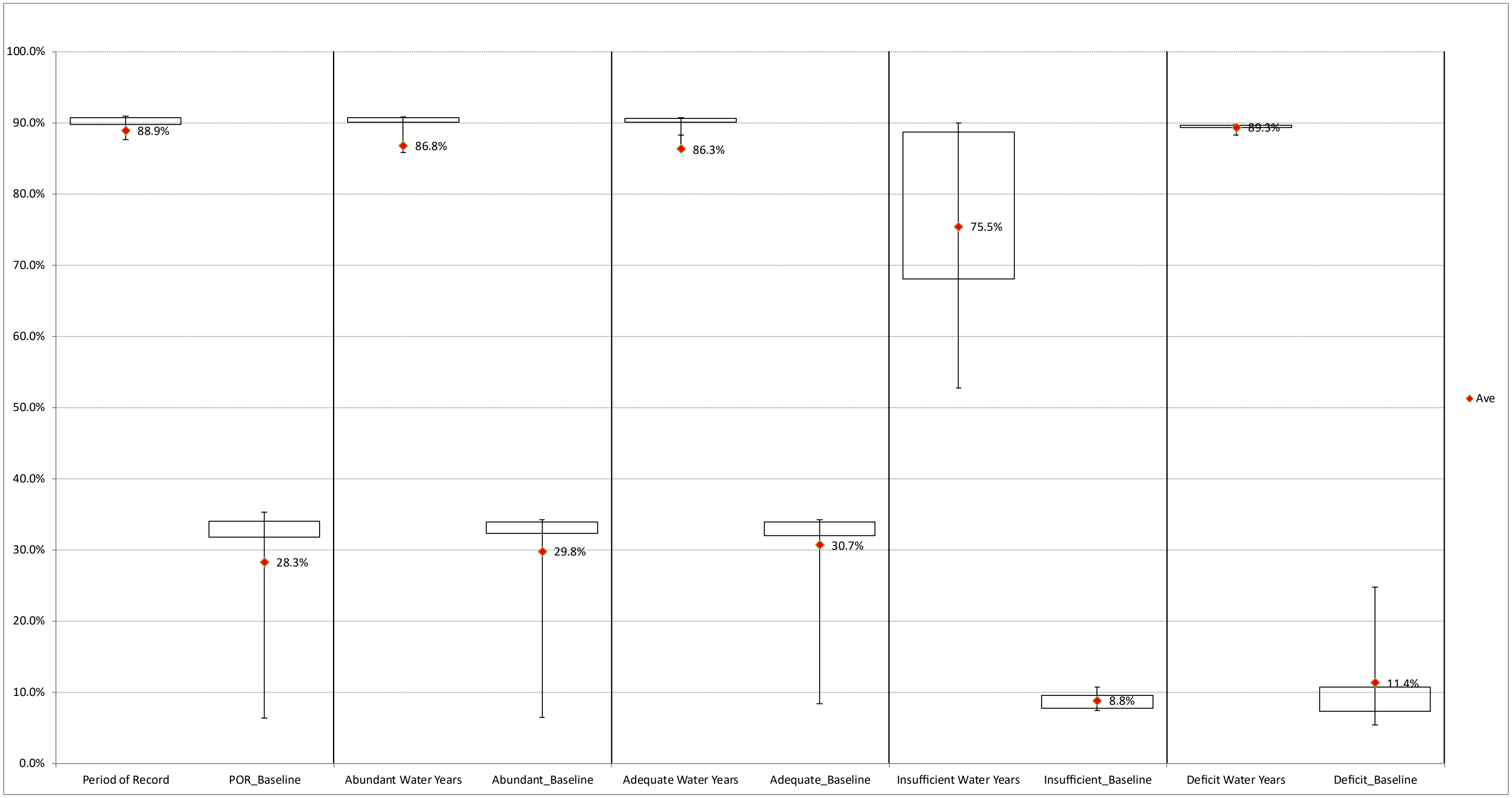


Figure 2-118. Detroit Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under Alternative 2a and 2b. *Downstream dam passage survival at Detroit for juvenile winter steelhead sub-yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities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

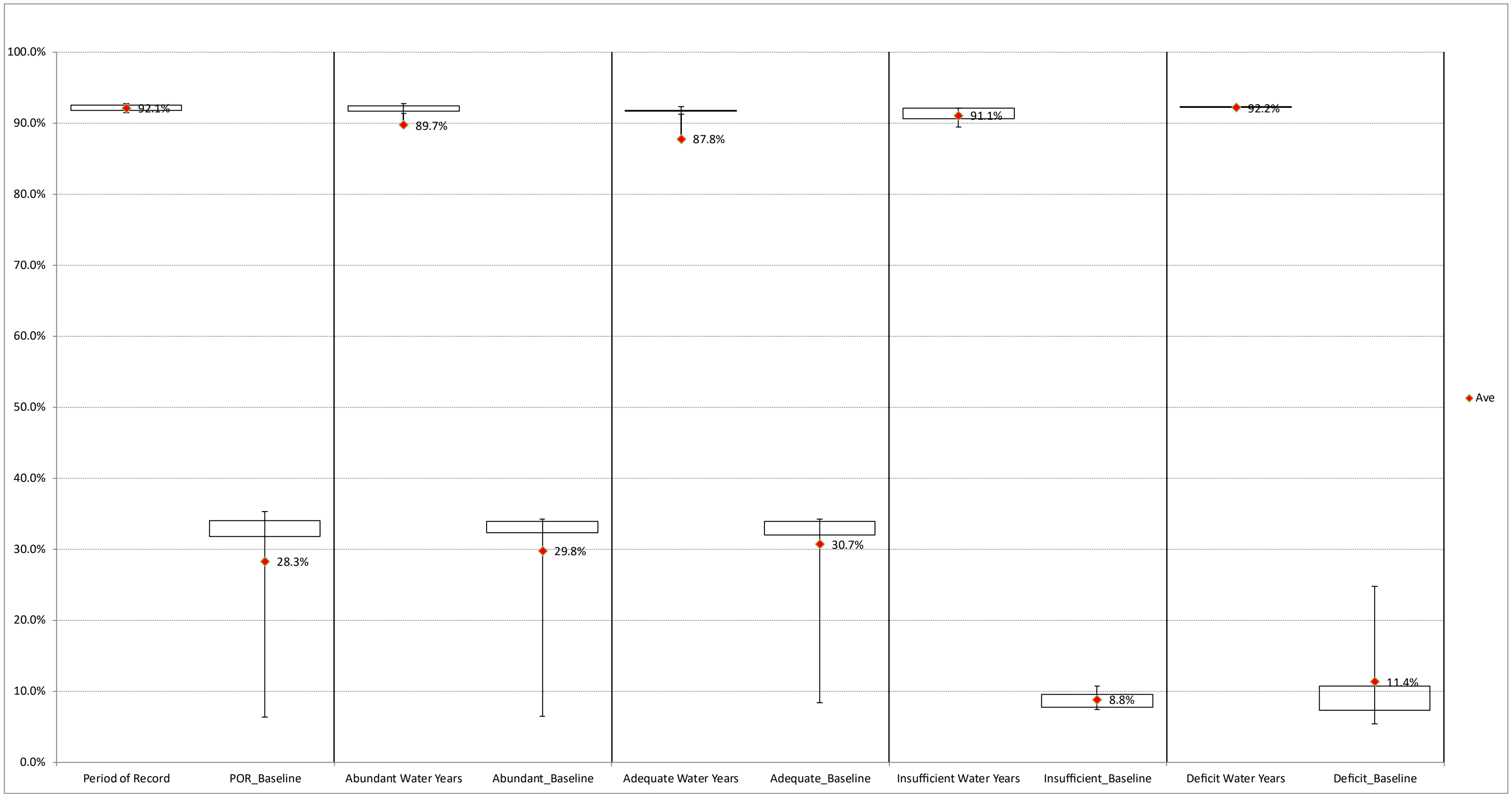


Figure 2-119. Detroit Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 2a and 2b. *Downstream dam passage survival at Detroit for juvenile winter steelhead yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities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

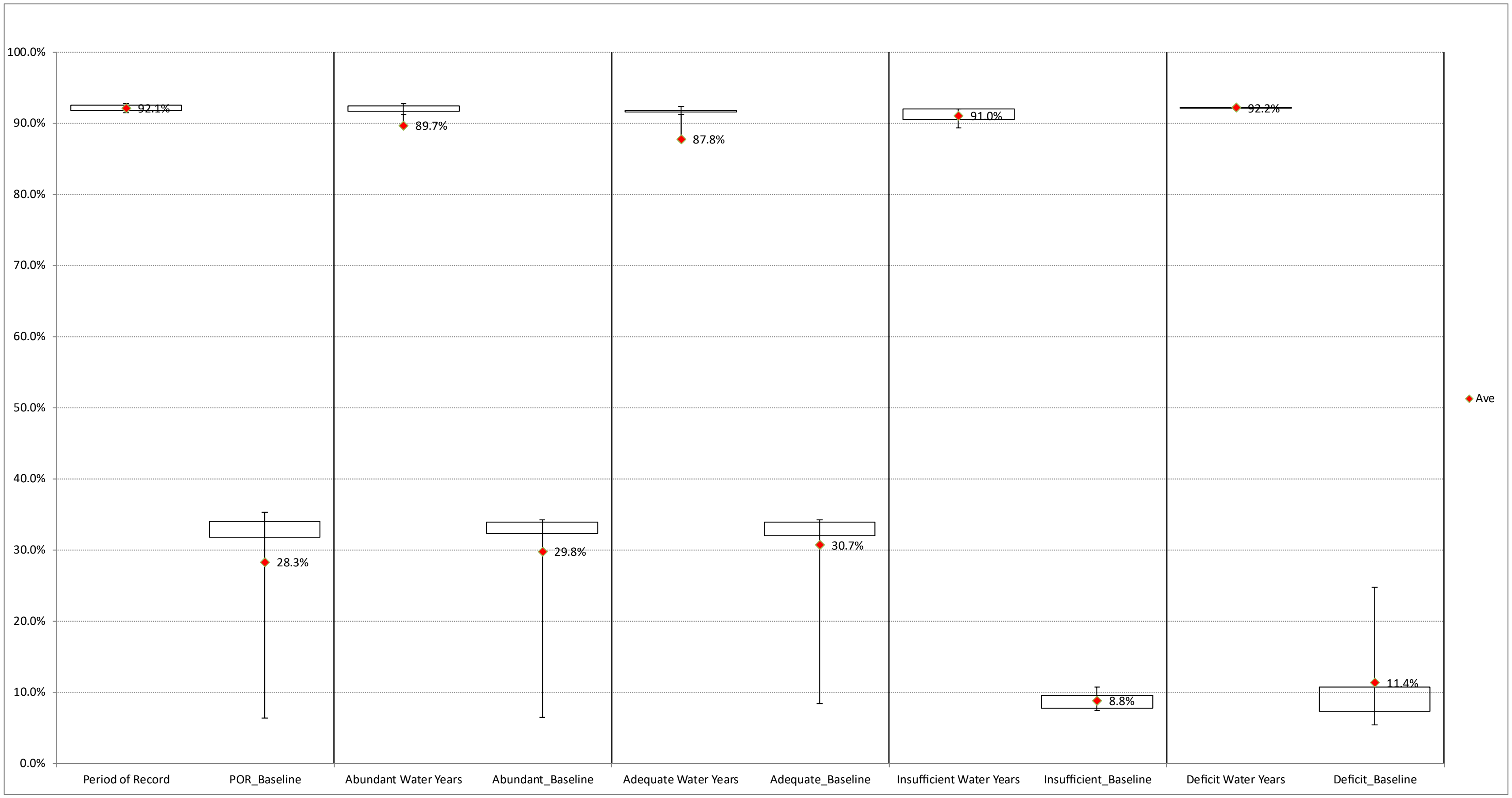


Figure 2-120. Detroit 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival Under Alternative 2a and 2b.
Downstream dam passage survival at Detroit for juvenile winter steelhead 2 year olds under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities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

2.10.2 South Santiam – Foster

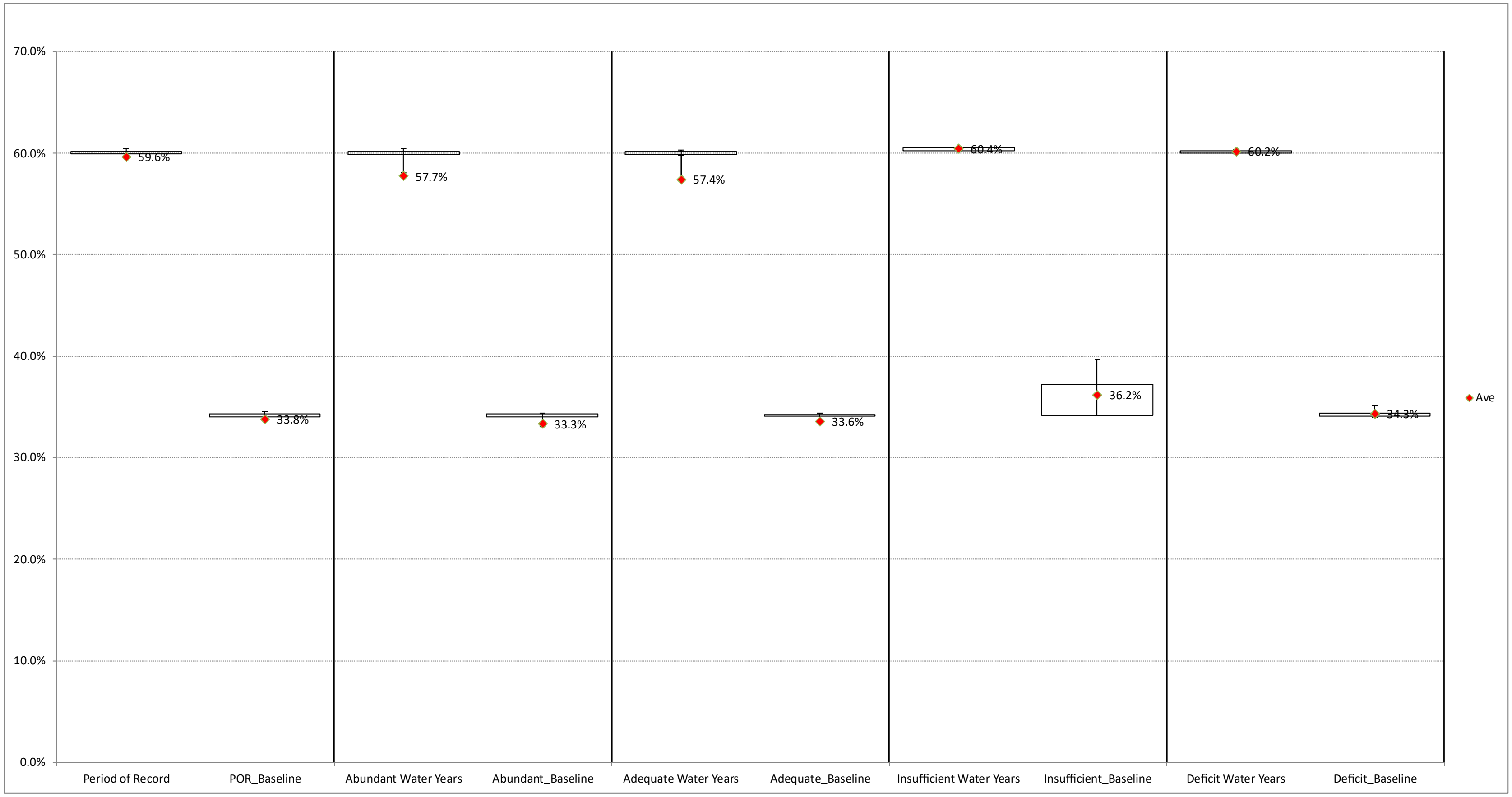


Figure 2-121. Foster Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under Alternative 2a and 2b. *Downstream dam passage survival at Foster for juvenile winter steelhead sub-yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities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

