Appendix B
Klickitat spring Chinook: Integrated program description, analysis, and implementation schedule updated February 2019

Overview of Klickitat spring Chinook and future program

The existing hatchery/wild composite population has substantially diverged from the original native population due to extensive hatchery introgression over many years. The goal of the Yakama Nation since taking over management of the Klickitat Hatchery is to implement actions that will, over time, improve the quality of the natural-origin population, and by using these fish for brood stock, to also improve the quality of hatchery-origin fish that escape to the natural spawning grounds.

We surveyed spring Chinook carcasses on the spawning grounds from 2007-2016 and observed an average proportion of hatchery-origin spring Chinook spawning naturally of 43% (36 of 81 carcasses). Radio telemetry results indicate that 25.7% of hatchery-origin spring Chinook (26 out of 101 known-fate fish tagged at Lyle Falls in 2010-2013) spawned in the wild. Very few, if any, natural-origin fish are presently used for brood stock. Therefore, we estimate that present PNI levels are likely less than 0.10 (Figure 1). In addition, hatchery-origin brood stock currently used in the Klickitat program have many generations of hatchery ancestry. Present levels of pHOS suggest the program will require 40-60% natural-origin fish in our brood stock to achieve the stated target proportionate natural influence of 0.67. Monitoring data (see Table 6-8 in 2018 Master Plan) indicate that collection of the number of natural-origin spring Chinook required to achieve the target PNI at Lyle Falls trap is neither possible nor desirable at the present time. Therefore, we intend to implement a phased approach and the following actions beginning in the spring of 2020, to reduce pHOS and move us toward our goal of improving the quality of natural-origin fish and ultimately increasing the natural population.

- Increase the harvest rate in recreational and Tribal fisheries above Lyle Falls. The increase in harvest is expected to reduce pHOS initially by about 10% given current levels of natural escapement.
- Maintain or increase existing hatchery-origin adult returns from a reduced juvenile release by implementing actions to increase smolt survival which should in turn increase adult returns. This is an interim measure that we believe is required to affect an immediate increase in the proportion of hatchery-origin fish returning from a relatively small number of natural-origin parents incorporated into the hatchery program brood stock. Table 6-3 in the 2018 Master Plan indicates that only 420,000 smolts were released in 2010; yet adult returns from

this release in 2012 were comparable to returns from the average release of about 600,000 smolts in most recent years. While the mechanism responsible for the improved survival observed for the 2010 release in unknown, we hypothesize that smolt survival can be improved substantially by releasing spring Chinook yearlings at a more normative release time (on or about April 15) compared to late-February-to-mid-March releases presently. A more normative release timing will coincide with Bonneville Dam spring spill schedules thus allowing quicker migration past any predatory barriers and more timely arrival to feeding grounds in the lower Columbia River and estuary. Implementing a more normative release timing will require increased rearing capacity at the Klickitat hatchery. Spring Chinook yearlings are pushed out in mid-March due to the need to accommodate rearing space for other stocks. Improved survival of hatchery releases should allow us to begin increasing the proportion of one-generation hatchery parents incorporated into broodstock beginning in 2023. As the proportion of returning hatchery-origin fish with reduced hatchery-influence increases, the effects of hatchery-origin fish on the natural spawning grounds should be reduced (Araki et al. 2007a).

Description and analysis of phased approach to program reform

The All-H-Analyzer (AHA model) was used to quantify the progressive phases that will be required to transition the current hatchery stock to one more compatible with natural production while simultaneously providing sustained harvest opportunities. A total of 4 phases have been identified to fully transition the current hatchery program to the proposed long term program. While an implementation schedule is provided in this analysis, the actual timeline for transitioning from one phase to the next will rely on performance standards for one or more metrics such as adult return rates for hatchery origin Chinook, and abundance trends for the natural population. Thus, the timeline (Tables 3-5) provided represents the quickest possible transition period assuming all performance standards are being met. Included in the modeling analysis is a current conditions scenario that depicts the current performance of hatchery and natural populations given the current state of the habitat conditions, historical hatchery practices and harvest. The current conditions scenario is an essential part of the analysis that provides a reference point for which performance parameters and metrics of the hatchery and wild composite population can be evaluated against as a result of future hatchery reform efforts, re-colonized habitat, future restoration activities, and recent changes in harvest management. A synopsis of the program's phased approach is provided below followed by the modeling analysis for each phase describing assumed changes in habitat conditions, hatchery practices, and performance metrics.

Phase I- Implement collection of NOR adults for new hatchery stock (N_1 line).

Approximately 68 NOR adults will be collected during this phase of the program thus, producing a smolt release of ~100,000 yearling smolts. NOR adults will be spawned with NOR adults and differentially marked from the existing hatchery line (H_1 line) to allow unique identification and improved survival through mark-selective fisheries (no adipose clip will be applied). The 2012 Master Plan indicated the broodstock collection rate will not exceed 25% of the natural run, per guidelines recommended by the HSRG. The most recent 10 years of NOR run size estimates at Lyle Falls suggest that collection of 68 adults would result in a collection rate of about 14.1% (10.3% to 22.0%) of the natural population for broodstock annually (Table 1).

Table 1. Estimated natural-origin (NOR) spring Chinook run size and brood collection rate at Lyle Falls adult trap to support an initial integrated hatchery program release of 100,000 smolts (we estimate that 68 adults are required to support this initial program size).

Year	Est. Run	NOR brood collection rate
2007	393	17.3%
2008	449	15.2%
2009	620	11.0%
2010	508	13.4%
2011	685	9.9%
2012	579	11.7%
2013	462	14.7%
2014	309	22.0%
2015	663	10.3%
2016	442	15.4%
Mean Nat Orig. Brood Take: 14.1%		

Returning adults from the N_1 line will be used as the founder broodstock for the new, H_2 line (long-term harvest component of the program) during phase II of the program. In addition, adults from the N_1 line may be used for re-colonization of the upper watershed above Castile Falls if returning adult numbers allow.

The N_1 program is designed to minimize the broodstock collection rate on the NOR population while providing a minimum number of returning adults to begin propagation of the new H_2 hatchery line while terminating the existing H_1 hatchery line as quickly as possible. Recent improvements in hatchery SARs from an average of 0.32% to 0.50% will greatly assist in the programs ability to expedite transition into the next phase. Furthermore, both current and near future hatchery reform efforts are expected to bolster the SARs of the hatchery program Chinook. The recent changes to hatchery culturing practices (reduction in mini-jacks, reduced rearing densities) combined with a shift in release timing to a more normative spring period is hypothesized to improve outmigration survival and translate to improved SARs. Currently, spring Chinook smolts are released directly into the Klickitat River from the hatchery on or about March 1st. The release timing is typically prior to any spring freshets in the Klickitat River, or commencement of spill schedules at Bonneville Dam. Maintaining a SAR of 0.50% or greater is a viable goal considering the SAR values recently observed in other neighboring Columbia Gorge spring Chinook programs (Table 2). In order to accommodate a shift in release timing, a reduction in release numbers will be necessary due to temporal space constraints of existing hatchery infrastructure. The projected total release number of yearlings will be temporarily reduced from 600,000 to 400,000-450,000 (100,000 N_1 line and 300,000 to 350,000 H_1 line). The broodstock collection and release numbers for phase I of the program transition are summarized in Tables 3 and 4.

Table 2. Estimated SARs for Columbia River spring Chinook hatchery programs. Values are presented in 2011 CSS Annual Report.

Brood Year	Klickitat	Carson NFH	LWS NFH	Warm Springs
1998	0.62%	2.85%		
1999	1.31%	1.49%		
2000	0.32%	1.01%		0.95%
2001	0.32%	0.23%		
2002	0.09%	0.62%		
2003	0.04%	0.30%		
2004	0.02%	0.42%		
2005	0.05%	0.54%		0.30%
2006	0.13%	1.48%	1.87%	0.84%
2007		1.47%	1.01%	0.63%
Mean	0.32%	1.04%	1.44%	0.68%

Phase II- Implement harvest augmentation hatchery stock conversion (H_2 line)

Phase II will begin propagation of the new H_2 hatchery line while simultaneously terminating brood collection for the H_1 hatchery line. The founder stock to be used for the new H_2 hatchery line will consist of returning adults from the N_1 hatchery line. Collection of N_1 adults for the H_2 line will be triggered by the first year when sufficient numbers of adults return with all age classes present from the N_1 line. Phase II will terminate the H_1 line when N_1 returns are sufficient to maintain a release number equivalent to 300,000-350,000 smolts. Actual release numbers may vary during the transitional phase II due to adult return rates of the N_1 line, and trapping efficiencies from combined efforts at the Lyle Falls adult trap and volunteer trap at the Klickitat hatchery. The initial size of the N_1 program was specifically designed to minimize the NOR broodstock collection rate while producing enough adults to maintain the reduced smolt release of 300-350,000 thus, allowing for a quick transition from the H_1 to H_2 hatchery line. Depending on adult return rates and trapping efficiencies of the Lyle adult trap, any surplus N_1 line adults collected will be released into the natural habitat above Castile Falls to aid in the re-colonization process of the upper Basin. Further, the survival rates of the N_1 line and the status of NOR population will be continuously evaluated for possible, or necessary refinements to the number of NOR adults collected for the N_1 line. A summary of the implementation schedule, number of adults to be collected, and number of yearlings to be released are summarized in Tables 3and 4.

