Infrastructure and Operations Audit of Dworshak National Fish Hatchery 2022

Dworshak National Fish Hatchery
Lower Snake River Compensation Plan

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Executive Summary

On September 19, 2022, Nathan Wiese, Program Coordinator LSRCP, Steve Rodgers, Complex Manager, Jeremy Sommer, Hatchery Manager, Mark Drobish, Hatchery Manager, Denys Chewning, Clearwater Hatchery Manager, Joe Wannemuehler, Clearwater Assistant Hatchery Manager, and Hayden Fitte, Clearwater Assistant Hatchery Manager, conducted a high-level one-day infrastructure and operations assessment of the Dworshak National Fish Hatchery.

The purpose of this document is to provide the Lower Snake River Compensation Plan (LSRCP) and other stakeholders ample conceptual-level information of the current infrastructure challenges. The goal is to incorporate audit findings into a 10-year strategic plan for LSRCP that will maximize in-house and external improvement opportunities by developing solutions that fit resources, budgets, and supportive programs in a logical sequence. These efforts are intended to significantly improve water quality, program capacity, efficiency, and flexibility at the facility and ultimately increase opportunities for LSRCP to meet adult mitigation targets.

The LSRCP plans to assess all spring/summer Chinook rearing facilities within the program prior to the 10-year spring/summer Chinook Program Review for the Independent Scientific Review Panel (ISRP) in December 2022. With this review, the LSRCP intends to identify strategies toward improving performance of achieving project area goals of 58,700 spring/summer Chinook salmon adult returns. From 2004-2017, the LSRCP averaged 29,115 spring/summer Chinook salmon adult returns and failed to achieve the project area goal on any year during the period.

The analysis identified installing a shade structure over the existing rearing raceways to improve on-station rearing conditions and associated adult returns. Cost of this project is estimated at $4.1M.

In addition, LSRCP currently supports production of an additional 500,000 Southern Resident Killer Whale (SRKW) spring Chinook smolts at Dworshak by allowing water supplies for the raceways to be utilized for this program. If the SRKW program funding falters, LSRCP could pick up this production.

Total cost: $154,159 annually for fish food, marking, etc. and $135,150 for Burrows Pond rental (5) through COE/NPT/USFWS Cost Allocation process.

Finally, a new pipeline to the Clearwater Fish Hatchery could provided additional rearing space for 1.6 million spring Chinook smolts at Clearwater and 1.8 million at Dworshak returning an estimated 16,000 additional adults. Total cost is estimated at $61.2M.

Additional options identified and discussed are not feasible because they involve assets owned by the Corps of Engineers and are not under the purview of the Lower Snake River Compensation Plan.

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1 Scope

On September 19, 2022, Nathan Wiese, Program Coordinator LSRCP, Steve Rodgers, Complex Manager, Jeremy Sommer, Hatchery Manager, Mark Drobish, Hatchery Manager, Denys Chewning, Clearwater Hatchery Manager, Joe Wannemuehler, Clearwater Assistant Hatchery Manager, and Hayden Fitte, Clearwater Assistant Hatchery Manager, conducted a high-level one-day infrastructure and operations assessment of the Dworshak National Fish Hatchery.

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2 Background

The Dworshak National Fish Hatchery (Dworshak) began fish production operations in 1968. The original pump station had 5 pumps and a total maximum of 64,000 gallons per minute (Peltz 2014). The original construction also included 84 Burrows Ponds, biofilters, UV sterilizers, and boilers or chillers.

A spring Chinook salmon program was started in in 1981 under the umbrella of the Lower Snake River Compensation Program. Chinook raceway construction was initiated in 1981 and completed in 1982. Thirty raceways were added to the hatchery to raise spring Chinook salmon. The goal for Dworshak National Fish Hatchery is to return 9,135 adults to the Clearwater Basin.

Infectious Hematopoietic Necrosis virus (IHN) was diagnosed in rainbow trout in October of 1981. IHN was found in returning adult steelhead that were collected Dec. 1981 to May 1982. Over 2 million fish were lost in June and July of 1982 due to IHN for 47.7% mortality rate for BY 82.

In 1992, a water supply directly from Dworshak Reservoir was added with the construction of Clearwater Fish Hatchery. The pipeline could provide 6400 gpm of IHN-free water to the nursery.