Figure 2-122. 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.*

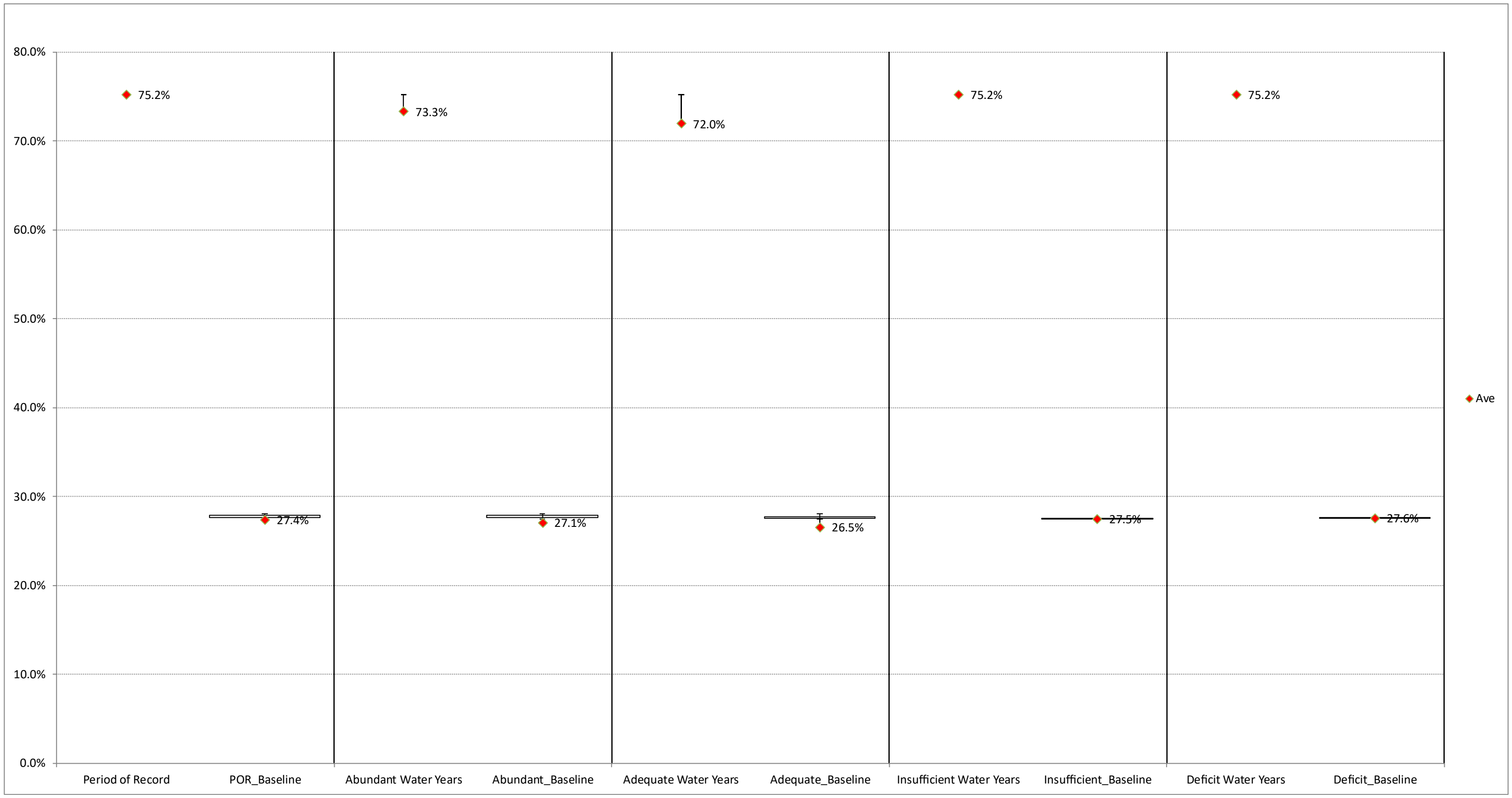


Figure 2-123. Foster 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival Under Alternative 2a and 2b. *Downstream dam passage survival at Foster for juvenile winter steelhead 2 year olds under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities 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

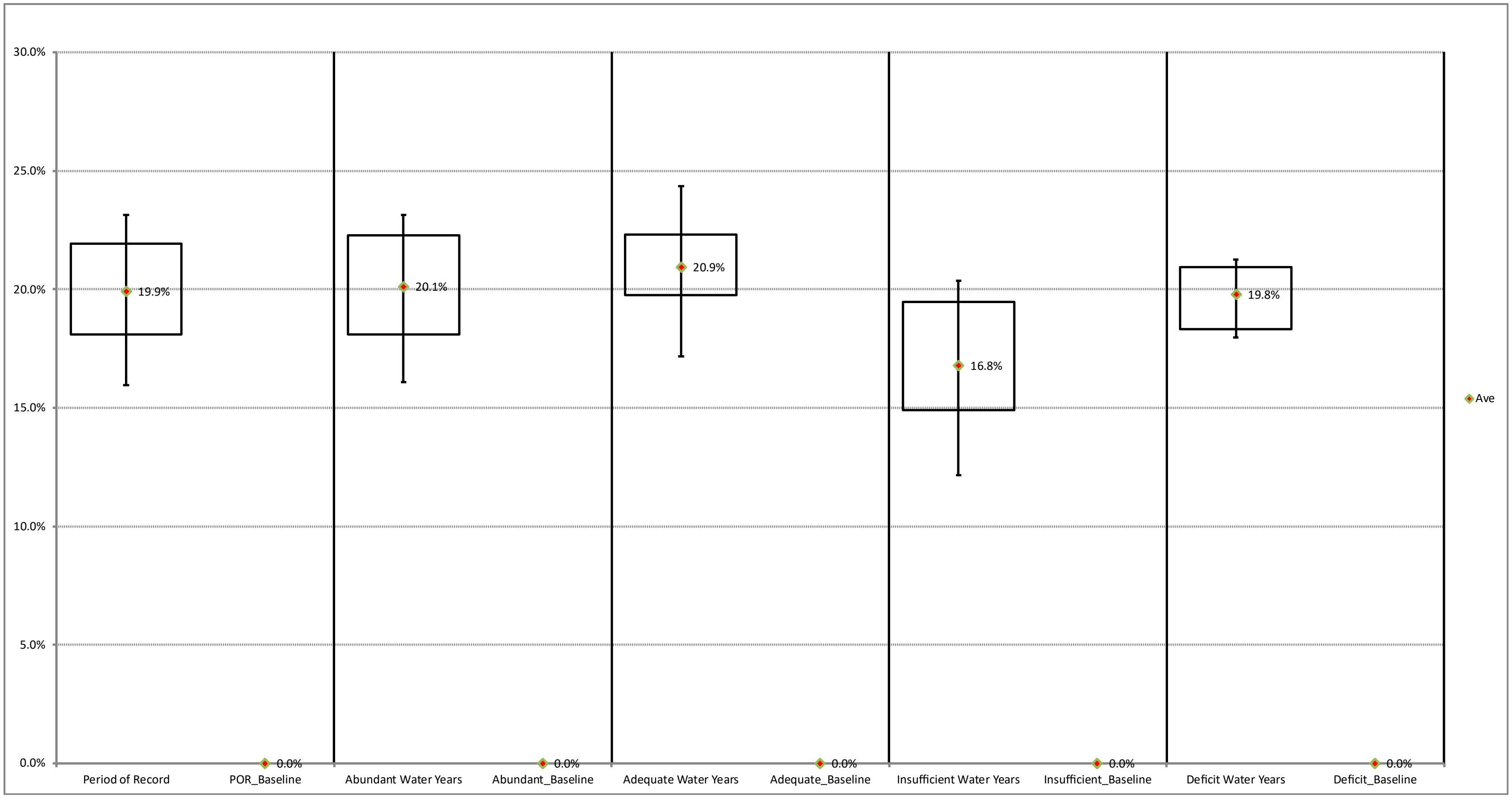


Figure 2-124. Green Peter Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under Alternative 2a and 2b. *Downstream dam passage survival at Green Peter for juvenile winter steelhead sub-yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival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

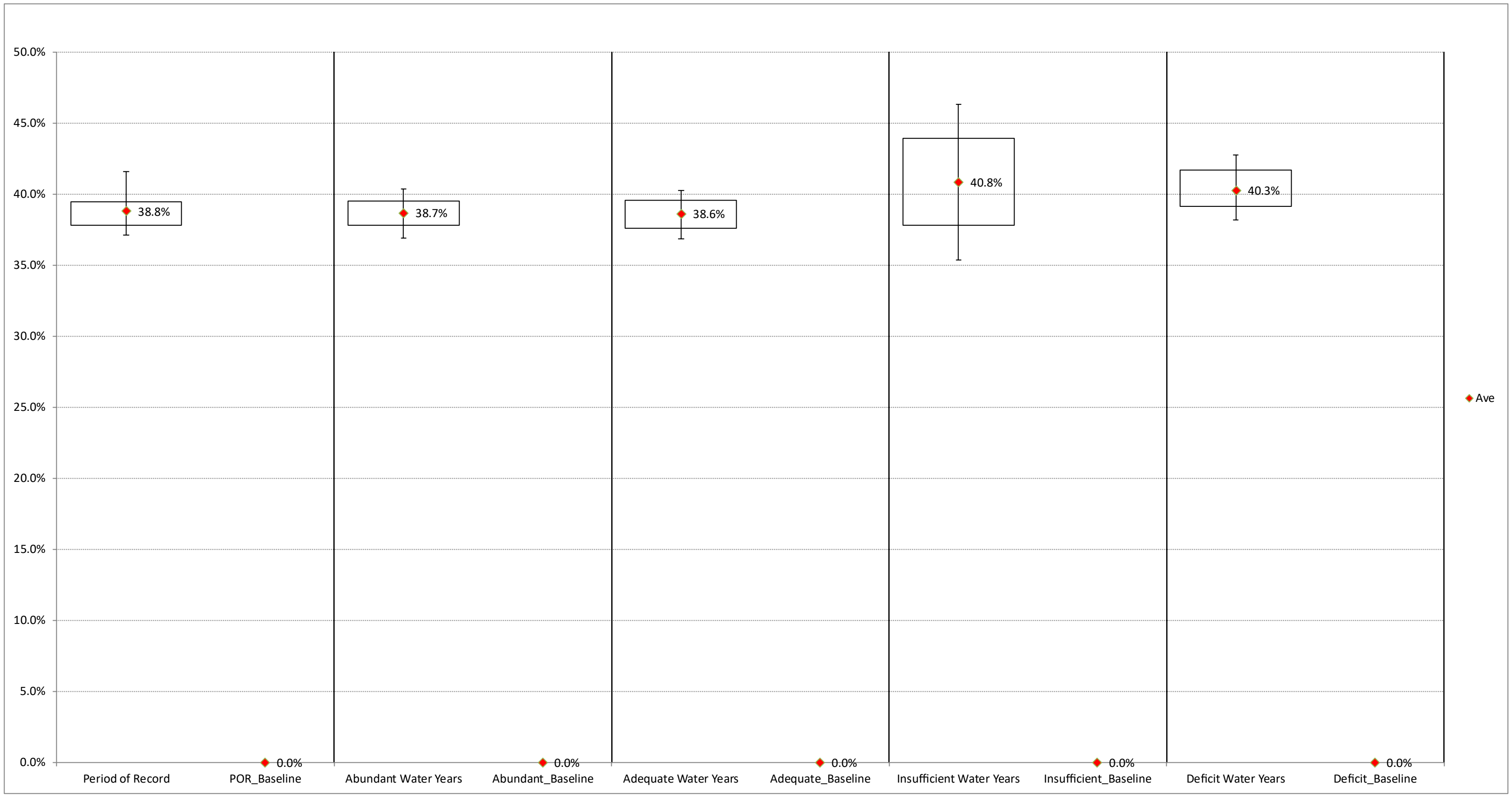


Figure 2-125. Green Peter Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 2a and 2b. *Downstream dam passage survival at Green Peter for juvenile winter steelhead yearlings under Alternative 2a. The mean is given by the point estimate (filled dot). Survival probabilities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

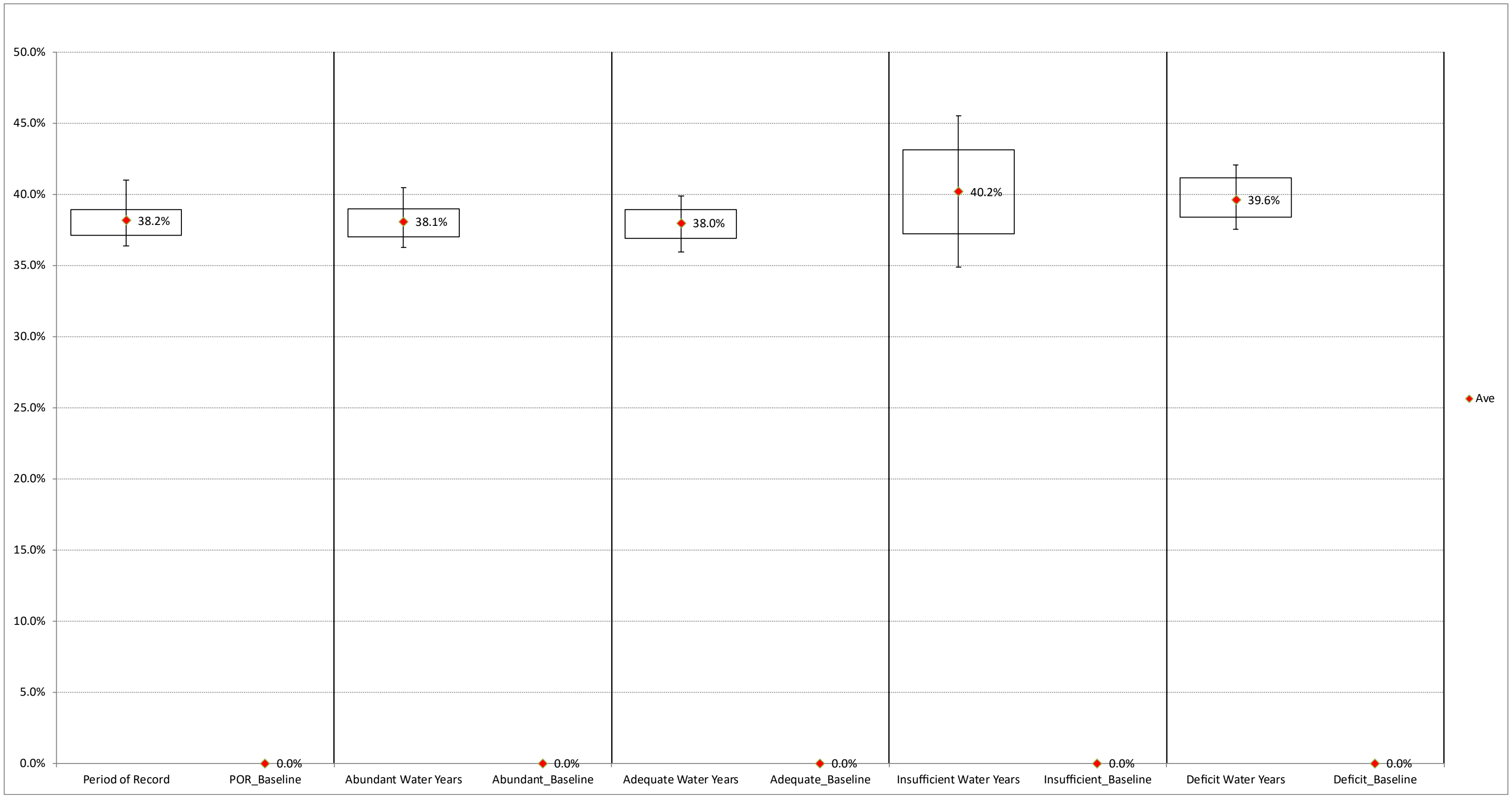


Figure 2-126. Green Peter 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival Under Alternative 2a and 2b. *Downstream dam passage survival at Detroit for juvenile winter steelhead 2 year olds under Alternative 1. The mean is given by the point estimate (filled dot). Survival probabilities 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