Phase III- Complete hatchery stock conversion; begin increasing total hatchery release numbers toward project's final release numbers.

The beginning of phase III should mark a point in time when H_1 line adults are no longer returning to the basin, and increases in natural production are potentially realized due to the initial recolonization of habitat above Castile Falls. This phase of the program will begin increasing the number of hatchery releases toward the Master Plan's stated release goals. Information to be analyzed in the decision framework to initiate phase III will include a stock status review of the natural population, and performance (adult return rates) of N_1 and H_2 hatchery lines. Improved performance of the natural and hatchery populations may allow the program to transition from phase II to III based on the following:

- **Increased natural production of the NOR population-** This will allow for the option of the N_1 line to increase production from 100,000 (68 adults) to 150,000 (102 adults) while keeping the NOR broodstock collection rate below 25%. A small proportion of NORs could also be included in the H_2 line to help bolster PNI values of the composite population.
- **Improved Smolt-to-adult return rates of hatchery fish-** Additional N_1 line adults may be available for broodstock if smolt-to-adult return rates meet or exceed 0.50%. Surplus N_1 line adults released into the upper watershed during phase II of the program could also be re-prioritized for H_2 line broodstock needs, thus eliminating the need to collect additional NORs.

Phase IV- Final increase of N_1 hatchery line and/or H_2 hatchery line release numbers to meet stated project objectives.

The final phase of the program will increase hatchery releases to the full extent as outlined in the Master Plan. Similar to phase III, information to be analyzed in the decision framework to initiate phase IV will include a stock status review of the natural population, and performance (adult return rates) of N_1 and H_2 hatchery lines. The following elements are necessary to achieve the project's long term conservation goals for a PNI 0.67%:

- **Improved habitat conditions and survival-** A combination of seeded habitat in the upper basin, habitat restoration actions, and slight improvements in NOR smolt-to-adult survival rates may be required to increase NOR abundance for the Klickitat spring Chinook population.
- **Increased harvest of HORs-** A reduction in pHOS through harvest management practices will improve the PNI. In particular, increasing the harvest and reducing escapement of the H_2 hatchery line will have a greater positive effect on improving the PNI due to the small proportion of NORs used for this program, as opposed to the N_1 line that uses 100% natural-origin broodstock. Current WDFW regulations do not allow spring Chinook fishing until June 1st. The majority of the spring Chinook run enter the Klickitat and migrate upriver toward the hatchery between mid-April and the end of May. The fishery is restricted until the hatchery has met the majority of its broodstock needs from adults volunteering into the hatchery. Collection of broodstock at Lyle Falls will allow the fishery to be open during the month of May.

Table 3. Broodstock collection schedule for Klickitat spring Chinook Integrated hatchery program. N_1 line = NOR x NOR crosses; H_1 line = current/historical hatchery stock; H_2 line = New hatchery line consisting of F_1 hatchery adults (from N_1 line) that may include some proportion of NORs in phase III and IV.

Program Phase	Broodstock Collection Schedule			
	Brood Year	# N_1 Line Brood	# H_1 Line Brood	# H_2 Line Brood
Phase I	**2018**	68	240	-
	2019	68	240	-
	2020	68	240	-
	2021	68	240	-
	2022	68	240	-
Phase II	**2023**	68	-	240
	2024	68		240
	2025	68		240
	2026	68		240
	2027	68		240
Phase III	**2028**	104		310
	2029	104		310
	2030	104		310
	2031	104		310
	2032	104		310
Phase IV	2033	138		411
	2034	138		411
	2035	138		411
	2036	138		411
	2037	138		411
	2038	138		411

Table 4. Juvenile release schedule for Klickitat spring Chinook Integrated hatchery program. N_1 line = NOR x NOR crosses; H_1 line = current/historical hatchery stock; H_2 line = New hatchery line consisting of F_1 hatchery adults (from N_1 line) that may include some proportion of NORs in phase III and IV.

Release year	# N_1 Line Releases	# H_1 Line Release	# H_2 Line Releases	Total Releases
2020	100,000	350,000		450,000
2021	100,000	350,000		450,000
2022	100,000	350,000		450,000
2023	100,000	350,000		450,000
2024	100,000	350,000		450,000
2025	100,000		300-350,000	400-450,000
2026	100,000		300-350,000	400-450,000
2027	100,000		300-350,000	400-450,000
2028	100,000		300-350,000	400-450,000
2029	100,000		300-350,000	400-450,000
2030	150,000		450-500,000	550-600,000
2031	150,000		450-500,000	550-600,000
2032	150,000		450-500,000	550-600,000
2033	150,000		450-500,000	550-600,000
2034	150,000		450-500,000	550-600,000
2035	200,000		600,000	800,000
2036	200,000		600,000	800,000
2037	200,000		600,000	800,000
2038	200,000		600,000	800,000
2039	200,000		600,000	800,000
2040	200,000		600,000	800,000

Table 5. Adult return schedule for Klickitat spring Chinook Integrated hatchery program. N_1 line = NOR x NOR crosses; H_1 line = current/historical hatchery stock; H_2 line = New hatchery line consisting of F_1 hatchery adults (from N_1 line) that may include some proportion of NORs in phase III and IV.

Adult Return Schedule			
Return Year	N_1 Line Adults	H_1 Line Adults	H_2 Line Adults
2022	-		-
2023	-		-
2024			-
2025			-
2026			-
2027			-
2028			
2029		Terminated	
2030			
2031			
2032			
2033			
2034			
2035			
2036			
2037			
2038			
2039			
2040			
2041			

Model parameterization and analysis

The analysis includes scenarios for current conditions and for each of the four phases of the proposed program. The analysis modeled the progressive changes in management actions and strategies linked to hatchery practices, habitat restoration actions and potential changes in harvest rates. As noted in preceding paragraphs and tables of this document, the projected timelines for each phase of the project hinge upon performance standards for both hatchery and wild spring Chinook, and should be viewed as the minimal timeframe needed for project progression. Actual timelines for each phase of the project may be delayed due to a number of factors. Similarly, modeling results for each phase of the project do not have a specified number of years tied directly to them. The modeling results for each phase of the project demonstrate the responses in NOR and HOR abundances, harvest, and PNI values based on phase specific management actions regardless of projected timelines. In essence, the results for each phase can be viewed as the long-term projections and benefits of each phase of the program. A summary of model parameters influenced by changes in management actions and habitat conditions is summarized in Table 1 below.

Current Conditions:

Habitat- EDT modeled estimates of natural production potential for the current state of the habitat in the absence of harvest. "Current Conditions" is defined as a baseline model run representing natural production potential prior to basin wide habitat restoration activities and passage improvements at Castile Falls completed as of 2005. The current conditions scenario serves as a reference point for natural production potential prior to re-colonization of the upper basin above Castile Falls, and future habitat restoration activities.

Phase I- Implement collection of NOR adults for new hatchery stock (N_1 line).

Management Actions and translated changes in model attributes:

- **Implement collection of NOR adults for new, small scale hatchery program (N_1 line)**
  68 NOR adults collected from NOR population to maintain a smolt release of 100,000 yearlings. Returning adults will be unclipped and therefore subjected to lower harvest rates due to mark-selective fisheries. Adults escaping fisheries and not required for brood stock will be allowed to spawn with natural population.

- **Reduce H_1 line release numbers**
  The current hatchery line (H_1 line) release numbers will be reduced from 600,000 to 350,000 smolts.

- **Reduce rearing densities and change release timing of yearling smolts from approximately March 1st to mid-April**
  Combining these hatchery reform efforts with recently improved culturing practices (reduction in mini-jacks and disease culling) will yield a higher quality smolt and improved out-migration survival. The analysis assumed these changes will yield an improved mean SAR to meet or exceed 0.50%

- **Increase terminal harvest on H_1 hatchery line**
  Terminal harvest of spring Chinook has been constrained historically due to the need for adequate adult escapement to the hatchery to meet broodstock requirements (via volunteer trap). Therefore, harvest between Lyle falls (rm .05) and the hatchery (rm 45) has been minimal during the migration period when the majority of spring Chinook are moving through the lower and middle parts of the Klickitat River. With recent improvements to the Lyle Falls trapping facility, the program will attempt to collect 100% of the spring Chinook broodstock for all phases of the project at Lyle Falls rather than relying on hatchery rack returns at rm 45. This management action will allow for an increase in the terminal harvest rate on hatchery spring Chinook. We assumed an initial increase of 15% for a fishery that has been minimal during the peak migration month of May through the lower River.

- **Other Phase I analysis assumptions**
  We assumed no changes in habitat conditions had occurred at this point in time due to the minimal time frame projected for phase I.