For almost two decades, IHN seemed under control and biggest issues were Ich in the re-use system. However, over 500,000 fish were lost to IHN in BY08 production and over 1,100,000 fish were lost in BY09 production. This was the first major outbreak of IHN since 2002 and largest losses of fish since the nursery was switched to reservoir water use only. The outbreaks occurred in larger size fish (> 90 fpp) that had been thought to be capable of fighting off the disease.

Because of this outbreak, the staff worked with Clearwater Hatchery to find additional reservoir water supplies to rear the fish to 60 fpp on reservoir water. For the most part, that has eliminated IHN issues for steelhead. Although Chinook juveniles have tested positive for IHN, they appear resistant to the disease and have limited mortality.

Dworshak no longer uses the re-use system for rearing and the systems have been re-purposed to handle effluent and cleaning waste for NPDES permits. In addition, water flows per Burrows Pond have been dramatically increased from 400 gpm to 700 gpm (2022).

Dworshak is a large production facility and has served as an emergency rearing location in several recent instances. In 2012, 2.5million spring Chinook were transferred to Dworshak and reared in 25 Burrows Ponds. Additional secondary reservoir water in System 1 allowed the hatchery to allocated additional river water to System III for the increased rearing. In 2019, Fall Chinook salmon from Lyons Ferry Fish Hatchery were transferred to Dworshak because of a pipeline failure there.

Also in 2011, the BY10 Spring Chinook smolts were consolidated to 24 raceways instead of 30 raceways. The remaining 6 raceways were used for the production of 280,000 coho smolts. This change was done to reduce the space needed in System 3 to meet NPDES requirements. After the success of the 2011 rearing, the Hatchery Evaluation Team (HET) met to consider increasing the numbers of Chinook smolts per raceway from an average of 30,000 smolts per raceway at 20 fpp to 45,000 smolts per raceway. The Hatchery Evaluation Team agreed to increase the number of smolts based on several factors:

Based on the BY11 Chinook successes, the Dworshak HET recommended increasing the smolts reared per raceway from 45,000 to 65,000 in 6 raceways, later termed "The Density Study". The corresponding DI at 65,000 (20 fpp) is 0.35. To compensate for a higher Density Index, the Flow Index was lowered below 0.5 (1.5 Max FI) by utilizing additional river water and the serial re-use channels between the raceway banks.

In 2014, Dworshak installed shade cloth over the Chinook rearing raceways to reduce algae growth and improve rearing conditions. That has continued until today (2022).

In 2016, Dworshak removed existing vacuum degassers and installed Low Head Oxygenation system (LHO's) to strip Nitrogen from incoming river water supplies. Because of the ability of the LHO's to also add oxygen, raceway water was decreased in 2021 by 3500 gpm to accommodate an additional 5 Burrows Ponds of Southern Resident Killer Whale spring Chinook smolt production.

In over 50 years, Dworshak NFH has undergone many changes from an original re-use facility to an almost 100% flow-through facility. It has and continues to be one of the largest conservation hatcheries in Idaho and routinely produces over 500,000 pounds of fish annually.

2.1.1 Adult Targets and Broodstock source

The goal of Dworshak National Fish Hatchery is annual returns of 9,135 adult spring Chinook salmon above Lower Granite Dam for the Lower Snake River Compensation Plan. (BIOP 2017).

Dworhak also rears 2.1 M steelhead for the Corps of Engineers to 5.8 fish per pound (200mm) in 59 Burrows Ponds. Steelhead are taken in 10 egg takes from January until April to maintain acceptable density limits and meet fishery management objectives.