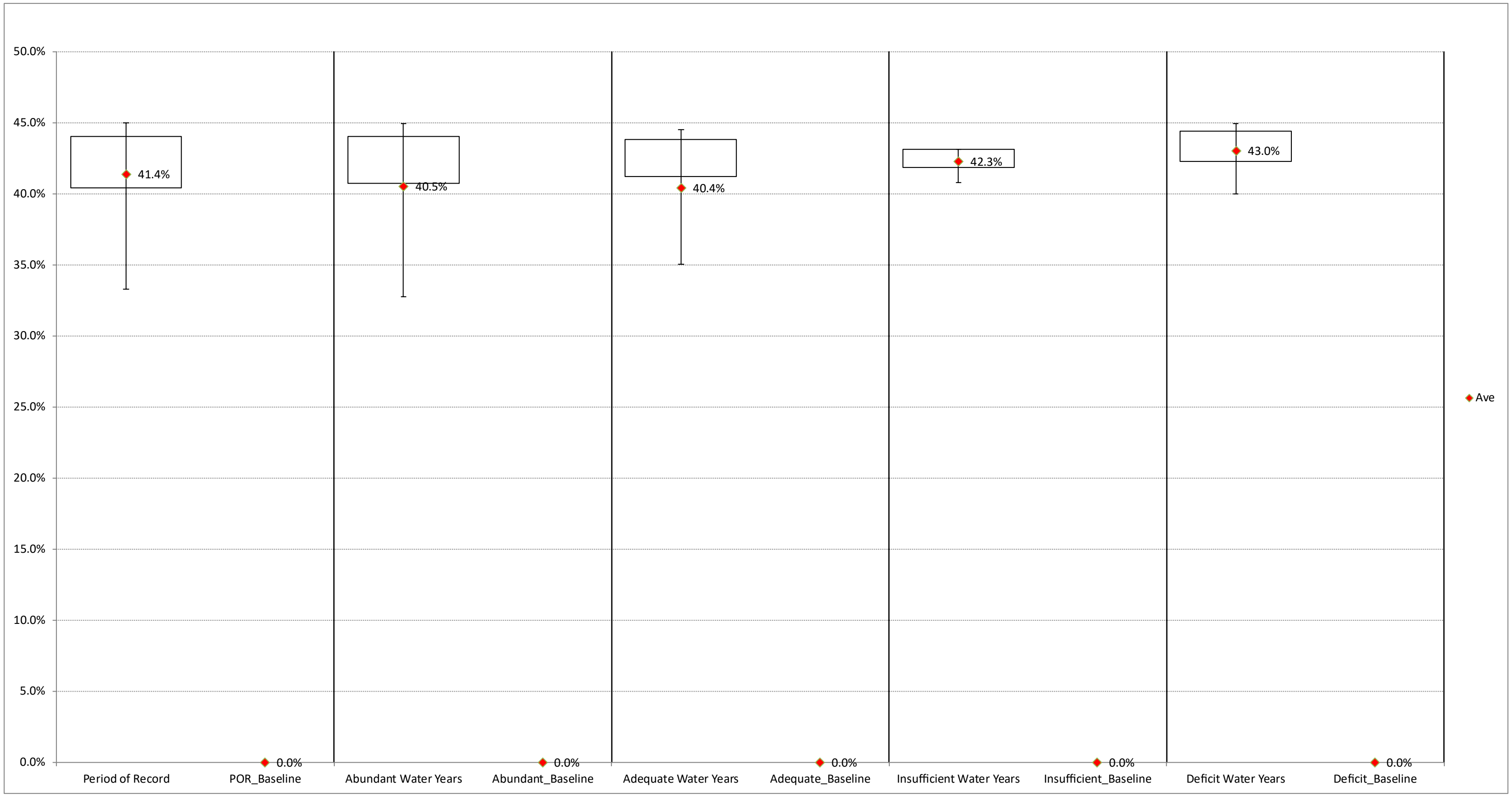


Figure 2-127. Detroit Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Detroit for juvenile winter steelhead sub-yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities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

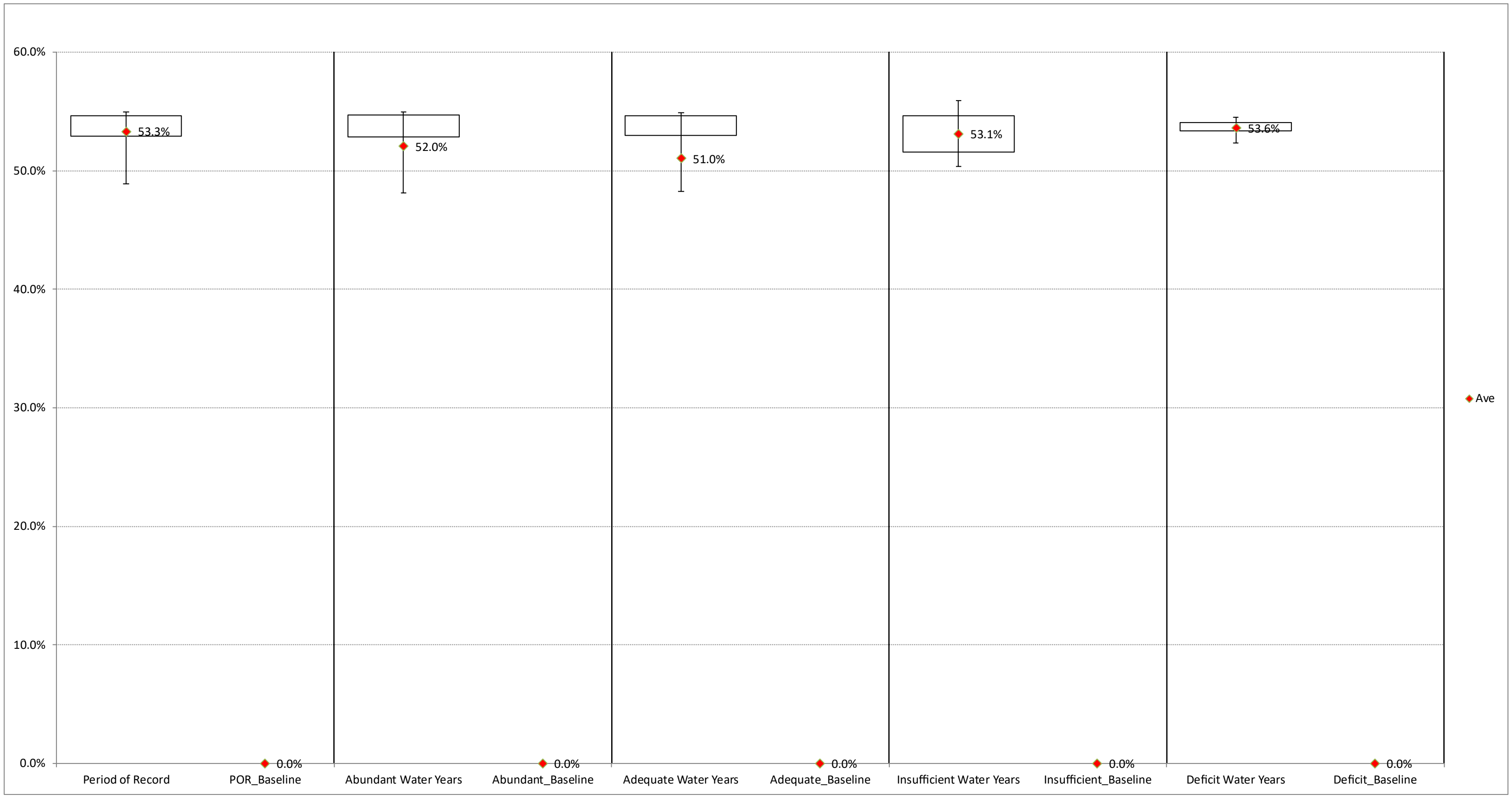


Figure 2-128. Detroit Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Detroit for juvenile winter steelhead yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given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

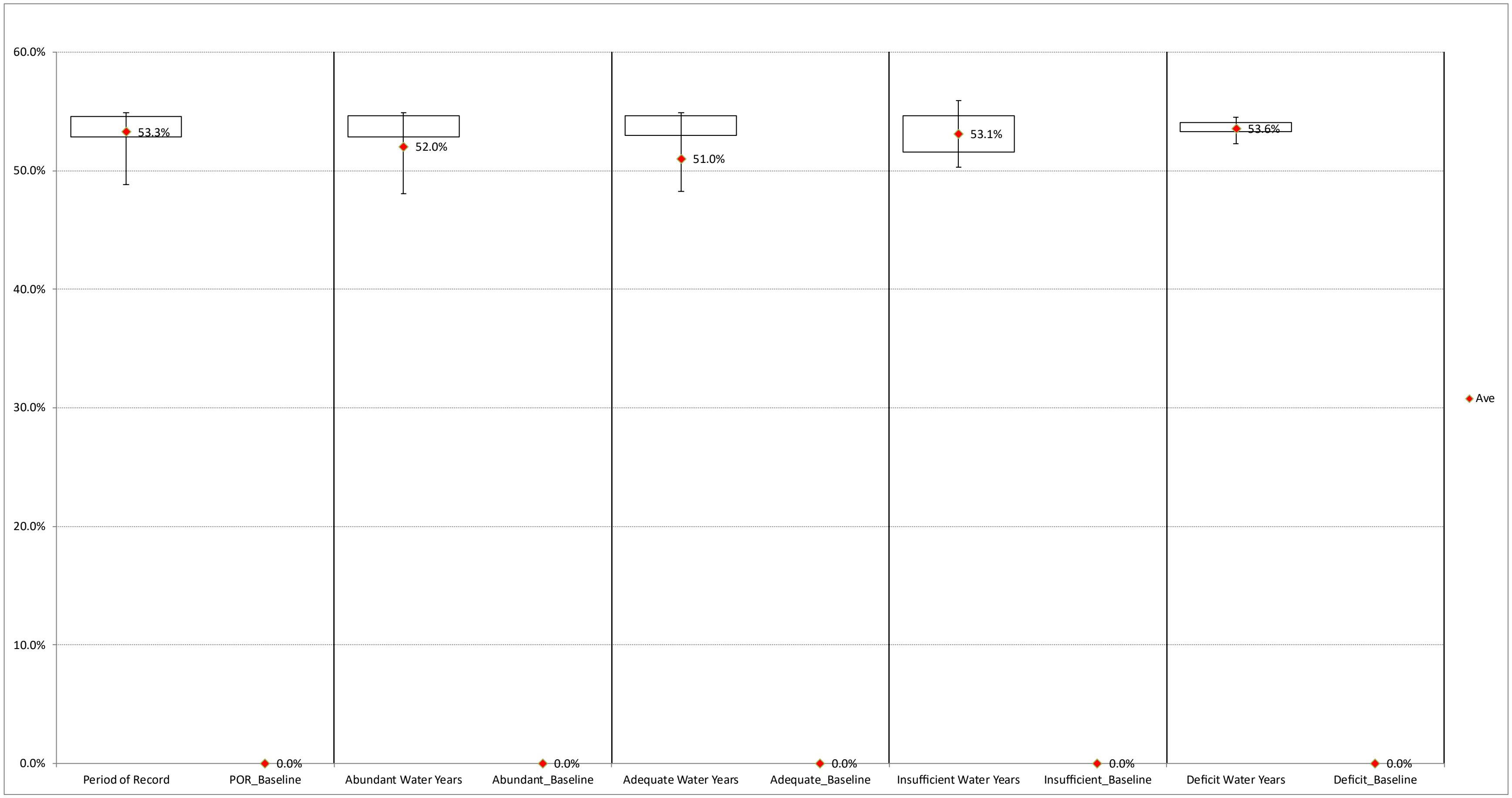


Figure 2-129. Detroit 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Detroit for juvenile winter steelhead 2 year olds under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are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

2.11.2 South Santiam – Foster

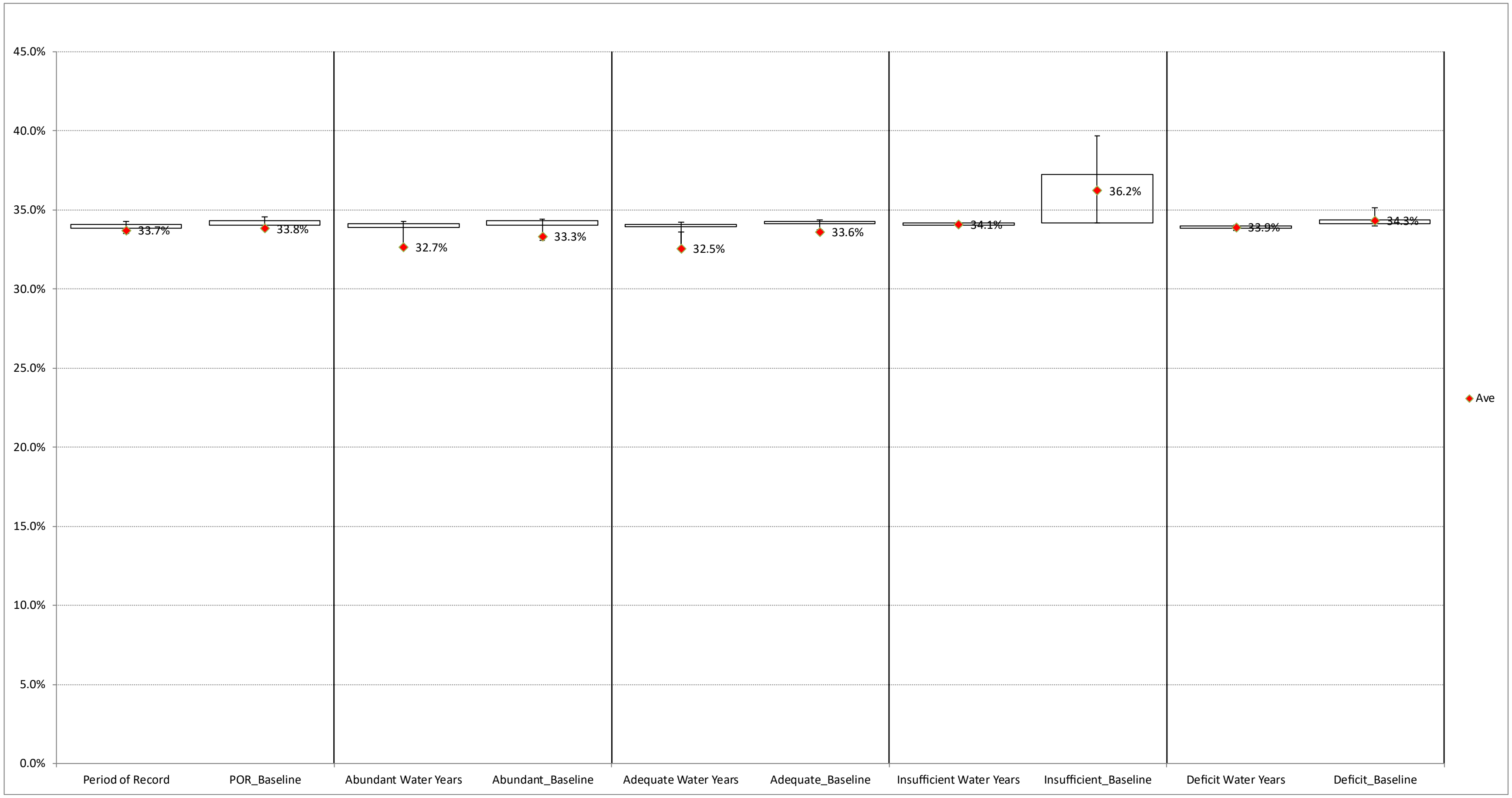


Figure 2-130. Foster Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Foster for juvenile winter steelhead sub-yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are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