Phase II- Implement harvest augmentation hatchery stock conversion

Management Actions and translated changes in model attributes:

- **Terminate broodstock collection and juvenile releases of the H_1 hatchery line; begin collection of N_1 line returning adults for new H_2 hatchery line.**
  This management action directly replaces the broodstock and 350,000 H_1 line juvenile release with the new H_2 line hatchery stock. Performance differences between the two hatchery stocks were modeled as differences in the relative reproductive success (RRS). The HSRG has consistently used a RRS value of 0.8 for all spring Chinook hatchery stocks regardless of differences in types of programs (low vs high pNOB values) or the number of generations the hatchery

line has been subjected to the hatchery environment. The Klickitat hatchery stock has a distinct propagation history that not only excluded natural-origin adults for the majority of its 60+ years of culturing, but also mistakenly mixed out of basin Ocean-type ancestral lineages with the Klickitat Stream-type stock during historic brood collection practices (Hess et al. 2011). Due to these compounded effects and unique circumstances, a survival difference at one or more life-stages may theoretically exist between the historic H_1 hatchery line and the future H_2 hatchery line. Therefore, we assumed a RRS value of 0.5 for the historic H_1 line, and a RRS value of 0.8 for the new H_2 line.

- **Continue re-colonization of upper basin**
  We assumed that some amount of natural production will be realized by the end of Phase II given that:
  a) Passage improvements were completed at Castile falls in 2005, allowing spring Chinook 3 to 4 generations to begin the re-colonization process of the upper Basin.
  b) Surplus adults captured from the N_1 hatchery line will be released into the natural environment of the upper basin during this phase.

  In order to evaluate the natural spawning of the additional N_1 line adults in the wild, the total proportion of N_1 line returning adults that are trapped and removed from the natural environment were reduced (Table 1), thus increasing escapement of N_1 hatchery adults to the natural spawning grounds. We also assumed that re-colonization by NOR spring Chinook, combined with additional escapement of the N_1 hatchery line adults will lead to an approximate 50% increase in utilization of the upper basin's habitat potential by the end of phase II. Therefore we estimated an increase of 50% utilization of the upper basin's habitat capacity and a 50% increase in intrinsic productivity in the phase II habitat model parameters (Table 6).

- **Other Phase II analysis assumptions**
  Smolt-to-adult return rates and assumed harvest rates were maintained (Phase I values) for both hatchery and wild spring Chinook.

Phase III- Complete hatchery stock conversion and begin increasing total hatchery release numbers toward project's final release numbers.

Management Actions and translated changes in model attributes:

- **Increase hatchery production**
  The analysis increased production of the N_1 line from a release of 100,000 (68 adults) to 150,000 smolts (102 adults), and production of the H_2 line from 350,000 (240 adults) to 450,000 smolts (310 adults). In order to accommodate the

additional broodstock needs for the H_2 line program, the N_1 line adults that were captured and artificially released for natural spawning during phase II will now be retained for the H_2 line broodstock. This was accomplished in the analysis by increasing the trapping rate of the N_1 hatchery line from 68 to 104. This phase also begins to incorporate a small proportion of natural-origin broodstock 10% (31 adults) into the H_2 line to further increase the PNI of the composite hatchery/wild population.

- **Continue re-colonization of upper basin**
  For the phase III analysis, we further assumed an even greater proportion of the upper basin's habitat will have been seeded with natural production. By assuming nearly complete re-colonization of the upper basin, the analysis used 100% of the estimated habitat capacity and intrinsic productivity of the entire Klickitat basin (Table 6).

- **Increase harvest**
  With an increase in hatchery production during Phase III, additional harvest opportunities within the Basin would be provided (e.g., fishery can be opened and sustained throughout the entire run-timing, including the month of May which currently has limited to no fishing opportunity in the River between Lyle Falls and the hatchery). We assumed the terminal harvest rate would increase by 5% which would also reduce pHOS.

- **Other Phase III analysis assumptions**
  Smolt-to-adult return rates were maintained (Phase I and II values) for both hatchery and wild spring Chinook. Harvest rates on natural-origin, and N_1 line hatchery-origin Chinook did not change.

Phase IV- Final increase of N_1 hatchery line and/or H_2 hatchery line release numbers to meet project objectives.

Management Actions and translated changes in model attributes:

- **Increase hatchery production to final release numbers**
  The analysis increased production of the N_1 line from a release of 150,000 (102 adults) to 200,000 smolts (138 adults), and production of the H_2 line from 450,000 (310 adults) to 600,000 smolts (411 adults). The additional broodstock needs of the H_2 line will be met from a combination of increased adult returns from the N_1 line (from increased release numbers in phase III) and a small number of additional NOR adults (increased from ~31 to 41 adults). The slight increase in NOR adults used as a broodstock source for the H_2 line will maintain a pNOB value of 10% for the H_2 hatchery line.

- **Continue to improve quality and quantity of habitat**
  For the phase IV analysis, we assumed that ongoing habitat restoration actions will have been realized. Specifically, we assumed restoration actions resulting in slight improvements in both quality (productivity) and quantity (capacity) will have matured prior to implementation of phase IV.

- **Increase harvest**
  With an increase in hatchery production, additional harvest opportunities within the Basin would be provided. We assumed the terminal harvest rate would increase by 5% which would also reduce pHOS.

- **Other Phase IV analysis assumptions**
  Smolt-to-adult return rates were maintained (Phase I-III values) for both hatchery lines of Chinook. Harvest rates on natural-origin, and N_1 line hatchery-origin Chinook did not change.

Table 6. Critical model parameters that were varied based on management actions, habitat re-colonization, habitat restoration, and harvest.

		Current Condition	Phase I	Phase II	Phase III	Phase IV
Habitat	Capacity	607	607	939	1271	1360
	Productivity	6.2	6.2	6.35	6.5	7.7
Smolt-to-adult survival (SARs)	NORs	.043	.043	.043	.043	.053
	HORs (H_1 line)	.024	.0050	-	-	-
	HORs (N_1&H_2 lines)	-	.0050	.0050	.0050	.0050
Harvest (Total Exploitation)	NORs	.409	.277	.277	.277	.277
	HORs (H_1 line)	.409	.553			
	HORs (N_1 line)		.277	.277	.277	.277
	HORs (H_2 line)		.553	.553	.593	.634
Hatchery Broodstock and Juvenile Release #'s	# NOR adults (H_1 line)	~3-8	-	-	-	-
	# NOR adults (N_1 line)	-	68	68	104	138
	# NOR adults (H_2 line)	-	-	-	16	41
	H_1 line Juvenile release #	600,000	350,000	-	-	-
	N_1 line Juvenile release #	-	100,000	100,000	150,000	200,000
	H_2 line Juvenile release #	-		350,000	450,000	600,000
Relative Reproductive Success (HORs)	HORs (H_1 line)	0.50	0.50	-	-	-
	HORs (N_1 line)	-	0.8	0.8	0.8	0.8
	HORs (H_2 line)	-	-	0.8	0.8	0.8

Table 7. Model estimates of natural-origin broodstock collection rates based on the projected number of adults needed and estimated NOR abundances for each phase of the program.

Estimated % of NOR run taken for broodstock				
	Phase I	Phase II	Phase III	Phase IV
# NOR adults	68	80	135	179
pNOB	28%	28%	33%	33%
% of NOR run	18.6%	13.5%	17.3%	16.7%

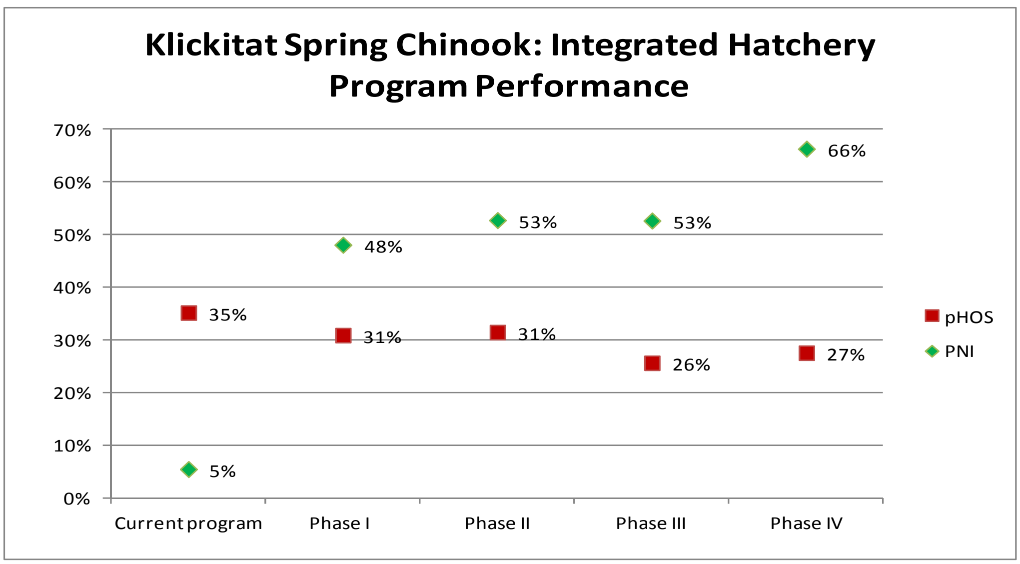

Figure 1. Model estimates of pHOS and PNI for each phase of the program.