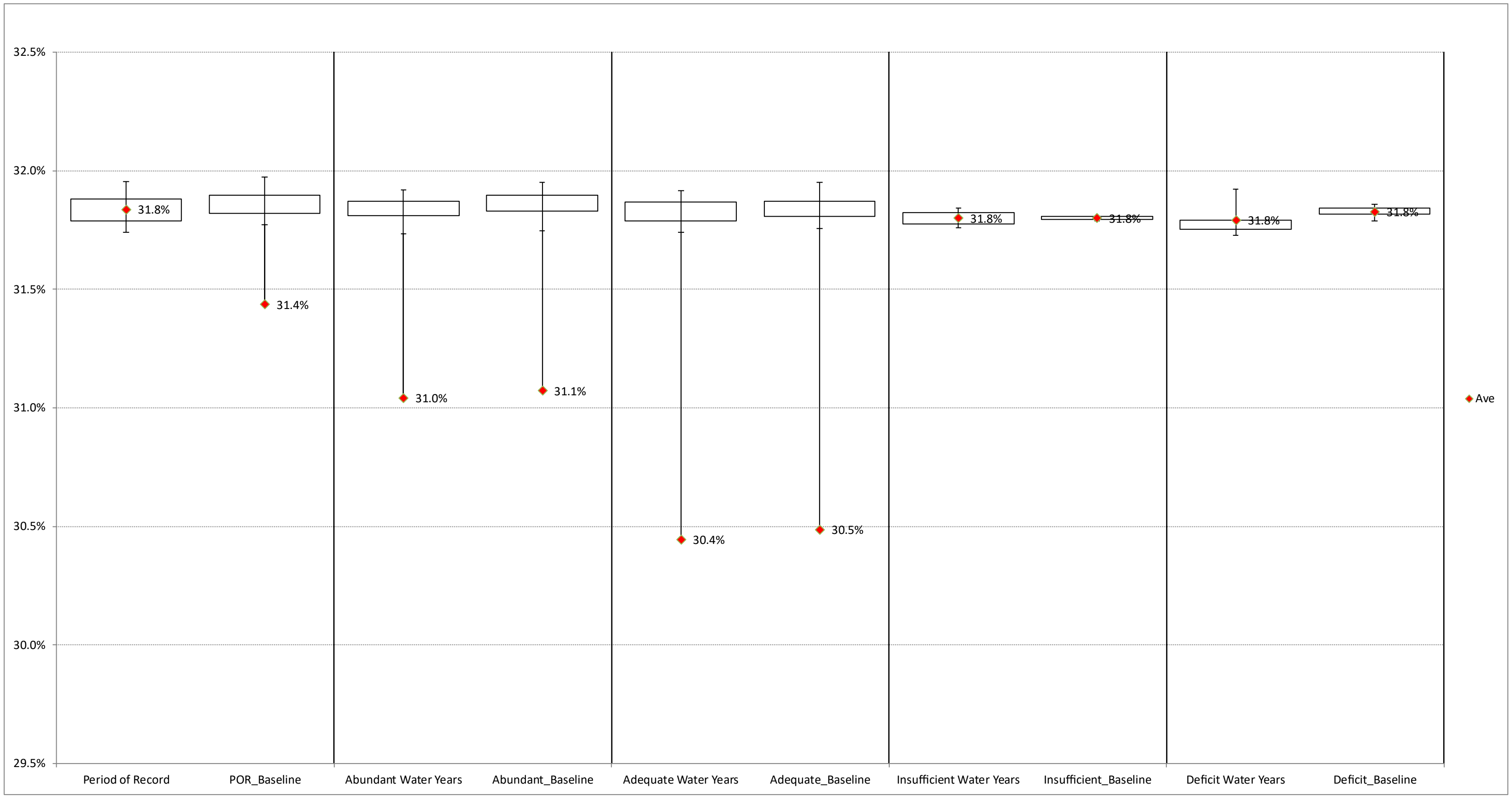


Figure 2-131. Foster Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Foster for juvenile winter steelhead yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given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

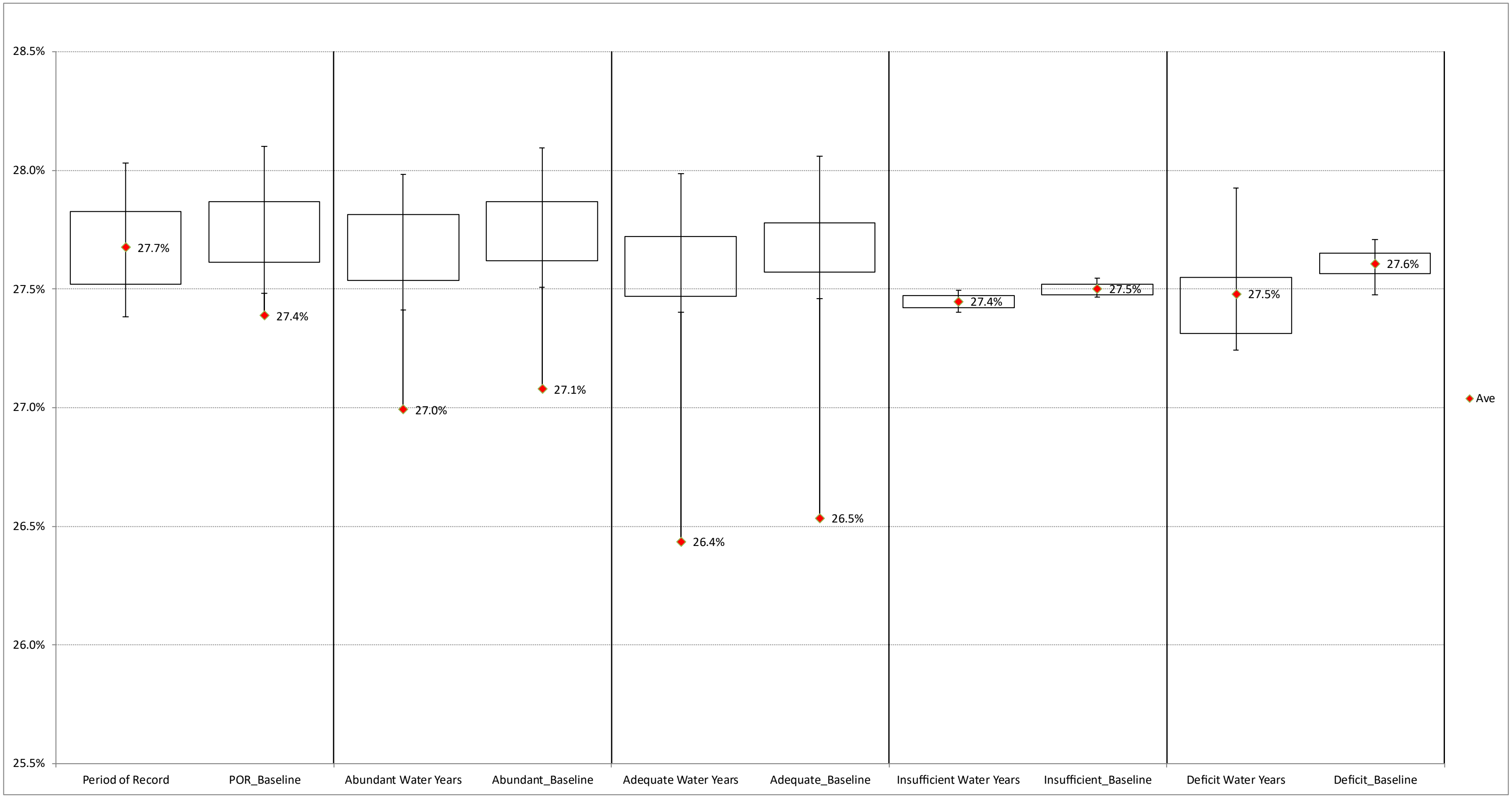


Figure 2-132. Foster Juvenile Winter Steelhead 2 Year Old Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Foster for juvenile winter steelhead 2 year olds under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities are given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

2.11.3 South Santiam – Green Peter

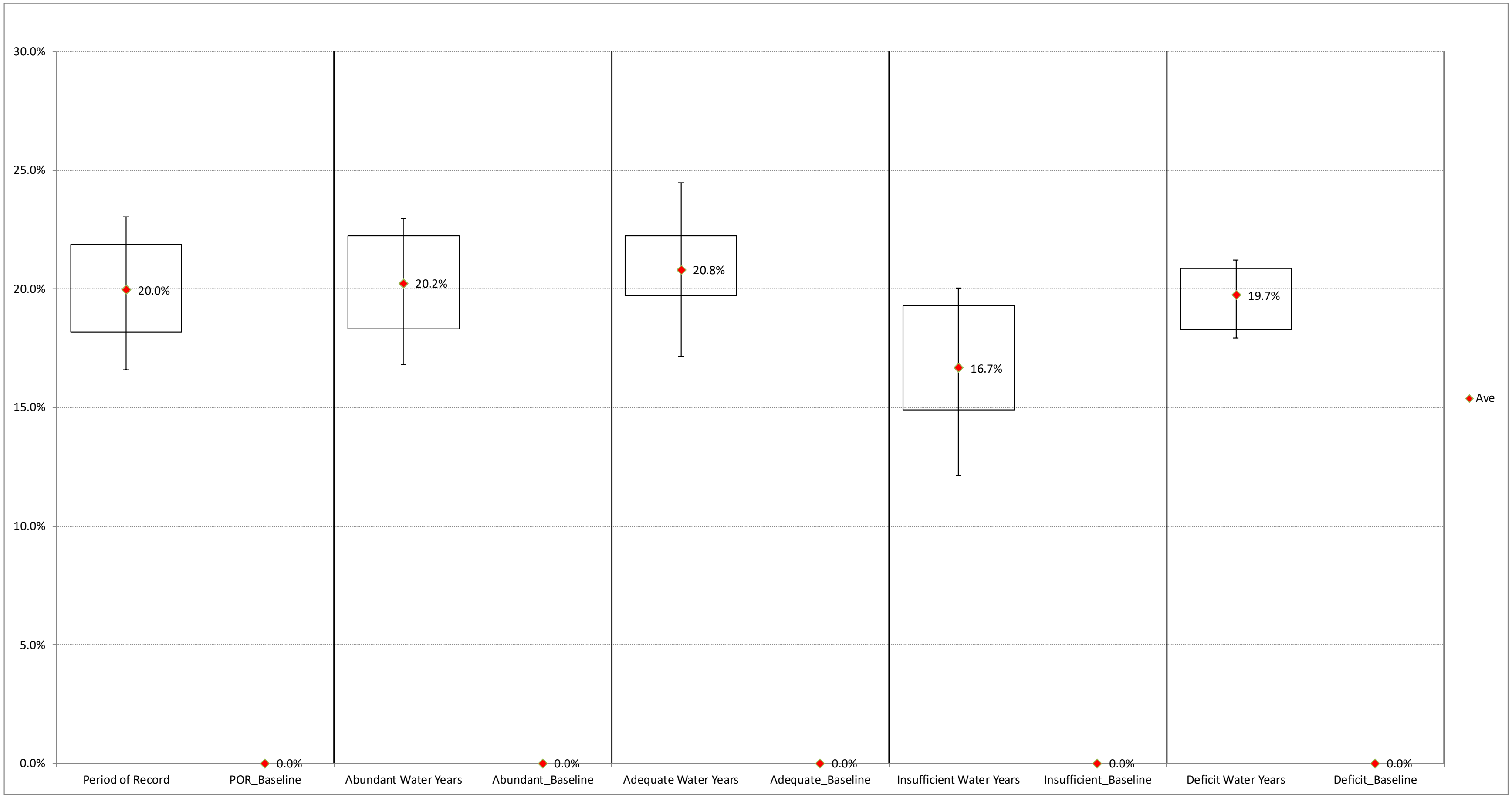


Figure 2-133. Green Peter Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Green Peter for juvenile winter steelhead sub-yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities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

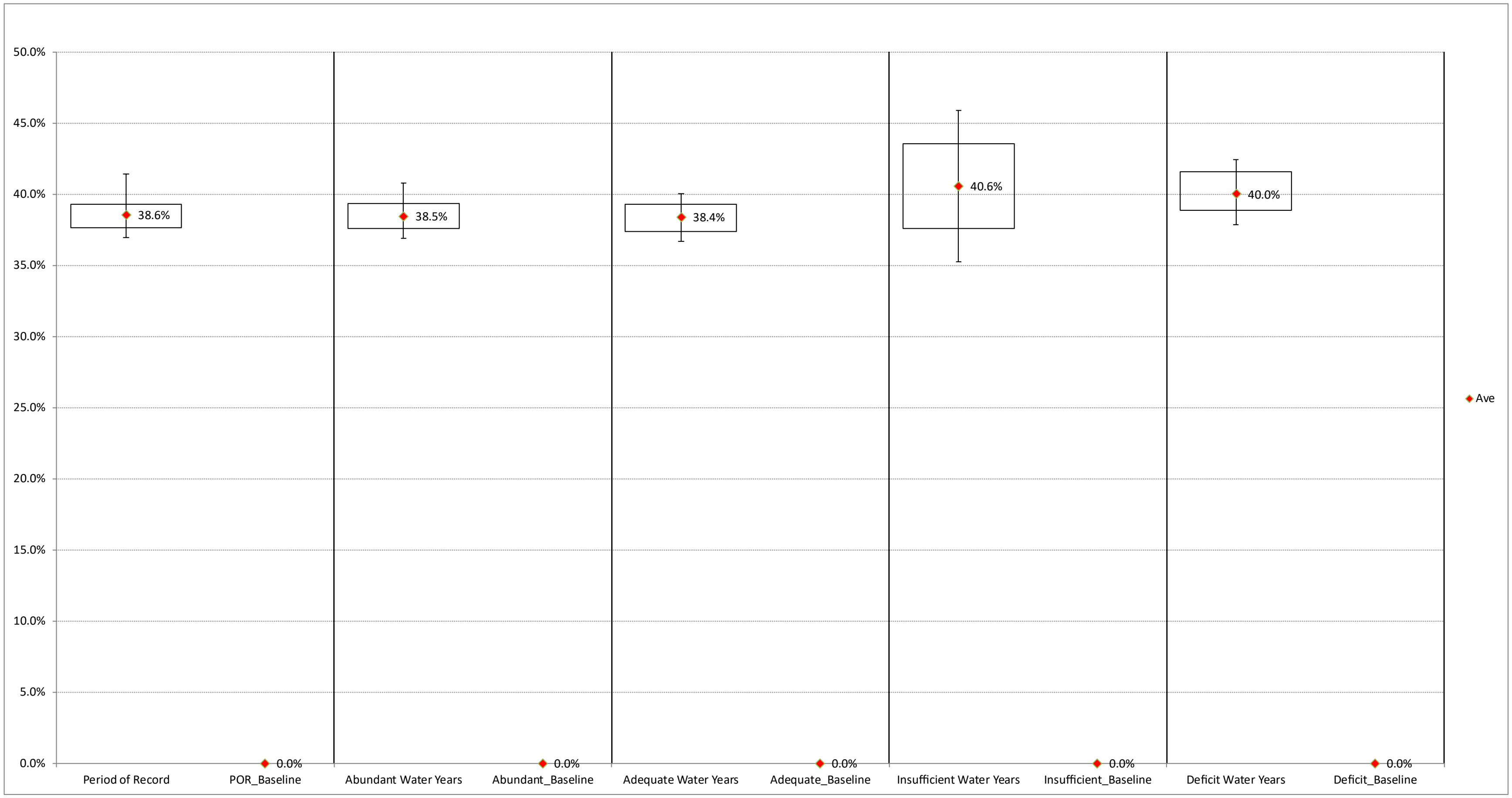


Figure 2-134. Green Peter Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Green Peter for juvenile winter steelhead yearlings under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities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