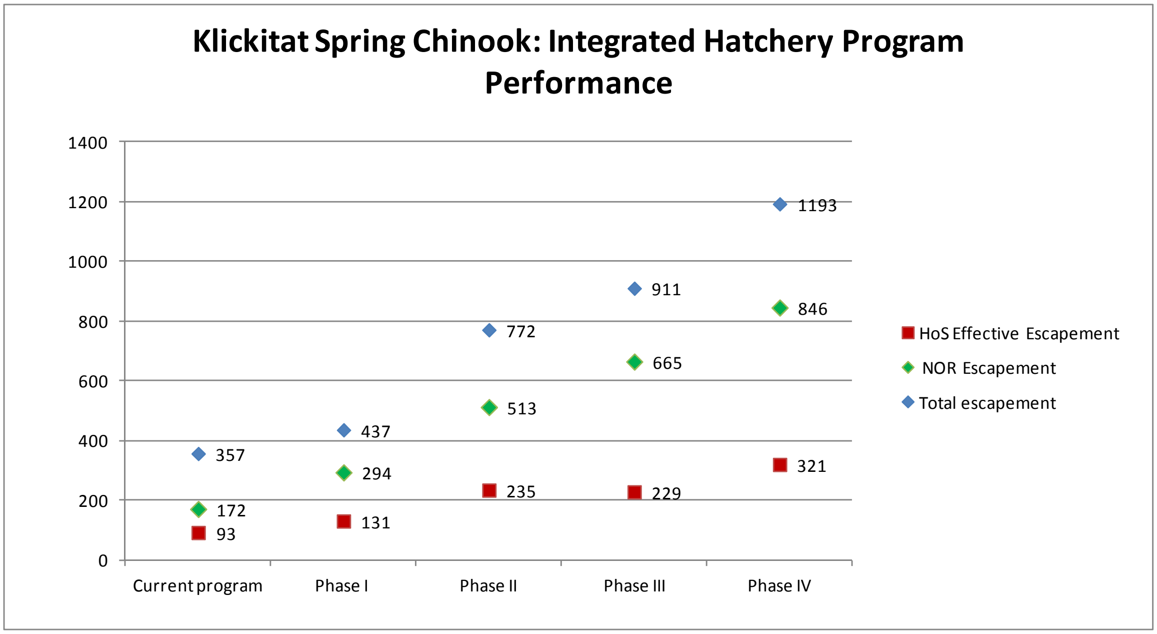

Figure 2. Model estimates for NOR, HOR, and Total Escapement for each phase of the program.

Survival Variability Scenarios

A stochastic model was built to simulate adult returns for both natural-origin and hatchery-origin spring Chinook. For natural-origin spring Chinook, variability in adult returns relied on the descriptive statistics of the observed range of returns over the last 10 years. Scenarios that examined reductions in survival and returns for natural-origin spring Chinook relied on incremental reductions in survival that were estimated for hatchery-origin spring Chinook. Variability in adult hatchery returns were based on the number of adults collected for broodstock, annual release numbers, and a random sequence of smolt-to-adult return rates. The purpose of this was to explore the effects of survival variability on adult returns and how this will affect the program's ability to successfully transition from phase to phase. Specifically, we used the modeling analysis to evaluate our broodstock collection abilities over a range of natural and hatchery origin adult returns, and target smolt release numbers over a range of survival scenarios using a random sequence of SARs.

Definitions
N1 line : Progeny of natural-origin (NOR) parents spawned at Klickitat Hatchery
H2 line : Progeny of N1 x N1 or N1 x NOR parents spawned at Klickitat Hatchery

Model input parameters included the following:

- Number of NOR (for N1 line) and HOR (for H2 line) adult spring Chinook collected for broodstock
- Number of smolts released from the N1 broodstock line
- Number of smolts released from the H2 broodstock line
- Smolt-to-adult return rates based on outmigration year cohort
- Age structures of returning adults
- Lyle Falls adult trapping efficiency
- Klickitat Hatchery adult volunteer efficiency

Scenarios modeled for Juvenile survival and hatchery adult returns:

The request was made to examine a range of SARs needed to transition from phase to phase, particularly using a plausible random sequence of low SARs and how this might affect the timeline for program progression and transition. Our approach to this relied on the use of NOAA's ocean ecosystem indicators that describe a range of physical and biological conditions of the ocean experienced by juvenile salmonids including the seasonal Pacific Decadal Oscillation Phase (PDO), seasonal temperatures, seasonal biological indicators (Copepod richness and biomass, Ichthyoplankton biomass and community index), and juvenile salmon catch indexes (Figure 3 and 4). For more information on the Ocean Ecosystem Indicators, a 2017 NOAA report can be found here: https://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/documents/Annual_Report_2017.pdf
Below is a brief summary describing NOAA's Ocean Indicators including the "stoplight charts", yearly comparisons of ocean indicator rank scores, correlations between yearly rank scores and adult Chinook returns, and correlations between yearly rank scores and Coho juvenile survival.

The NOAA "stoplight" chart describes the condition of the ocean ecosystem indicators in a qualitative sense when juvenile salmon enter the ocean. The condition of each ocean indicator is described as being positive, neutral or negative and are represented by green, yellow and red respectively (Figure 3).

Table SF-01. Ocean ecosystem indicators of the Northern California Current. Colored squares indicate positive (green), neutral (yellow), or negative (red) conditions for salmon entering the ocean each year. In the two columns to the far right, colored dots indicate the forecast of adult returns based on ocean conditions in 2017 (coho salmon) and 2016 (Chinook salmon).

	Juvenile Migration Year				Adult Return Outlook	
	2014	2015	2016	2017	coho 2018	Chinook 2018
Large– scale ocean and atmospheric indicators						
PDO (May - Sept)	■ red	■ red	■ red	■ yellow	● yellow	● red
ONI (Jan - Jun)	■ yellow	■ red	■ red	■ yellow	● yellow	● red
Local and regional physical indicators						
Sea surface temperature	■ yellow	■ red	■ red	■ green	● green	● red
Deep water temperature	■ red	■ red	■ yellow	■ red	● red	● yellow
Deep water salinity	■ red	■ red	■ yellow	■ red	● yellow	● red
Local biological indicators						
Copepod biodiversity	■ yellow	■ red	■ red	■ yellow	● yellow	● red
Northern copepod anomalies	■ green	■ red	■ red	■ red	● red	● red
Biological spring transition	■ yellow	■ red	■ red	■ red	● red	● red
Winter ichthyoplankton biomass	■ red	■ green	■ green	■ green	● green	● green
Winter ichthyoplankton community	■ yellow	■ red	■ red	■ red	● red	● red
Juvenile Chinook salmon catch – June	■ yellow	■ yellow	■ red	■ red	● red	● red
Juvenile coho salmon catch – June	■ yellow	■ yellow	■ yellow	■ red	● red	● yellow

Key:
- ■ green: good conditions for salmon; ● green: good returns expected
- ■ yellow: intermediate conditions for salmon; ● yellow: intermediate returns expected
- ■ red: poor conditions for salmon; ● red: poor returns expected

Figure 3. NOAA stoplight chart of Ocean Ecosystem indicators (Table SF-01 2017 NOAA Annual Report).

All years with ecosystem Indicator data collected were compared against one another in a relative sense with rank scores. The actual data for the rank scores can be found here: https://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/figures/2017/Table_SF-03.JPG.

Years 1998-2017 were ranked against one another for each of the ocean ecosystem indicators (Figure 2, Table SF-02 2017 NOAA Annual Report). Lower numbers for the rank scores represent better conditions for juvenile salmonid growth and survival, higher numbers indicate poorer growth and survival. The year with the lowest score for an ecosystem indicator received a rank score of 1, the year with the highest score for an ecosystem indicator received a rank score of 20. The rank scores for each of the ocean indicators were then averaged for each year, and the years were ranked relative to one another (Figure 4).

	Year																			
Ecosystem Indicators	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
PDO (Sum Dec-March)	17	6	3	12	7	19	11	15	13	9	5	1	14	4	2	8	10	20	18	16
PDO (Sum May-Sept)	10	4	6	5	11	16	15	17	12	13	2	9	7	3	1	8	18	20	19	14
ONI (Average Jan-June)	19	1	1	6	13	15	14	16	8	11	3	10	17	4	5	7	9	18	20	12
46050 SST (°C; May-Sept)	16	9	3	4	1	8	20	15	5	17	2	10	7	11	12	13	14	19	18	6
Upper 20 m T (°C; Nov-Mar)	19	11	8	10	6	14	15	12	13	5	1	9	16	4	3	7	2	20	18	17
Upper 20 m T (°C; May-Sept)	16	12	14	4	1	3	20	18	7	8	2	5	13	10	6	17	19	9	15	11
Deep temperature (°C; May-Sept)	20	6	8	4	1	10	12	16	11	5	2	7	14	9	3	15	19	18	13	17
Deep salinity (May-Sept)	19	3	9	4	5	16	17	10	7	1	2	14	18	13	12	11	20	15	8	6
Copepod richness anom. (no. species; May-Sept)	18	2	1	7	6	13	12	17	15	10	8	9	16	4	5	3	11	19	20	14
N. copepod biomass anom. (mg C m^{-3}; May-Sept)	18	13	9	10	3	15	12	19	14	11	6	8	7	1	2	4	5	16	20	17
S. copepod biomass anom. (mg C m^{-3}; May-Sept)	20	2	5	4	3	13	14	19	12	10	1	7	15	9	8	6	11	17	18	16
Biological transition (day of year)	17	8	5	7	9	14	13	18	12	2	1	3	15	6	10	4	11	20	20	16
Ichthyoplankton biomass (log (mg C 1000 m^{-3}); Jan-Mar)	20	11	3	7	9	18	17	13	16	15	2	12	4	14	10	8	19	5	6	1
Ichthyoplankton community index (PCO axis 1 scores; Jan-Mar)	9	13	1	6	4	10	18	16	3	12	2	14	15	11	5	7	8	17	20	19
Chinook salmon juvenile catches (no. km^{-1}; June)	18	4	5	15	8	12	16	19	11	9	1	6	7	14	3	2	10	13	17	20
Coho salmon juvenile catches (no. km^{-1}; June)	18	7	12	5	6	2	15	19	16	4	3	9	10	14	17	1	11	8	13	20
Mean of ranks	17.1	7.0	5.8	6.9	5.8	12.4	15.1	16.2	10.9	8.9	2.7	8.3	12.2	8.2	6.5	7.6	12.3	15.9	16.4	13.9
Rank of the mean rank	20	6	2	5	2	14	16	18	11	10	1	9	12	8	4	7	13	17	19	15
Ecosystem Indicators not included in the mean of ranks or statistical analyses																				
Physical Spring Trans. UI based (day of year)	3	7	19	16	4	12	14	20	12	1	6	2	8	11	17	9	18	10	5	15
Physical Spring Trans. Hydrographic (day of year)	19	3	13	8	5	12	14	20	6	9	1	9	17	3	11	2	15	7	16	18
Upwelling Anomaly (April-May)	9	3	16	5	8	13	12	20	9	4	6	7	14	16	14	11	18	1	2	19
Length of Upwelling Season UI based (days)	6	2	18	11	1	13	9	20	5	3	8	3	15	17	15	14	19	10	7	12
SST NH-5 (°C; May-Sept)	9	6	5	4	1	3	20	16	10	18	2	19	11	7	14	13	15	12	17	8
Copepod Community Index (MDS axis 1 scores)	19	3	5	7	1	13	14	17	15	10	2	6	12	9	8	4	11	18	20	16
Coho Juv Catches (no. fish km^{-1}; Sept)	11	2	1	4	3	6	12	14	8	9	7	15	13	5	10	NA	NA	NA	NA	NA

Figure 4. Rank scores derived from ocean ecosystem indicators (Table SF-02 2017 NOAA Annual Report).

NOAA fisheries has correlated Chinook returns and Coho juvenile survival with the yearly mean rank of ecosystem indicators (Figure SF-01 2017 NOAA Annual report). The regression lines explained 41% to 50% of the variation for adult chinook returns, and 28% of the survival variation for Coho juveniles (figure 5.) NOAA Fisheries has used the regression equations to predict 2018 and 2019 adult returns for both Spring Chinook and Fall Chinook.

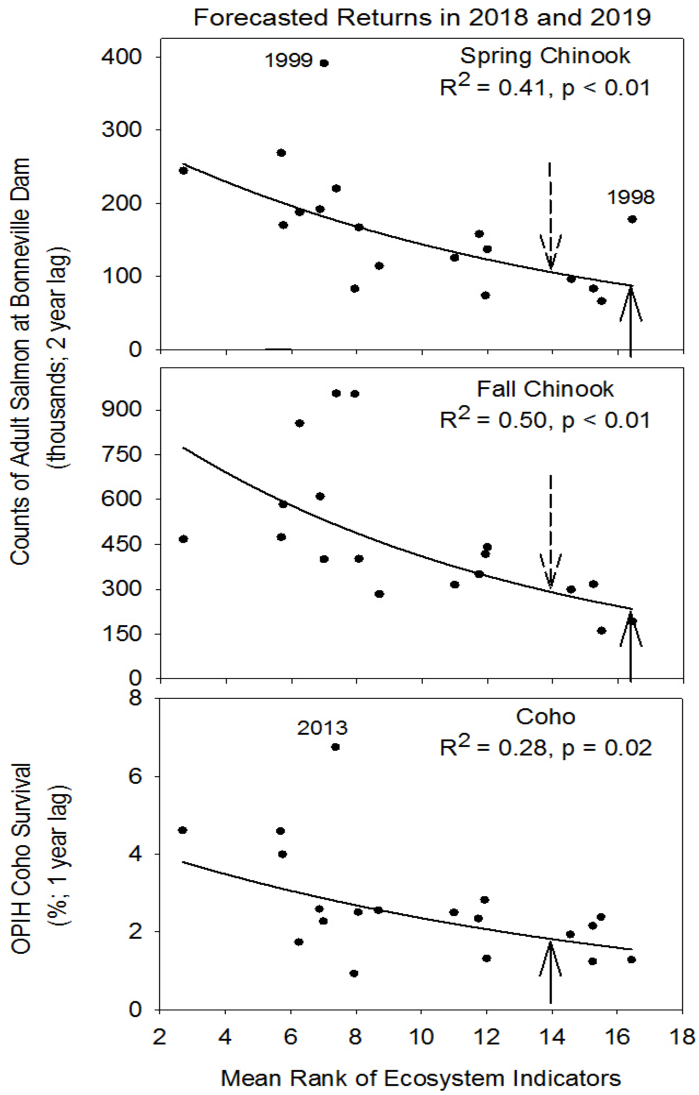

Figure 5. Correlations between Ecosystem Indicators and adult Chinook returns.

In order to model a random sequence of low SARs and their effects on adult returns, we first needed to categorize, and define SARs as low, medium or high. This required an examination of a smolt-to-adult survival time series that overlapped with NOAA's ocean ecosystem indicator dataset. The Carson Hatchery spring Chinook data set (2000-2014) was chosen due to the corresponding time series it had in common with the Ocean Indicator data time series, and also due to the close proximity to the Klickitat River (Table 8).

Table 8. Carson hatchery spring Chinook smolt-to-adult release to Bonneville Dam Adult return rates ("Rel to BOA without Jacks"; 2017 CSS report)

Juvenile migration year	Rel to BOA without Jacks
2000	2.85%
2001	1.49%
2002	1.01%
2003	0.23%
2004	0.62%
2005	0.30%
2006	0.42%
2007	0.54%
2008	1.48%
2009	1.42%
2010	0.75%
2011	0.33%
2012	0.54%
2013	1.05%
2014	0.56%

Similar to NOAA's use of the mean rank of ecosystem indicators, we plotted the Carson spring Chinook smolt-to-adult return rates as a function of the rank scores and generated a correlating regression line (Figure 6). The mean rank of ecosystem indicators explained approximately 48% of variability across the survival time series (R^2 value of 0.4828). The correlation was done by pairing the survival for each juvenile migration cohort year (Table 8) with NOAA's Ecosystem indicator rank of the mean rank for the same year. This allowed us to bracket, or "categorize" the SAR values and their respective years into similar qualitative bins used to describe ocean conditions as positive, neutral, and negative. SARs from juvenile migration years that correlated to ecosystem indicator years that had scores of 6 or less were considered "positive" years with high survival rates. SARs from juvenile migration years that correlated with ecosystem indicator years that had scores between 7 and 14 were considered "neutral" years with intermediate survival rates. Lastly, SARs from juvenile migration years that correlated with ecosystem indicator years that had scores between 15 and 20 were considered "negative" years with poor survival rates (Figure 6).

The regression equation (Figure 6) was used to generate 3 different types of SAR datasets that were then used in a random SAR sequence for three different scenarios extending across a 50 year time series. The scenarios included a baseline scenario, which assumes a similar range and variability in SARs to those observed in the last 20 years, and two scenarios where poor smolt-to-adult return rates become more prevalent over the next 50 years (degraded and very degraded).