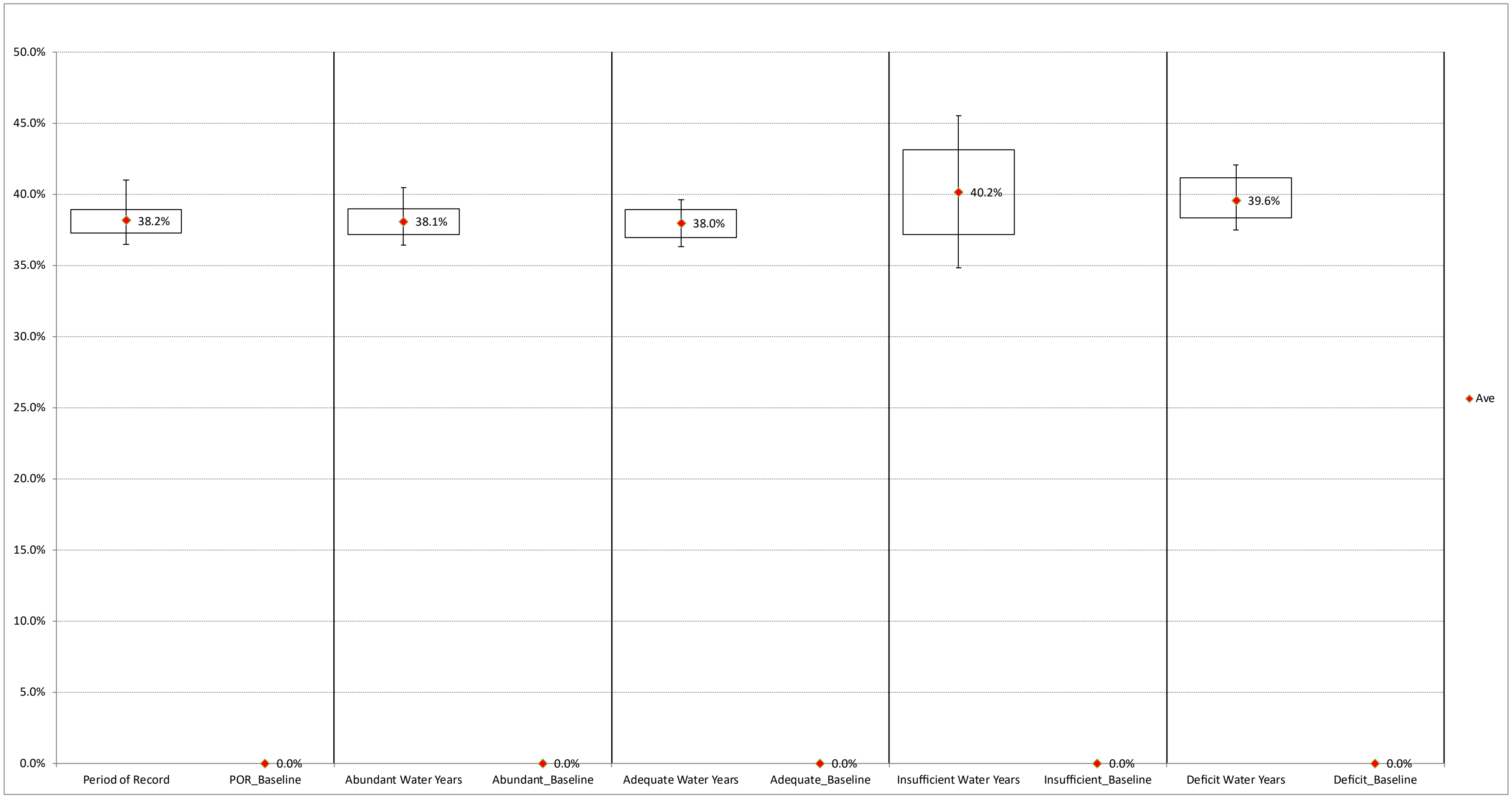


Figure 2-135. Green Peter 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival Under Alternative 3a. *Downstream dam passage survival at Green Peter for juvenile winter steelhead 2 year olds under Alternative 3a. The mean is given by the point estimate (filled dot). Survival probabilities 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

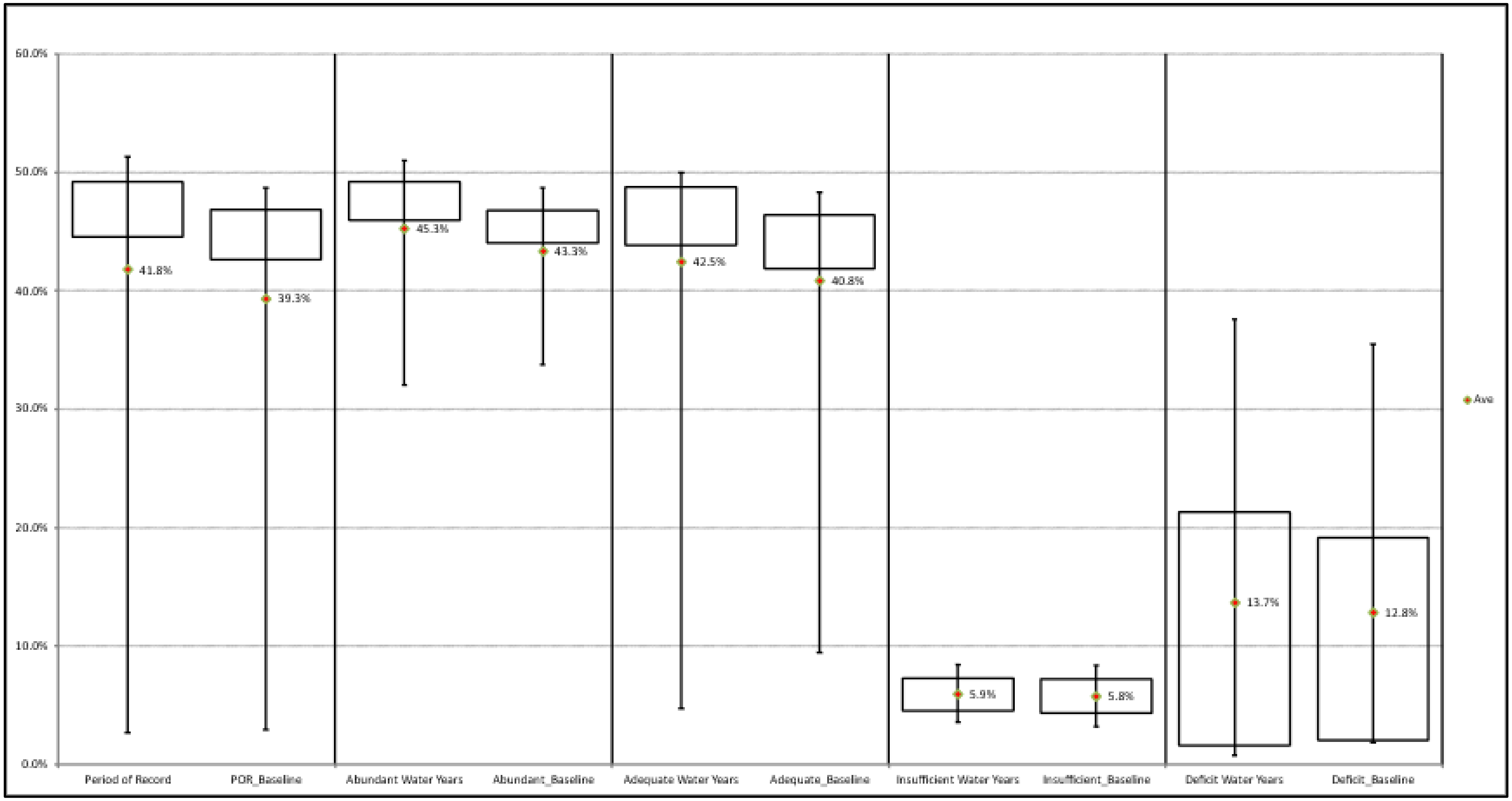


Figure 2-136. Detroit Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Detroit for juvenile winter steelhead sub-yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities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

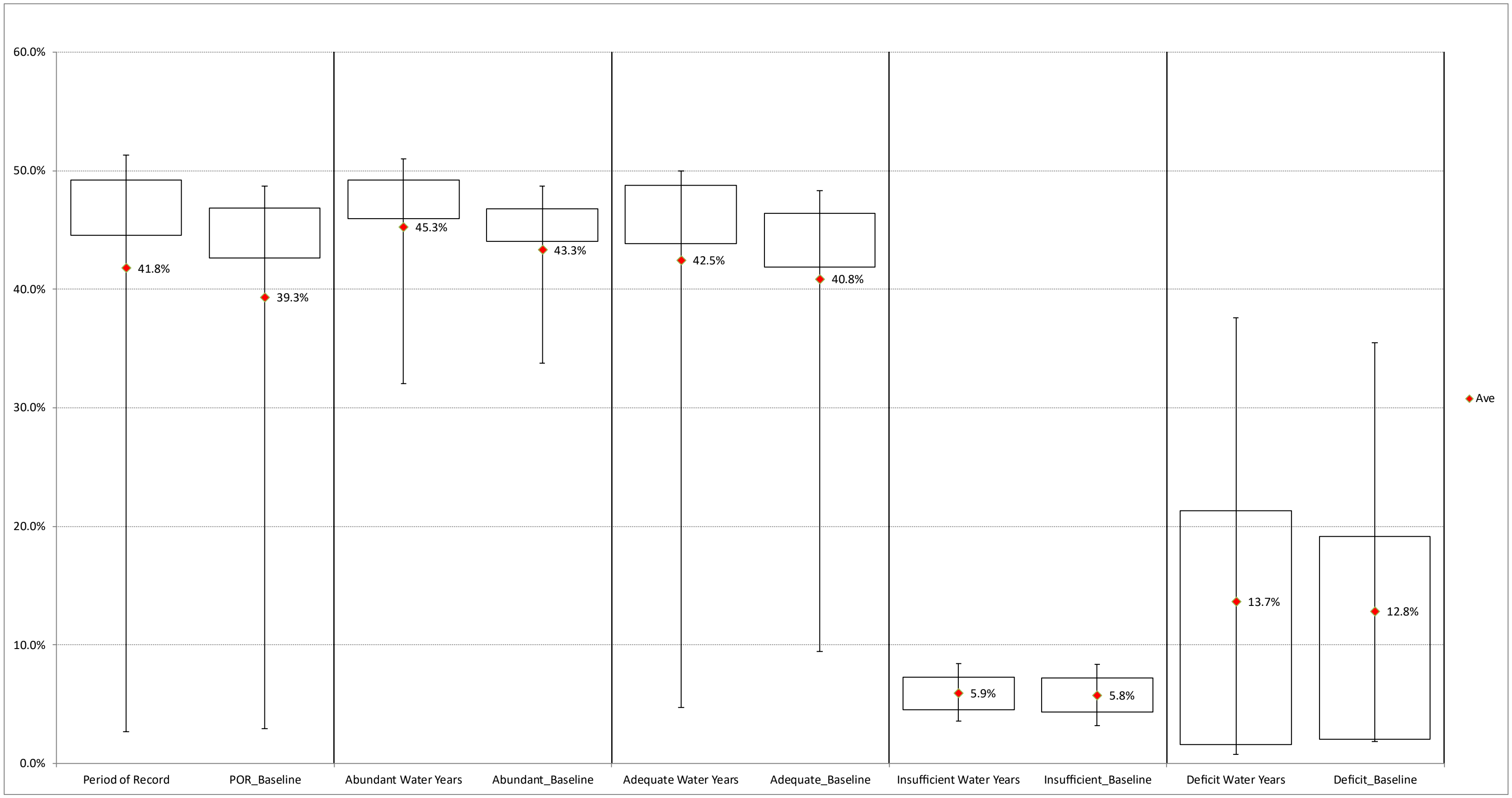


Figure 2-137. Detroit Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Detroit for juvenile winter steelhead yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given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

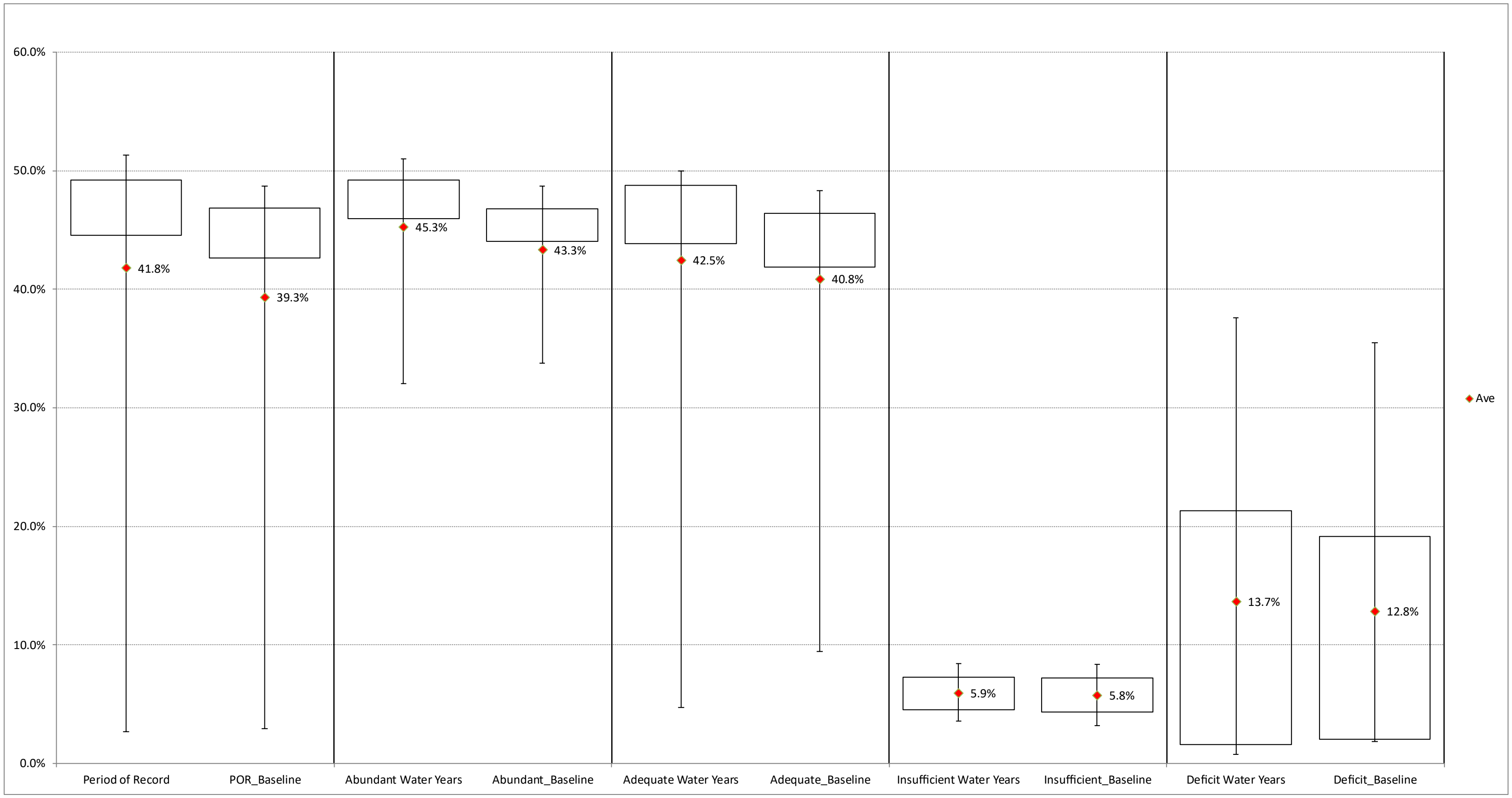


Figure 2-138. Detroit 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Detroit for juvenile winter steelhead 2 year olds under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are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