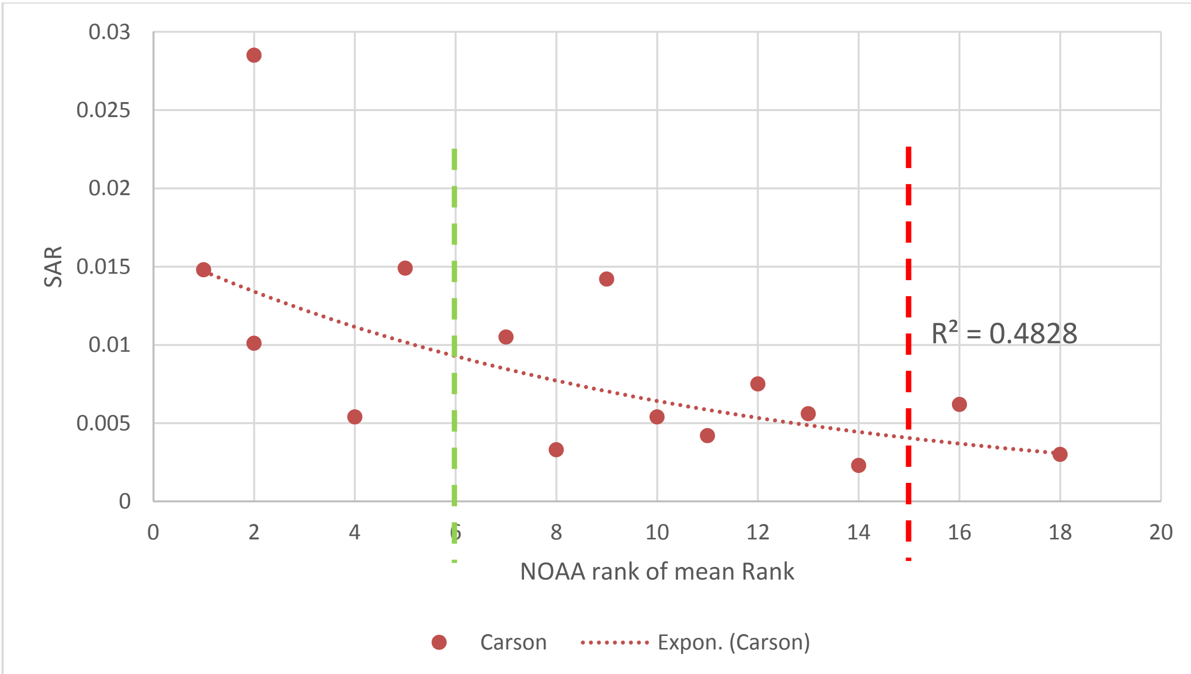

Figure 6. Correlation between Carson Spring Chinook Hatchery SARs and the mean Rank of NOAA Ecosystem Indicators (2000-2014). Years with rank of mean rank scores less than or equal to 6 are considered positive, years with rank of mean rank scores between 7 and 14 are considered neutral, years with rank of mean rank scores greater than or equal to 15 are considered negative.

Scenario Descriptions

Baseline Scenario (30/40/30)- Referring back to NOAA's yearly rank scores derived from ecosystem indicators (Figure 4), years are qualitatively described as being positive (green), neutral (yellow), or negative (red) for each year between 1998 – 2017 (rank of the mean rank). Within this 20 year time series, 6 years were considered negative (30%), 8 years were considered neutral (40%), and 6 years were considered positive (30%). Using the regression line equation from figure 5, we mimicked the 1998-2017 qualitative pattern by generating a SAR data set where 30% of the survival estimates fell within the range of "poor" survival conditions, 60% were within the range of "Intermediate" survival conditions, and 30% were within the range of "good" survival conditions. In essence, the baseline scenario is assuming the range, variability, and frequency (30/40/30) of survival will be very similar to those observed over the last 20 years (Figure 7).

Degraded Scenario (50/30/20)- This scenario increases the frequency in the number of years where smolt-to-adult survival rates fall within the qualitative category of "poor" survival, while decreasing the number of years that fall within the range of "intermediate" and "good" survival. The number and frequency of years experiencing poor survival conditions were increased from 30% to 50%, intermediate survival years were decreased from 40% to 30%, and good survival years were decreased from 30% to 20% (Figure 7).

Very Degraded Scenario (70/20/10)- This scenario further increases the frequency in the number of years where smolt-to-adult survival rates fall within the qualitative category of "poor" survival, while further decreasing the number of years that fall within the range of "intermediate" and "good" survival. The number and frequency of years experiencing poor survival conditions were increased from 50% to 70%, intermediate survival years were decreased from 30% to 20%, and good survival years were decreased from 20% to 10% (Figure 7).

Model Scenarios			
Year	Baseline(30/40/30)	50/30/20	70/20/10
1	20	20	20
2	6	17	17
3	2	15	15
4	5	5	5
5	2	2	2
6	14	14	14
7	16	16	16
8	18	18	18
9	11	15	17
10	10	10	15
11	1	1	7
12	9	9	9
13	12	15	15
14	8	8	16
15	4	4	18
16	7	7	17
17	13	13	13
18	17	17	17
19	19	19	19
20	15	15	15

Figure 7. Model scenarios under Baseline (30/40/30), degraded (50/30/20) and very degraded (70/20/10). Numbers in columns represent rank of mean rank ocean indicators used to generate yearly SAR estimates.

SARs that were generated for the three scenarios are presented in Table 9 below. From these, a plausible random sequencing of SARs were generated over a 50 year time period for each scenario using their descriptive statistics and autocorrelation.

Table 9. Twenty year time series of generated SARs for Model scenarios. SARs were generated using regression equation from correlation between Ecosystem Indicators and Carson hatchery spring Chinook SARs (Figure 5).

	Baseline (30/40/30)	Degraded (50/30/20)	Very Degraded (70/20/10)
	0.256%	0.256%	0.256%
	0.927%	0.337%	0.337%
	1.339%	0.405%	0.405%
	1.016%	1.016%	1.016%
	1.339%	1.339%	1.339%
	0.444%	0.444%	0.444%
	0.369%	0.369%	0.369%
	0.307%	0.307%	0.307%
	0.585%	0.405%	0.337%
	0.642%	0.642%	0.405%
	1.468%	1.468%	0.846%
	0.703%	0.703%	0.703%
	0.534%	0.405%	0.405%
	0.771%	0.771%	0.369%
	1.114%	1.114%	0.307%
	0.846%	0.846%	0.337%
	0.487%	0.487%	0.487%
	0.337%	0.337%	0.337%
	0.280%	0.280%	0.280%
	0.405%	0.405%	0.405%
Avg	0.709%	0.617%	0.485%

NOR Returns and Broodstock Collection: Phases I-III

We examined our ability to collect natural-origin broodstock over a range of spring Chinook natural-origin adult returns while maintaining a collection rate less than 25% of the run. The purpose of this was to evaluate the program's ability to collect enough NOR broodstock required to transition from phase to phase while minimizing collection rates on NOR spring Chinook. Specifially, we looked at phases I, II, and III under the same scenarios as those modeled for hatchery origin returns (e.g. baseline, degraded, and very degraded). The baseline scenario for natural-origin returns assumed a range of returns for NOR adult spring Chinook similar to those observed between 2007 and 2016 in an attempt to demonstrate our ability to move into, and through phases I-III if natural production remained similar to the recent 10 years. Transition from phase III to phase IV

will likely require an increase in natural production as demonstrated in the original appendix C of the masterplan. Therefore, this analysis is limited to the examination of phases I-III under current natural production and reductions in natural production.
Phase I & II of the program will collect approximately 68 NOR adults producing a smolt release of ~100,000 yearling smolts. Phase I of the program is designed to minimize the broodstock collection rate on the NOR population while providing a minimum number of returning adults to begin propagation of the new H_2 hatchery line. In the masterplan, it is stated the program will not collect greater than 25% of the NOR return at Lyle Falls. For the first part of this modeling analysis, we randomly generated a NOR return over a 50 year time series based on statistics of the observed return numbers between 2007 and 2016. Figure 8 illustrates the estimated total spring Chinook return to the mouth of the Klickitat annually, the Lyle falls fish bypass/adult trap NOR usage, and the phase I & II target collection rate. Over the 50 year time series that was modeled, the result suggests the program will have the ability to collect 68 adults needed for phase I and Phase II of the program. Furthermore, the analysis also suggests the program could collect enough NOR broodstock (104 adults) for phase III of the program while keeping the collection rate at or below 25% under the assumption that NOR spring Chinook will remain similar to those observed in the last 10 years.