2.12.2 South Santiam – Foster

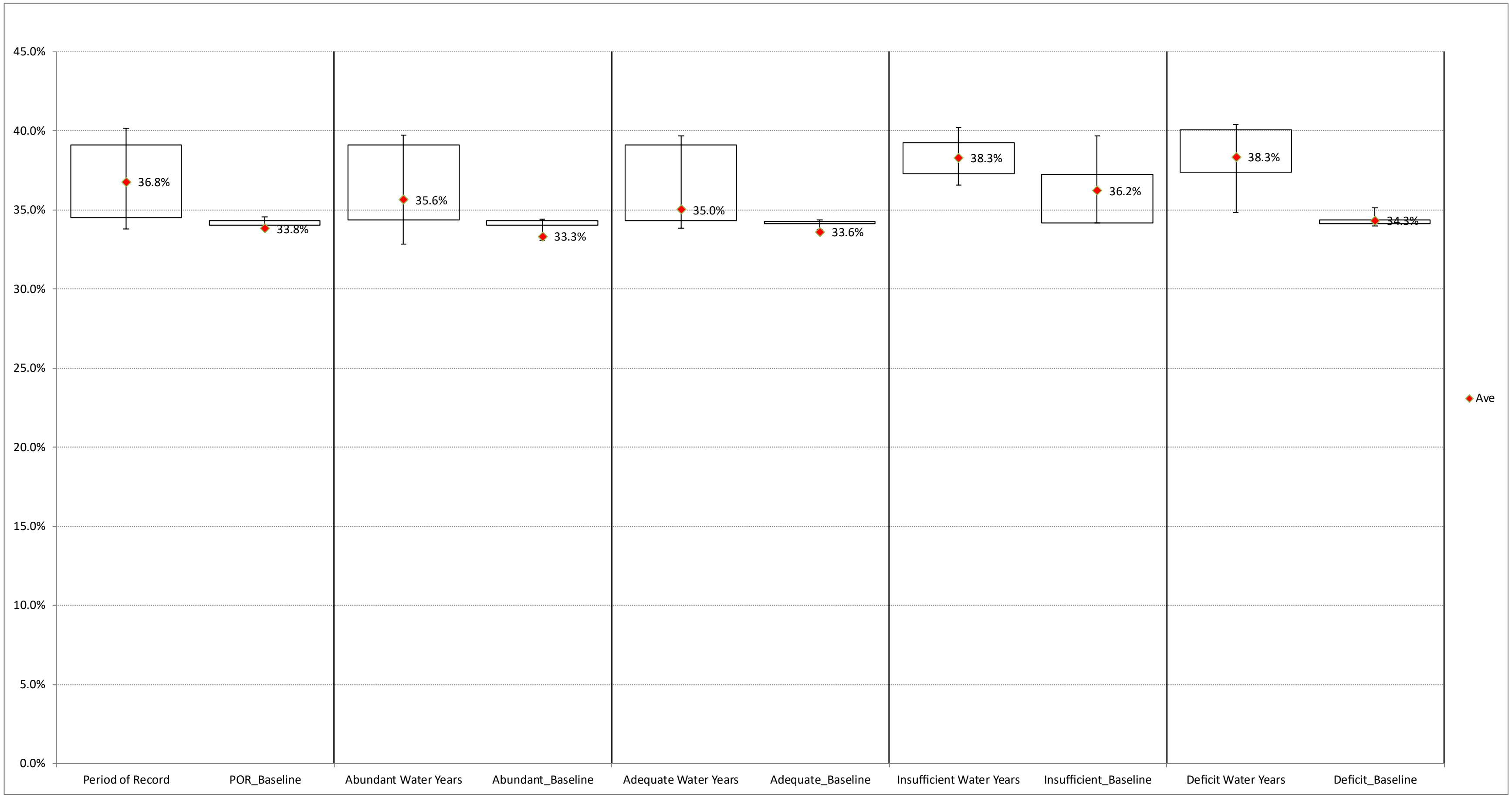


Figure 2-139. Foster Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Foster for juvenile winter steelhead sub-yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are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

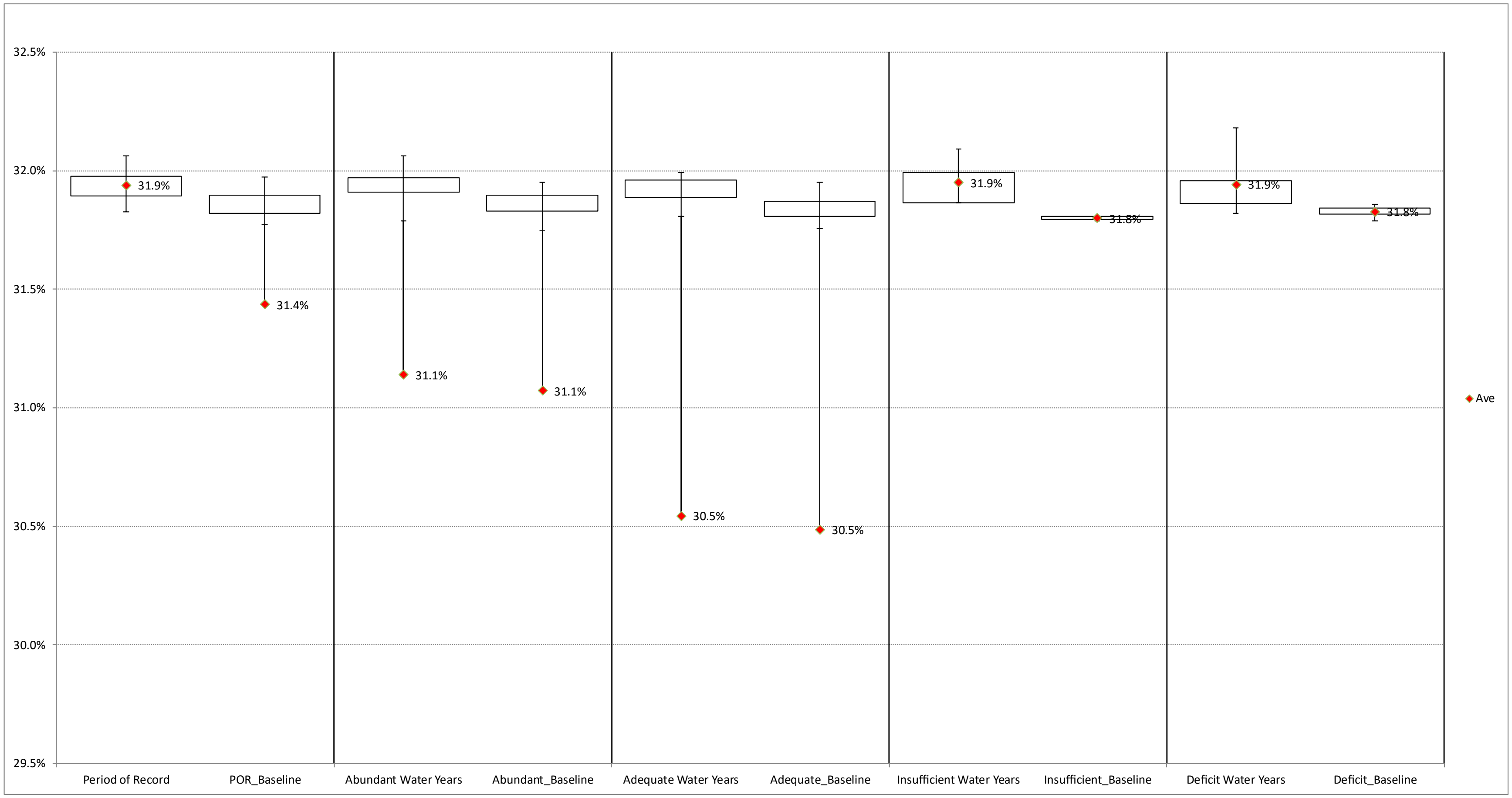


Figure 2-140. Foster Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Foster for juvenile winter steelhead yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given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

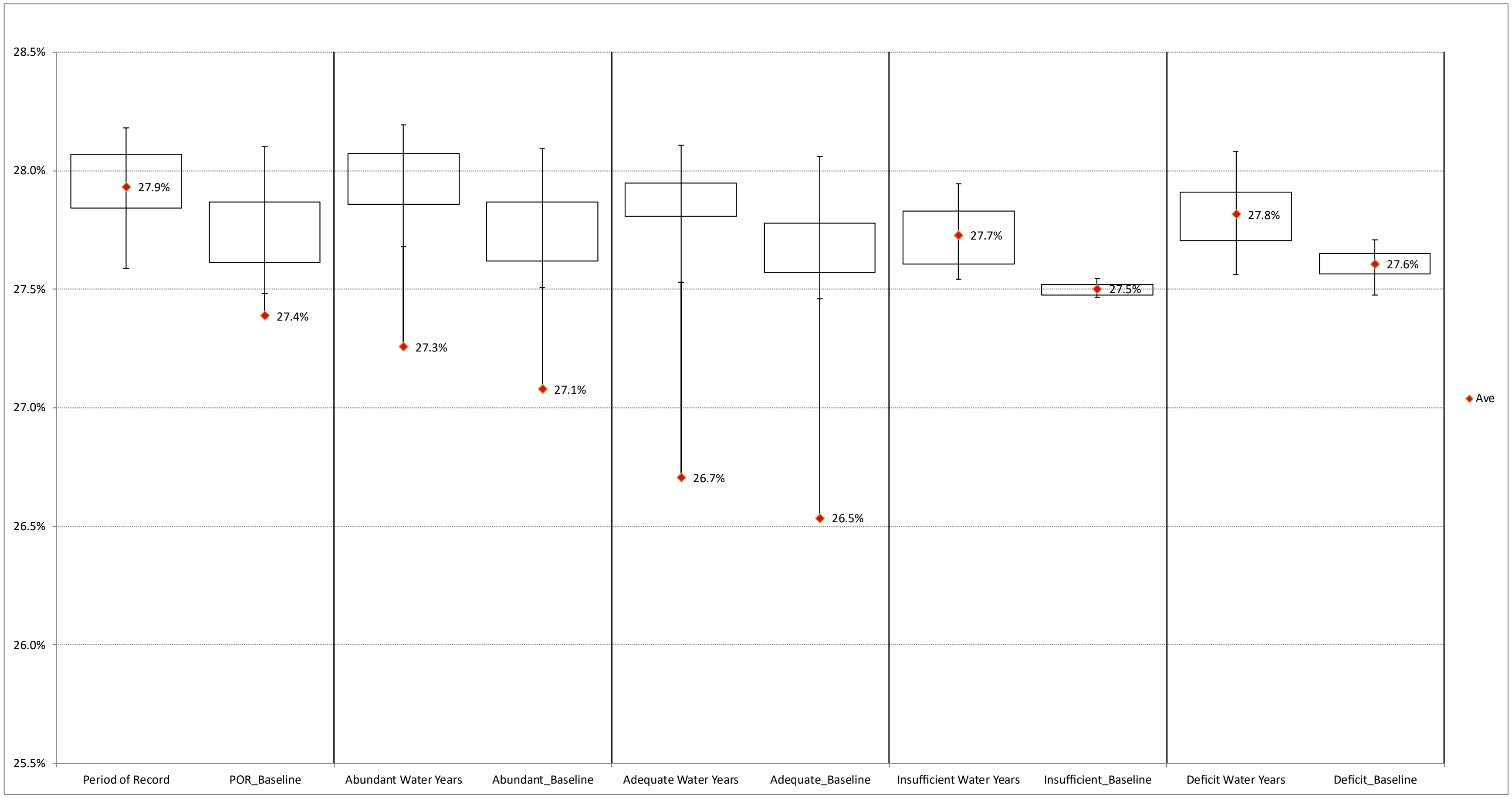


Figure 2-141. Foster 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Foster for juvenile winter steelhead 2 year olds under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given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

2.12.3 South Santiam – Green Peter

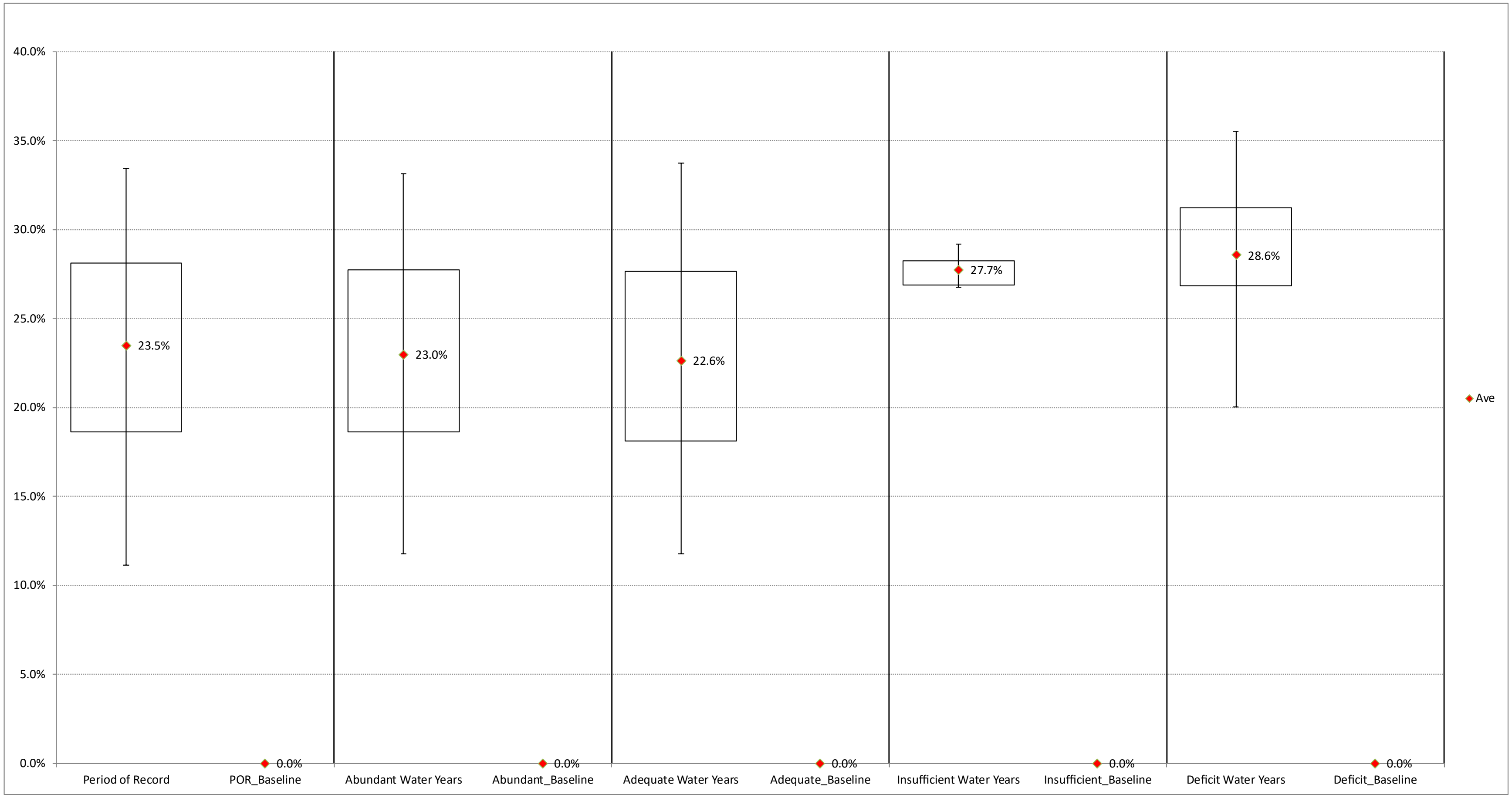


Figure 2-142. Green Peter Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Green Peter for juvenile winter steelhead sub-yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities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

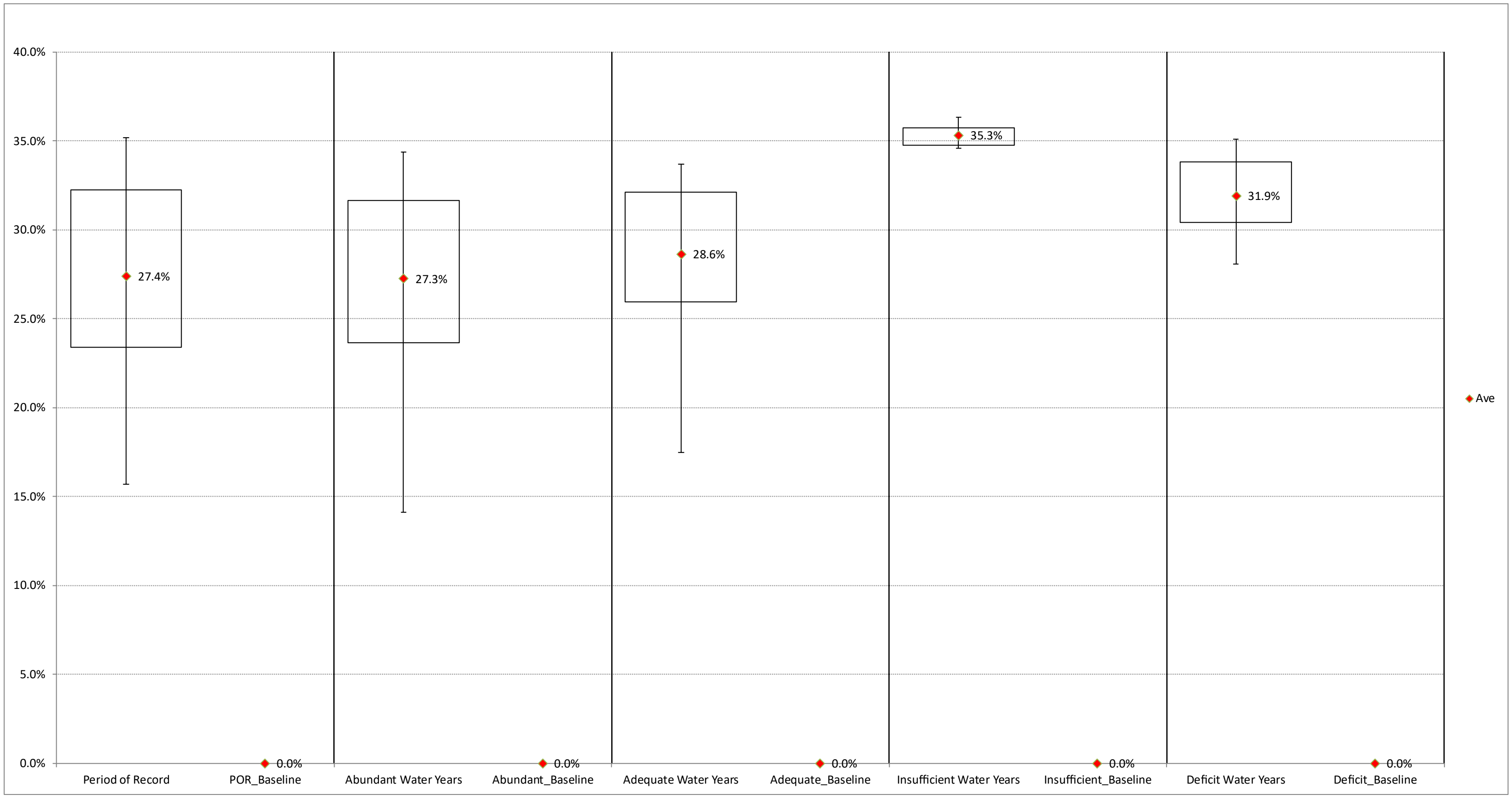


Figure 2-143. Green Peter Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Green Peter for juvenile winter steelhead yearlings under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

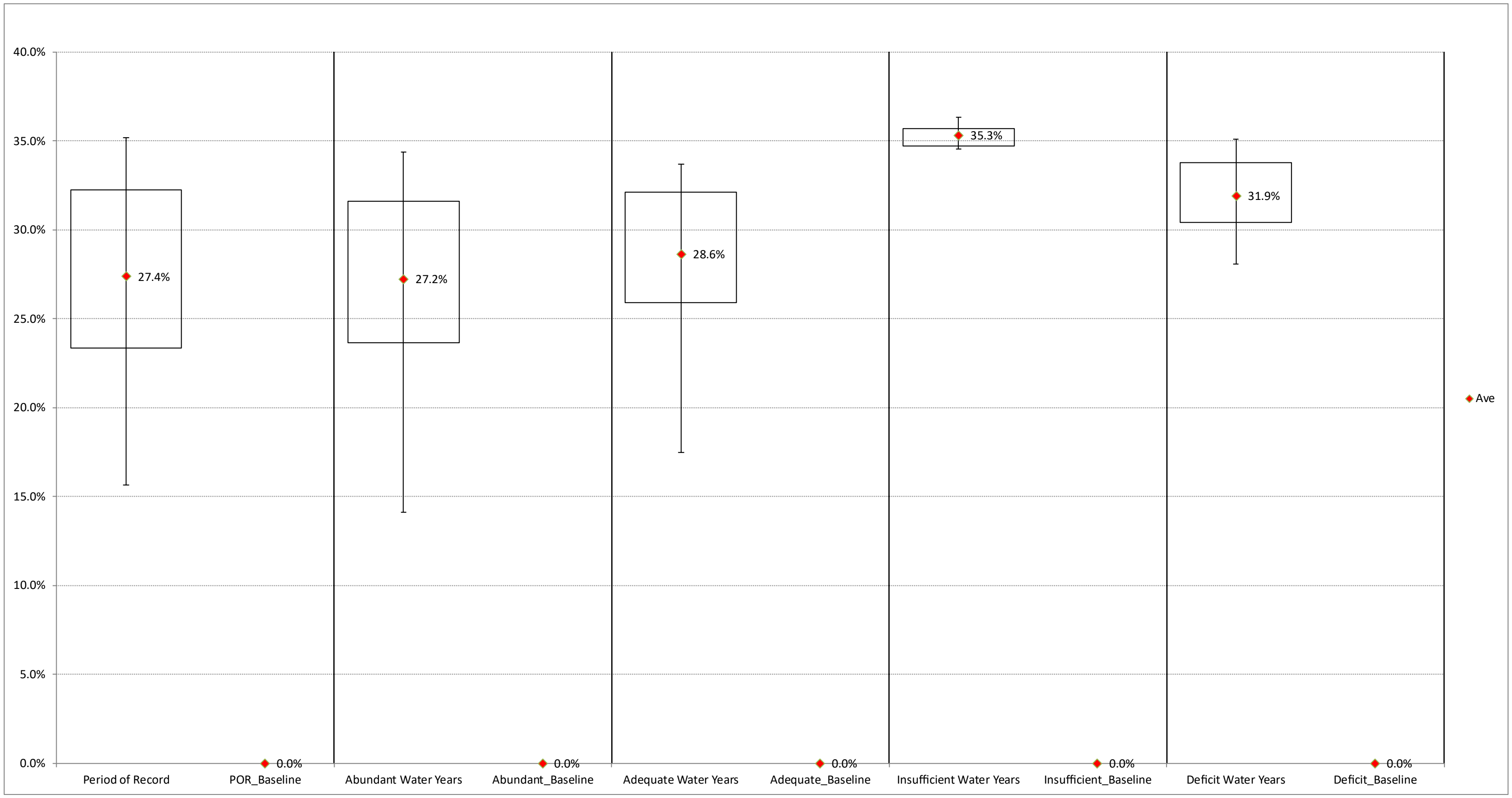


Figure 2-144. Green Peter 2-Year-Old Juvenile Winter Steelhead Downstream Dam Passage Survival Under Alternative 3b. *Downstream dam passage survival at Green Peter for juvenile winter steelhead 2 year olds under Alternative 3b. The mean is given by the point estimate (filled dot). Survival probabilities 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

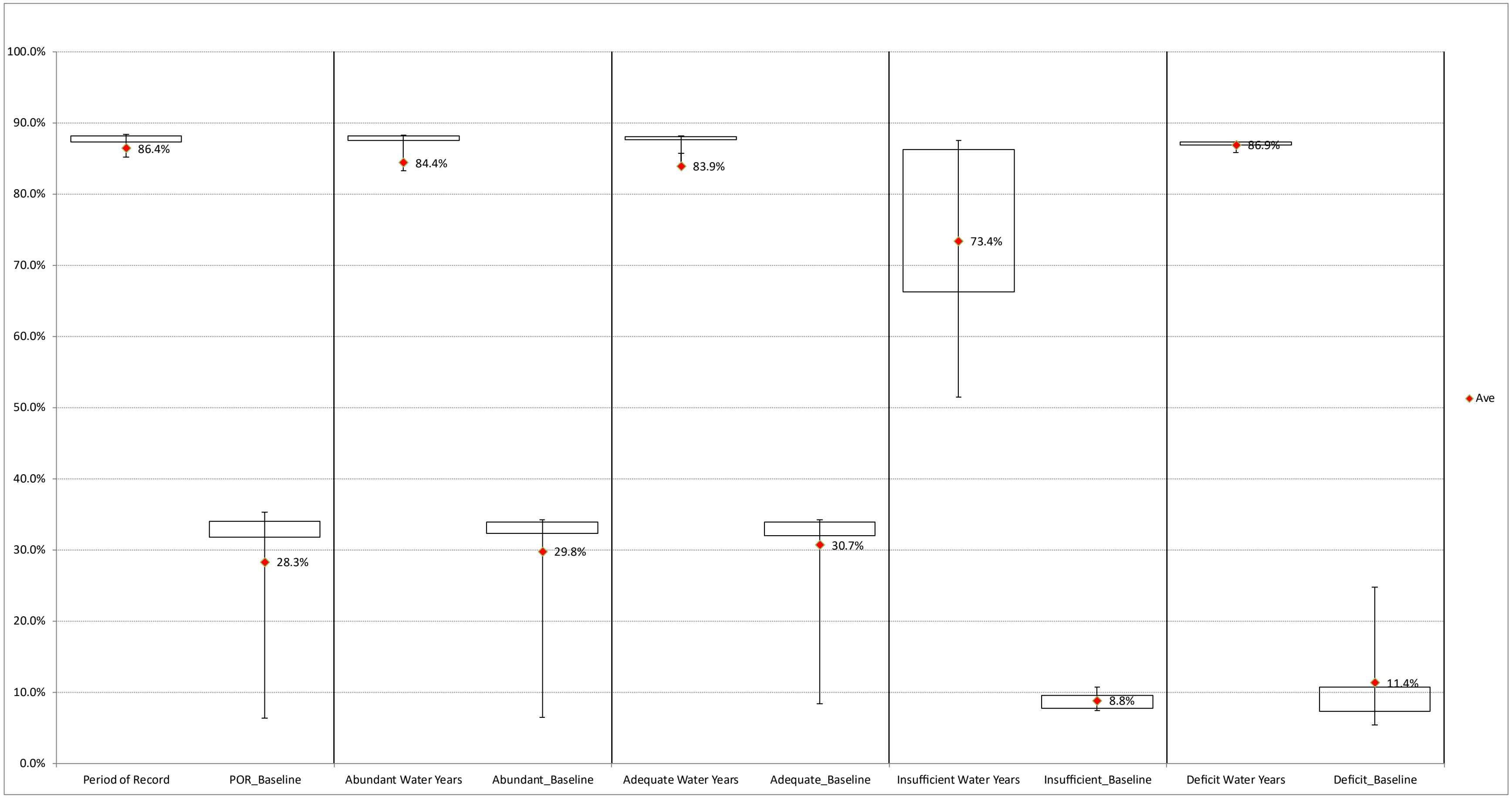


Figure 2-145. Detroit Juvenile Winter Steelhead Sub-Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Detroit for juvenile winter steelhead sub-yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are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

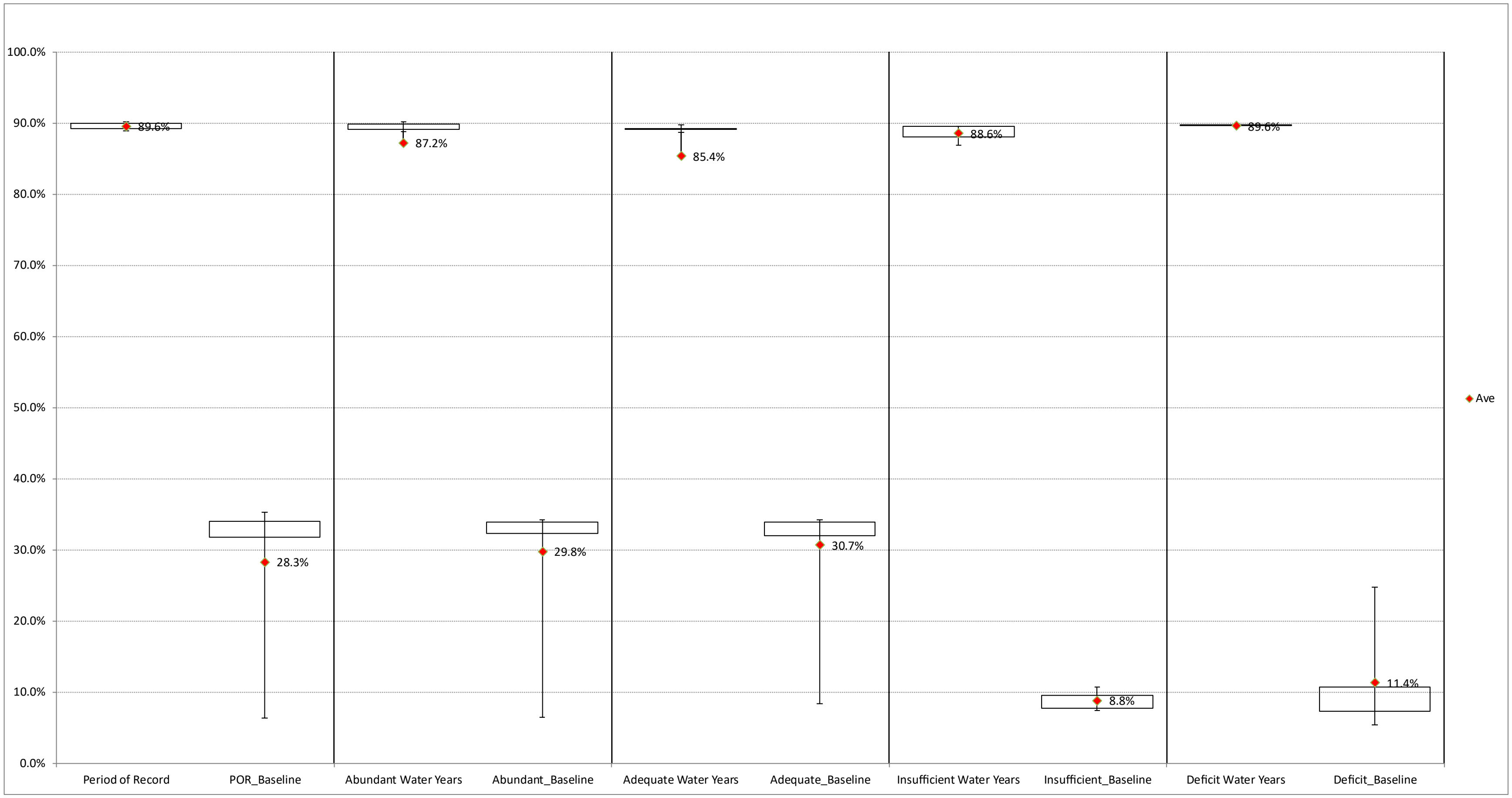


Figure 2-146. Detroit Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Detroit for juvenile winter steelhead yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given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

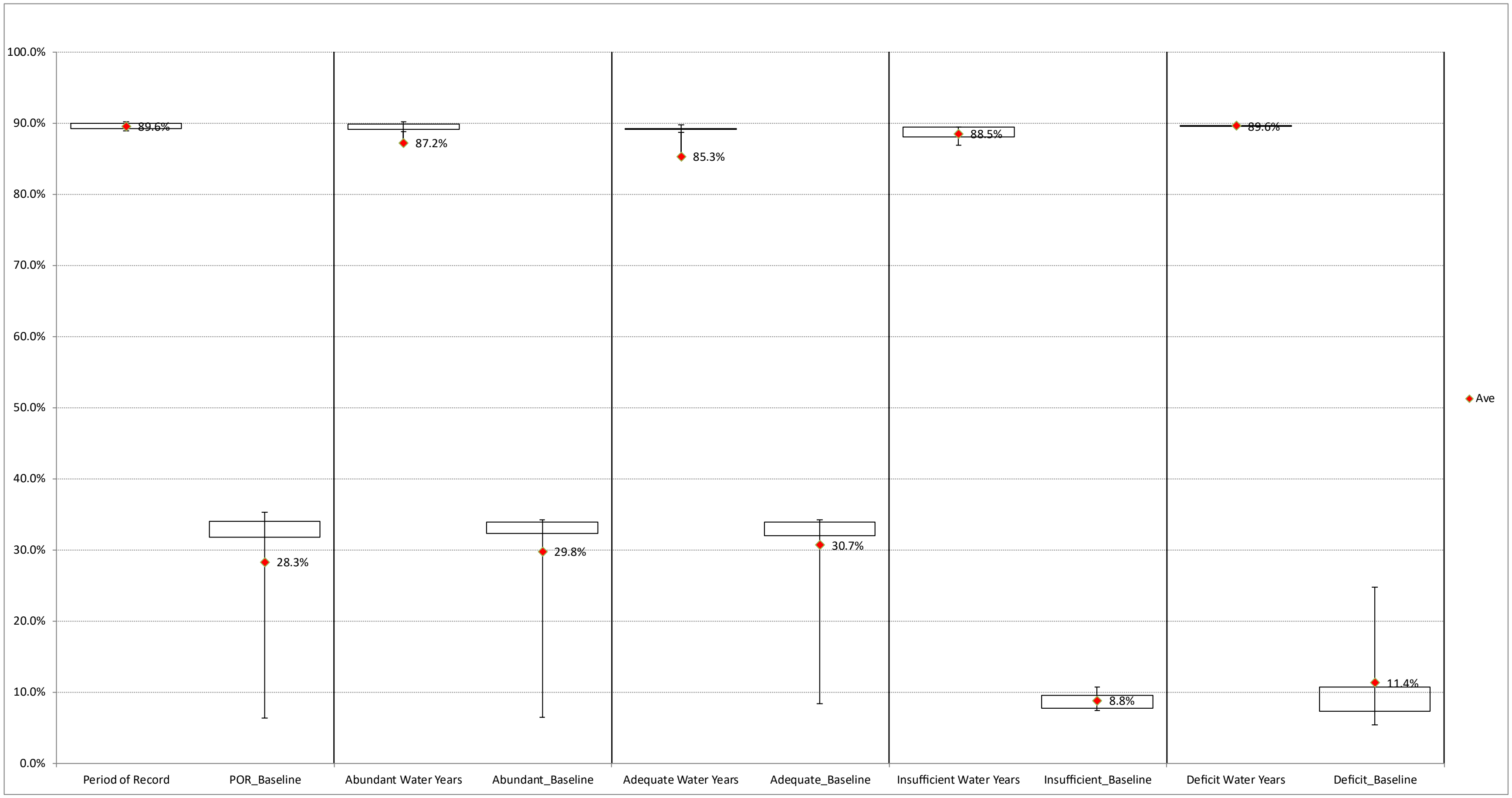


Figure 2-147. Detroit Juvenile Winter Steelhead 2-Year-Old Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Detroit for juvenile winter steelhead 2 year olds under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given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