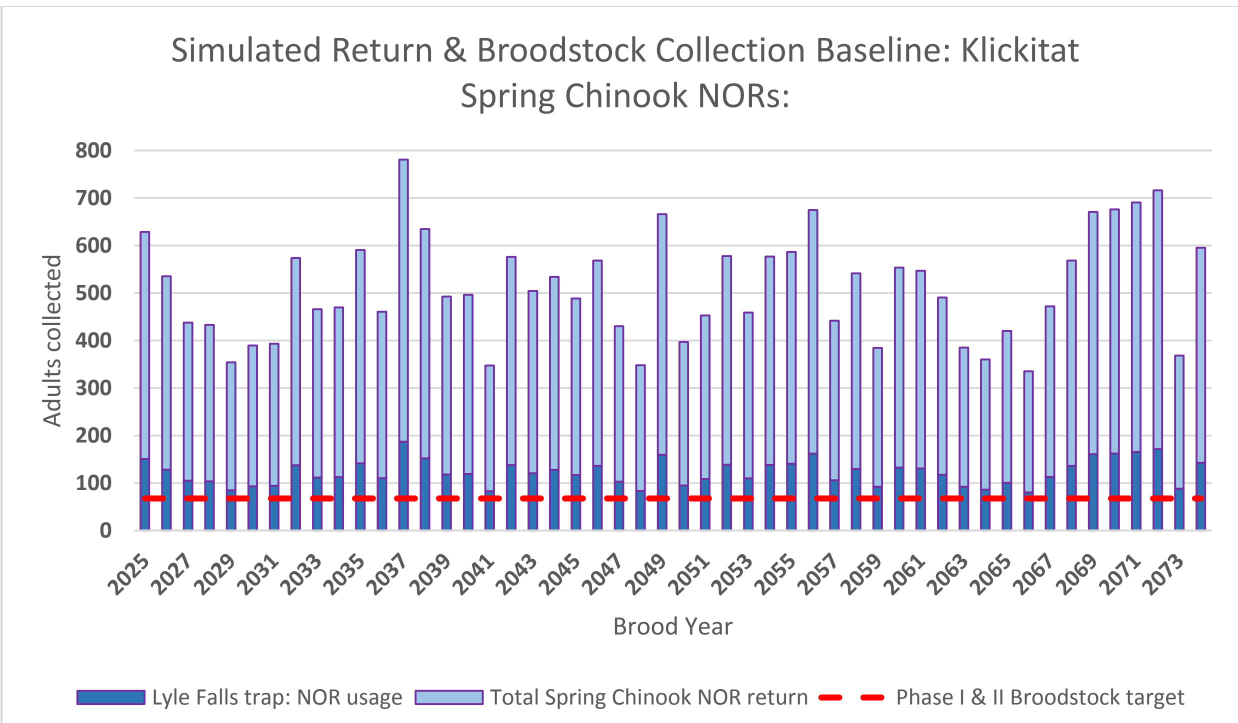

Figure 8. 50 year time series of randomly generated NOR returns of spring Chinook to the Klickitat mouth

Scenario results: Hatchery broodstock collection and smolt release numbers

Numeric results from the scenarios are summarized in Table 10 below. Graphical illustrations of the 50 year time series are presented for each scenario individually in Figures 9-13 below. The Phase II broodstock collection goal for the H2 line ranges from 205-240 adults, which is the estimated number of adults needed to meet the phase II production goals of 300k-350k yearling smolts.

For the baseline scenario, the modeling results suggest the program will have a high probability of successfully collecting enough adults to meet production goals on an annual basis, particularly for the 205 adult collection target. On rare or infrequent occasions, there will be years with poor survival restricting the program's ability to collect enough broodstock to release the targeted 300k-350k smolts (Figures 9 and 12). Probability of collecting 205-240 adults diminishes for both degraded and very degraded scenarios that experienced an increased frequency in "low" smolt-to-adult survival rates. If the "very degraded" scenario SARs become prevalent in future years, the program's ability to collect the target broodstock will decline to roughly 50% of time, with smolt release numbers ranging from 150k -350k.

There are other factors and modeling assumptions to consider when interpreting the results. For example, we assumed a trapping efficiency at the Lyle Falls facility of 25%, and an adult volunteer rate into the Klickitat hatchery of 27%. The trapping data is based empirical data from recent years of trapping operations and documented fish ladder use for spring Chinook. This is the average usage over a 10 year period, but should be acknowledged this will vary somewhat from year to year. The volunteer rates into the Klickitat hatchery have greater uncertainty, particularly in future years when infrastructure upgrades have been completed to the volunteer trap at the adult intake. Regardless, management strategies must be developed and implemented depending on the performance of hatchery program SARs. For example, alternative methods for collecting adult hatchery spring Chinook could be used to bolster the overall number of fish collected for broodstock. Methods may include but limited to, trapping at the Castile Falls facility, the use of temporary weirs in strategic River locations, or hook and line methods.

In the original Appendix C of the Masterplan, the modeling work suggested a hatchery SAR performance of approximately 0.50 was needed to expedite transition from one phase to the next without major setbacks. The modeling in this document further validates this, and reveals some program challenges for obtaining broodstock and maintaining target release numbers when smolt-to-adult return rates of about 0.40 or less become more prevalent than in recent years.

Table 10. Summary of scenarios demonstrating program ability to collect H2 line broodstock.

Scenario	Broodstock collection goal	# years at or above goal	# years below goal	% of years meeting goal
Baseline (30/40/30)	205	49	1	98%
	240	43	7	86%
Degraded (50/30/20)	205	36	14	72%
	240	32	18	64%
Very Degraded (70/20/10)	205	29	21	58%
	240	22	28	44%

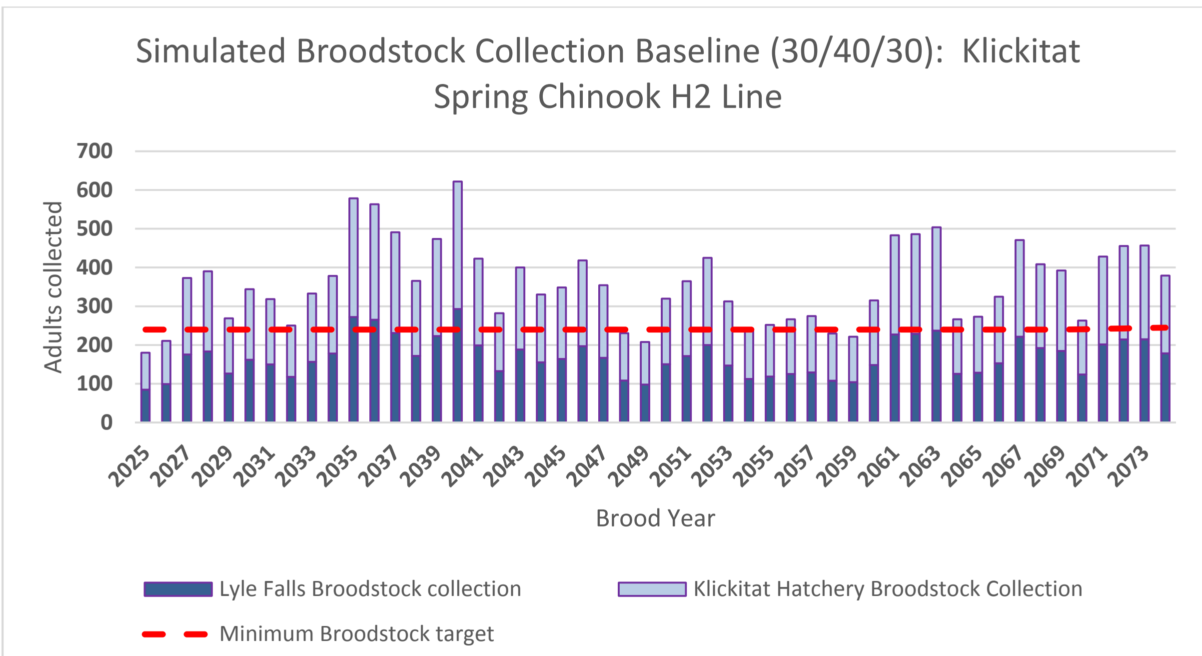

Figure 9. 50 year time series demonstrating broodstock collection for the H2 line under baseline conditions.

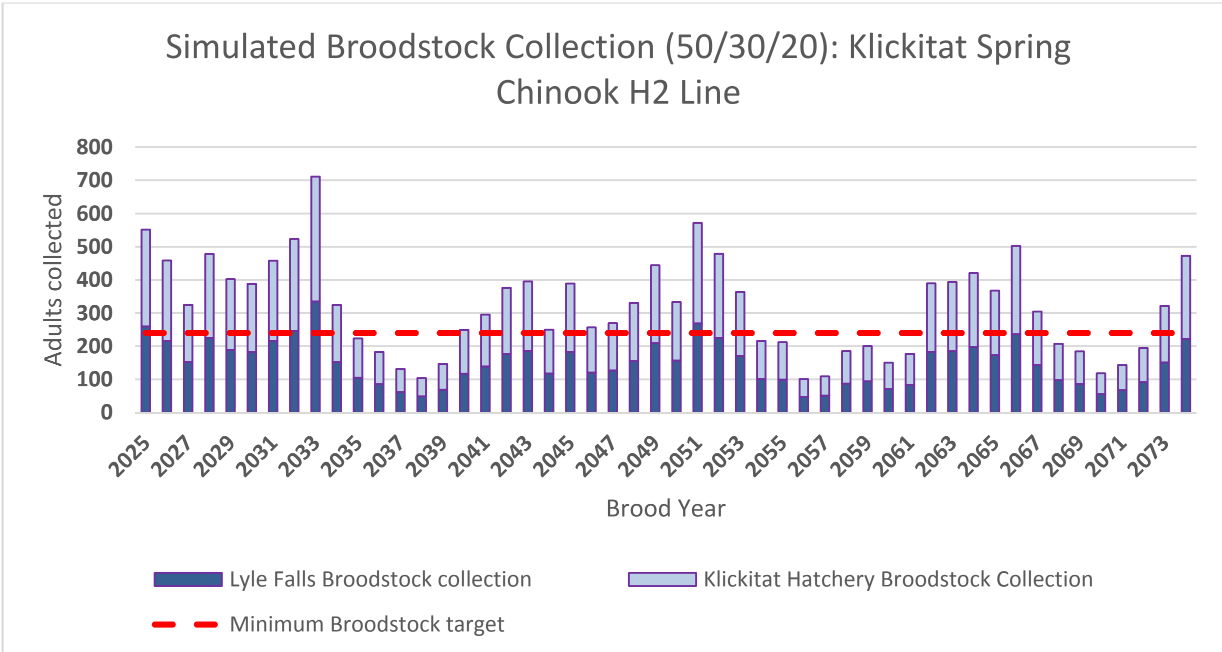

Figure 10. 50 year time series demonstrating adult returns and broodstock collection for H2 line under degraded conditions.