2.13.2 South Santiam – Foster

Figure 2-148. 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.*

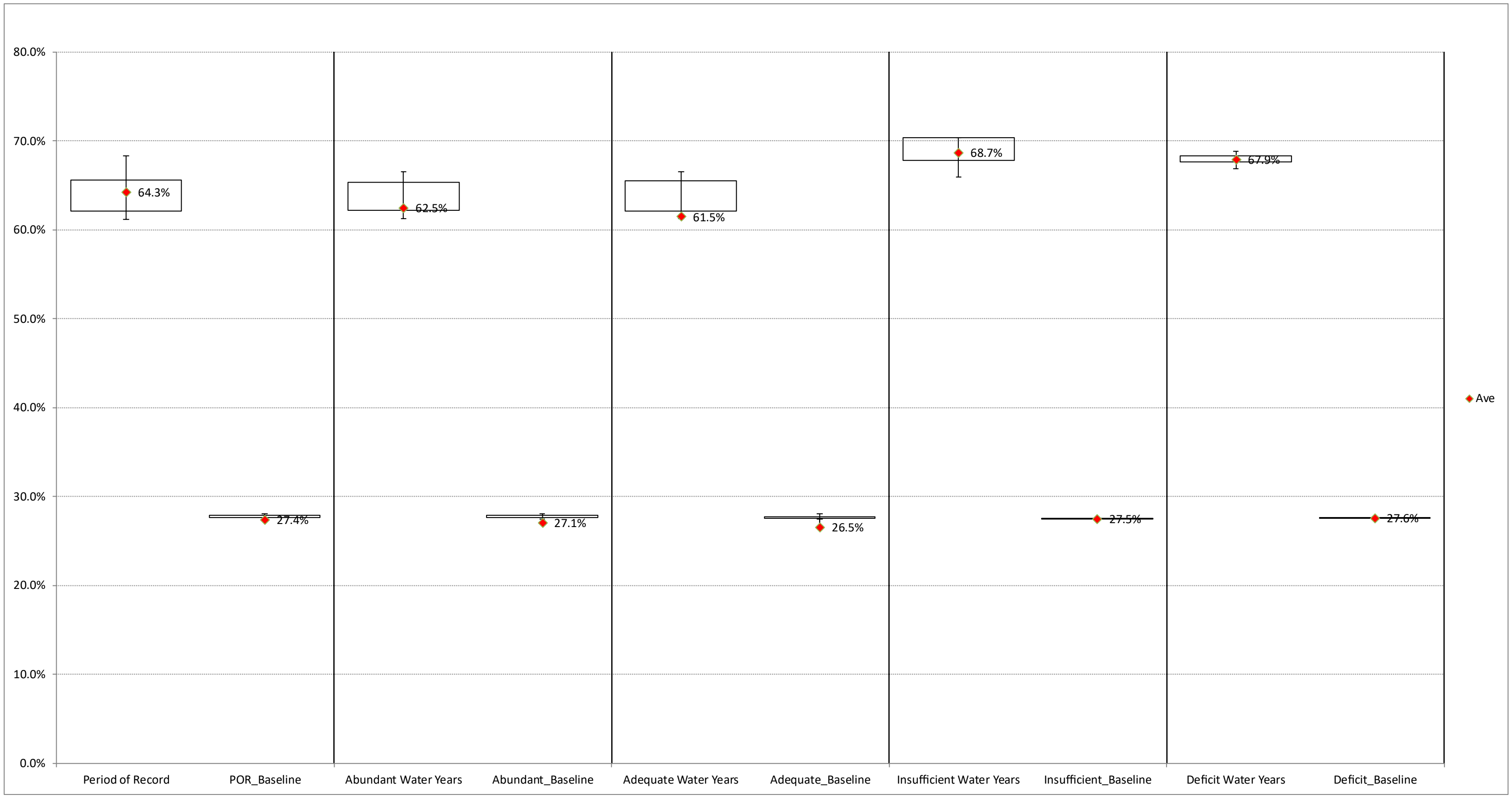


Figure 2-149. Foster Juvenile Winter Steelhead Yearling Downstream Dam Passage Survival Under Alternative 4. *Downstream dam passage survival at Foster for juvenile winter steelhead yearlings under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are given for the period of record (far left), compared to hydrologic year types denoted in each panel.*

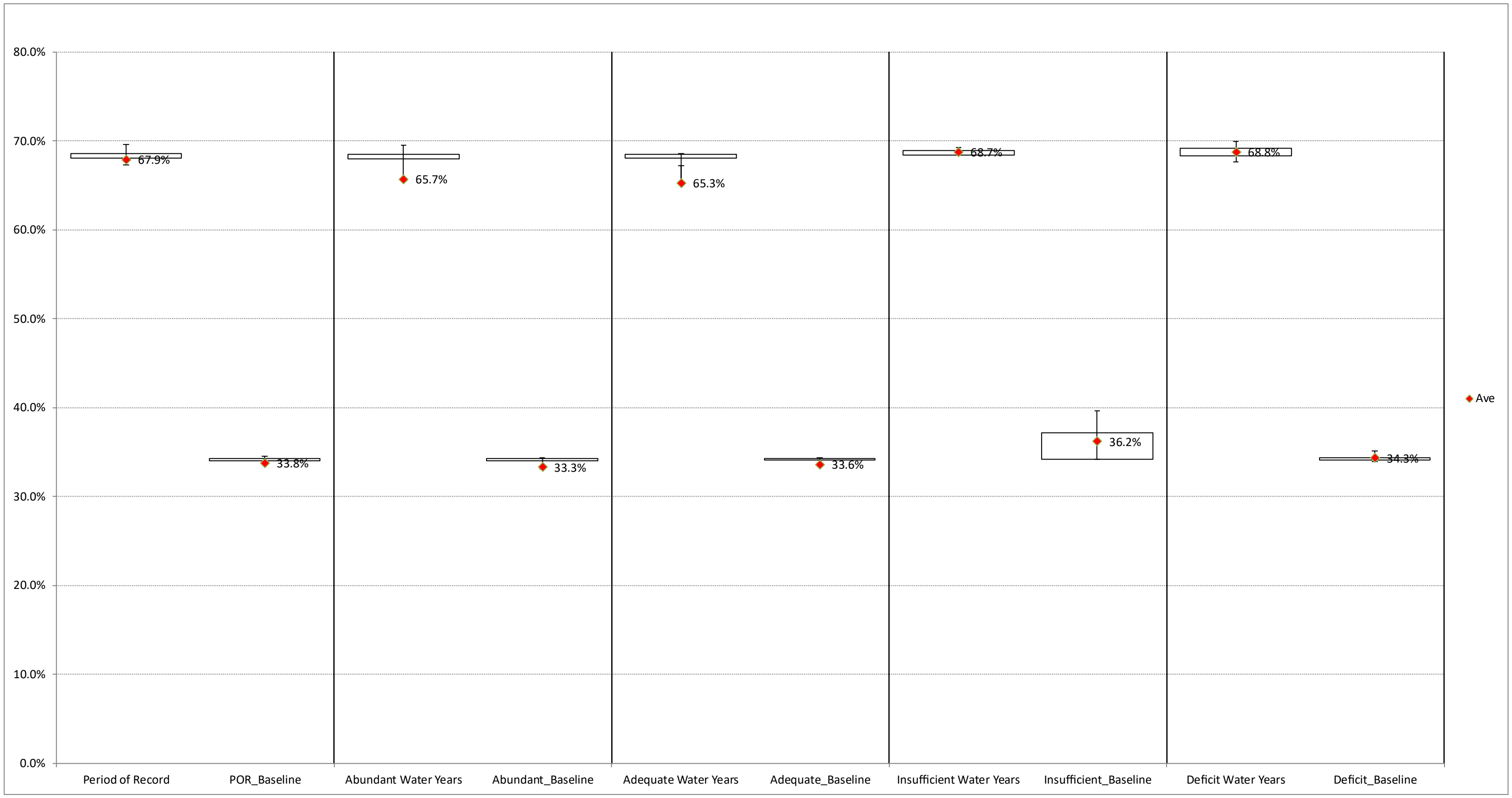


Figure 2-150. Foster for 2-year-old juvenile winter steelhead Downstream dam passage survival under Alternative 4. *Downstream dam passage survival at Foster for juvenile winter steelhead 2 year olds under Alternative 4. The mean is given by the point estimate (filled dot). Survival probabilities are 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. 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. 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				

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 3-3. Percent difference in average reservoir pool volume at Detroit Reservoir for each WVS EIS Alternative compared to the NAA by month.

	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 3-4. Percent difference in average reservoir pool volume in Hills Creek Reservoir for each WVS EIS Alternative compared to the NAA by month.

	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 3-5. Assessment of bull trout passage and key habitat attributes under the No Action Alternative (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 Detroit 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.

Table 3-6. Assessed change of the bull trout attributes under the 1, 2A, 2B, 4, and 5 Action Alternatives compared to the NAA in the North Santiam Sub-basin.

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.

Table 3-7. Assessed change of the bull trout attributes under the 3A and 3B Action Alternatives compared to the NAA in the North Santiam Sub-basin.

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 result 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 3-8. Assessment of bull trout passage and key habitat attributes under the No Action Alternative (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.

Table 3-9. The assessed change in the bull trout attributes under Alternative 1 compared to the NAA in the McKenzie Sub-basin.

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

Table 3-10. The assessed change in the bull trout attributes under Alternatives 2a and 4 compared to the NAA in the McKenzie Sub-basin.

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.

Table 3-11. The assessed change in the bull trout attributes under Alternatives 2b, 3b and 5 compared to the NAA in the McKenzie Sub-basin.

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 occurring 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 because this habitat is at least partially occupied by local rainbow trout and other species and further is stocked with rainbow trout annually.

Table 3-12. The assessed change in the bull trout attributes under Alternatives 3a and INTERIM OPERATIONS compared to the NAA in the McKenzie Sub-basin.

Attribute	Change from NAA	Alternative 3a and interim operations
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 3-13. Assessment of bull trout passage and key habitat attributes under the No Action Alternative (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

Table 3-14. The assessed change in the bull trout attributes under Alternative 1 compared to the NAA in the Middle Fork Sub-basin.

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

spawning populations		(McKenzie Sub-basin) will be improved with implementation 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 temporary 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.

Table 3-15. The assessed change in the bull trout attributes under Alternatives 2a, 2b and 5 compared to the NAA in the Middle Fork Sub-basin.

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 temporary 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

Table 3-16. The assessed change in the bull trout attributes under Alternatives 3a and 3b compared to the NAA in the Middle Fork Sub-basin.

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 autumn 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 result in some fish rearing or foraging below HCR Reservoir.

Table 3-17.The assessed change in the bull trout attributes under Alternative 4 compared to the NAA in the Middle Fork Sub-basin.

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 spawning populations	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 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.

Table 3-18. The assessed change in the bull trout attributes under interim operations compared to the NAA in the Middle Fork Sub-basin.

Attribute	Change from NAA	Alternative - INTERIM OPERATIONS
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 autumn 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 temporary 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 result in some fish rearing or foraging below HCR Reservoir.

3.2.3 Population Assessment and Effects Determinations

North Santiam

Table 3-19. 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 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 facility allowing adults	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 facility below CGR Dam will allow adults to return upstream to spawn.	Both resident and adfluvial life history forms 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.	Improved survival for the small percentage 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.

	to return upstream to spawn.			
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 with 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 3-20. 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	No change in abundance,

			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.	productivity or distribution/habitat availability. Negligible improvement in potential genetic exchange with other populations.
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	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	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	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.

	recruitment rates and spawner abundance if downstream emigrants return at a high rate. Ongoing upstream passage with operation of an adult fish collection facility below CGR Dam allowing adults to return upstream to spawn.	facility below CGR Dam will allow adults to return upstream to spawn.	fish facility operation.	
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	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	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	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

	due to prey availability. Risks increase for injury or mortality in local trout fisheries occurring in the McKenzie.	Reservoir. It is unclear if this results in a net change in habitat availability given downstream reaches are 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.	passage efficiency and survival and ongoing adult fish facility operation.	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.
3a and INTERIM OPERATIONS	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	No change for rearing upstream of or within CGR Reservoir. Negligible improvement to downstream passage conditions will result in some	Negligible improvement to downstream passage conditions will result in some increase in the number of fish rearing or foraging below CGR Reservoir,	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

	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, however risks of injury and mortality in the McKenzie trout fishery increases below CGR Dam.	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.	with potential to then migrate and spawn in other local McKenzie Sub-basin populations.	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 to re-enter and spawn.

Middle Fork Willamette River

Table 3-21. 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	Distributed in the Middle Fork Sub-basin above HCR Dam. Reservoir and	Both resident and adfluvial life history forms occur. Genetic exchange by volitional	(not applicable)

	abundance expected to stabilize with habitat availability. No major limiting factors identified that would reduce recruitment rates and average spawner abundance from currently levels.	tributaries provide for spawning, incubation, rearing and foraging. Recent population growth trend suggests additional habitat capacity available.	emigration blocked by dams and limited by poor habitat and other limiting factors at low elevations.	
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 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.
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	Negligible net improvement in rearing and foraging habitat availability: Reservoir operations will result in negligible reductions in rearing and foraging opportunity in 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	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.

	major improvement in upstream passage with operation of an adult fish collection facility allowing adults to return upstream to spawn.	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.	Fork will be transported upstream via truck and haul from the Dexter Adult Fish Facility. However downstream passage rates are 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	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	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.

		upstream to spawn.	Facility. Bul trout entering collection facilities will be collected and transported above and below the dam with a high survival rate. Downstream passage rates from HCR Reservoir are presumed to be low.	
INTERIM OPERATIONS	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	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	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.

		to downstream passage conditions will result in some fish rearing or foraging below HCR Reservoir.	Facility. However downstream passage rates are presumed to be low.	

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 significant 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. UWR Chinook and Steelhead Climate Change Vulnerability Assessment *

Vulnerability	UWR Chinook	UWR steelhead
Overall vulnerability	Very high	High

Vulnerability	UWR Chinook	UWR steelhead
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. 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 4-3. 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
# 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 4-4. 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 4-53. 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 4-64. 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 4-7. 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
Exposure Attributes stream temperature	Very High	Moderate	Low	Low	Low	Low	Low
Exposure Attributes sea surface temperature[1]	High	High	High	High	High	High	High
Exposure Attributes hydrologic regime[1]	High	High	High	High	High	High	High
Exposure Attributes summer water deficit above dams[1]	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Exposure Attributes summer water deficit below dams	Moderate	Moderate	Moderate	Moderate	High	High	Moderate
Sensitivity Attributes adult	Very High	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate

Attribute	NAA[1]	Alt. 1	Alt. 2a	Alt. 2b	Alt. 3a	Alt. 3b	Alt. 4
freshwater stage							
Sensitivity Attributes cumulative life-cycle effects[1]	Very High	Very High	Very High	Very High	Very High	Very High	Very High
Sensitivity Attributes 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. 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**
Overall Vulnerability	**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.