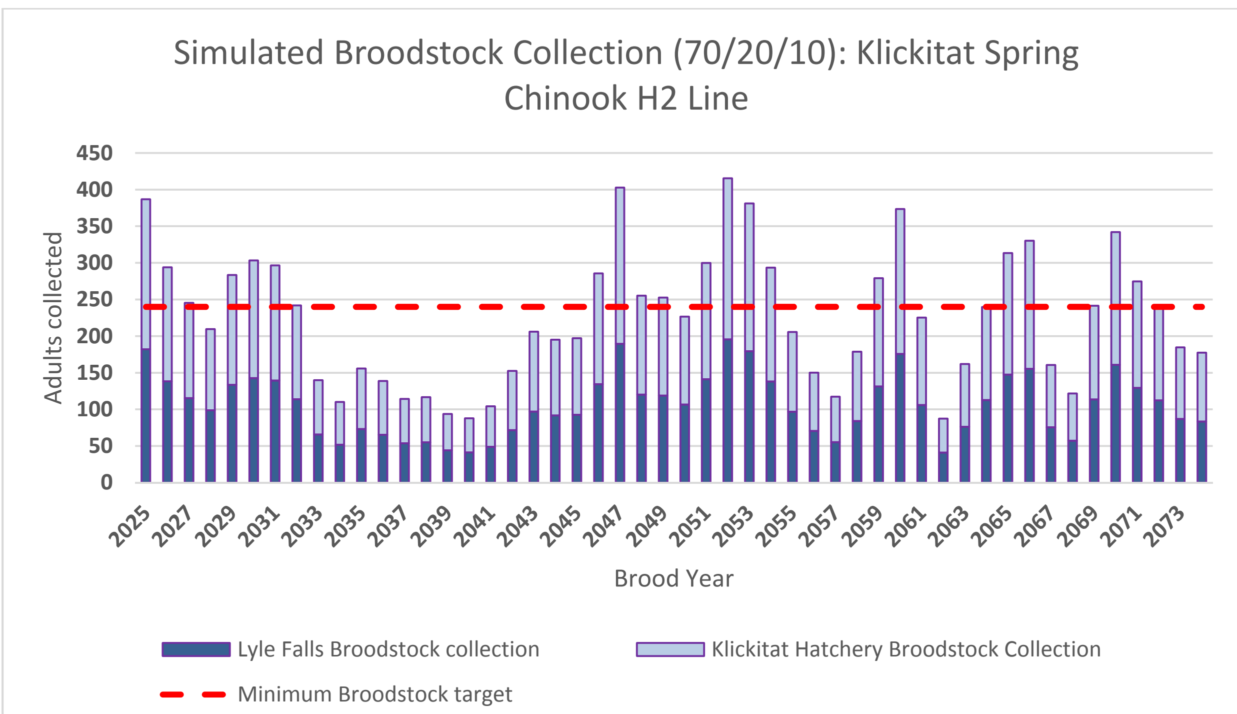

Figure 11. 50 year time series demonstrating adult returns and broodstock collection for H2 line under very degraded conditions.

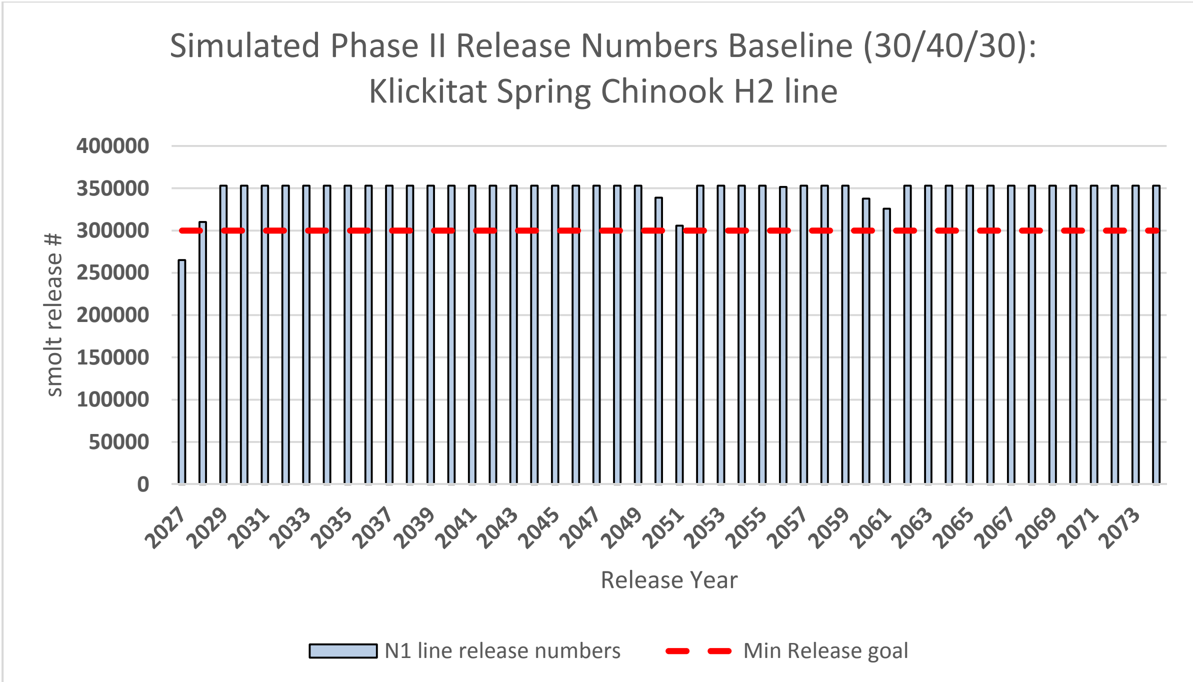

Figure 12. 50 year time series demonstrating release numbers of H2 line under Baseline conditions

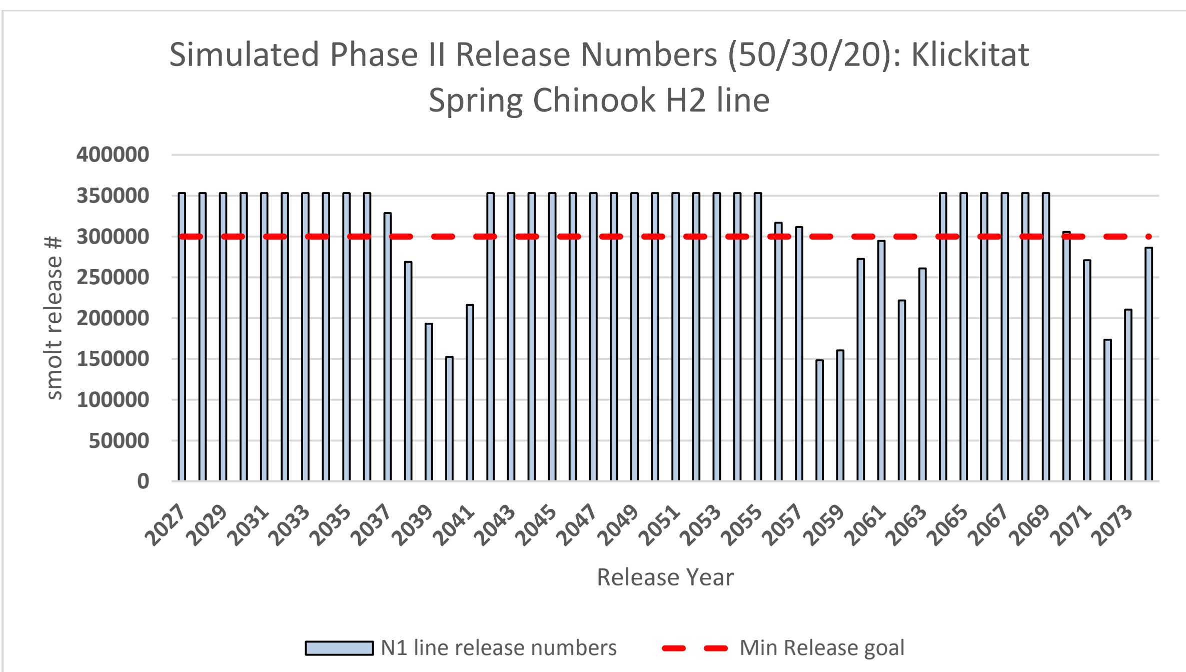

Figure 13. 50 year time series demonstrating release numbers of H2 line under degraded conditions.

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