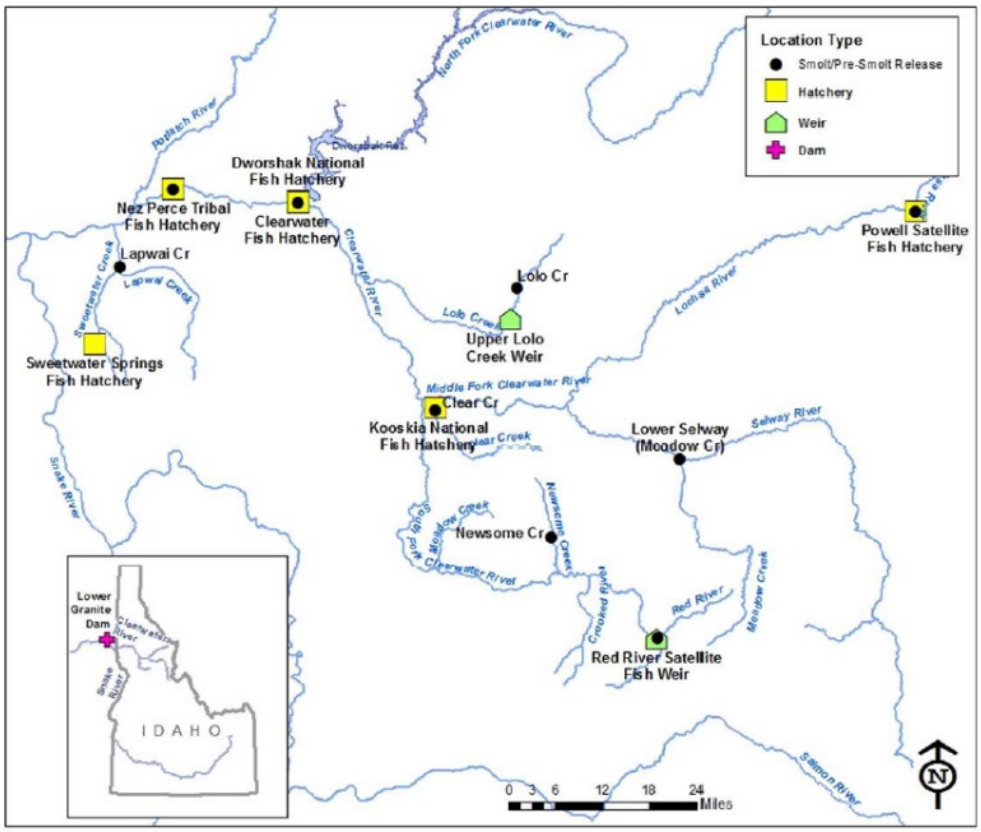
The Dworshak NFH spring Chinook salmon program was initially started using Chinook salmon stock from the Leavenworth and Little White Salmon NFH programs. Eggs were transferred from these facilities and made up the smolt releases from 1983 to 1986. Since these stocks were very strongly influenced by transfers to their programs from Carson NFH, the early Dworshak Chinook stock was considered a Lower Columbia River Carson derivative. The Chinook programs for brood years 1985 and 1986 consisted entirely of eggs that had been transferred from Rapid River State Fish Hatchery, which used Chinook returning to the Snake River at Hells Canyon Dam. Thus, smolts released in 1987 and 1988 were entirely Rapid River stock, shifting

the program away from using the Lower Columbia River Carson Chinook stock. Since then, Dworshak NFH has maintained its program from returns to its own rack. In 1995, when returns were too low to meet broodstock needs, Dworshak NFH back filled its program using excess eggs from Kooskia NFH. The recent returns to Dworshak NFH (1989 and later) are referred to as Dworshak stock, since they are progeny of returns to Dworshak NFH, rather than direct products of transfers of Rapid River stock (HGMP 2002).

2.1.2 Current Chinook targets

The target release number for spring Chinook salmon are 2.15 million smolts (1.65M are U.S. v Oregon and 500K are Southern Resident Killer Whale) direct released into the North Fork Clearwater River and 400,000 parr transferred to NPTH (200K are U.S. v Oregon).

Rearing and release locations of spring/summer Chinook in the Clearwater basin (AOP 2022):



2.1.3 Current Rearing Bottlenecks

There are two rearing bottlenecks in November. There is a brief period of time where the incubation room is nearing maximum water flow (450 gpm) capacity as the Coho are spawned. Coho double load their trays at 4 gpm and ship eggs to Eagle Creek in December ending the bottleneck. The other bottleneck in November is that Dworshak hatchery reaches full capacity with the addition of SST adults and trapping. All programs are in final rearing at this point.

The April bottleneck is when the SST nursery fills up and system 1 needs to be disinfected and cleaned to allow SST to move out. SCS also cannot go out into rearing until raceways are cleaned and prepped. This has gotten more difficult as late releases (mid-April) mean smolts are on station 2 weeks longer than in the past (pers comm. Jeremy Sommer).

2.1.4 Adult Returns

Average adult returns for Dworshak spring Chinook smolts is 0.27% SAR from release year 1983-2020.

Dworshak Adult Returns

Release Year	SAR
1983	0.07%
1984	0.28%
1985	0.26%
1986	0.16%
1987	0.10%
1988	0.19%
1989	0.01%
1990	0.05%
1991	0.05%
1992	0.00%
1993	0.01%
1994	0.15%
1995	0.37%
1996	0.29%
1997	0.82%
1998	1.01%
2002	0.91%
2003	0.21%
2004	0.34%
2005	0.20%
2006	0.51%
2007	0.48%

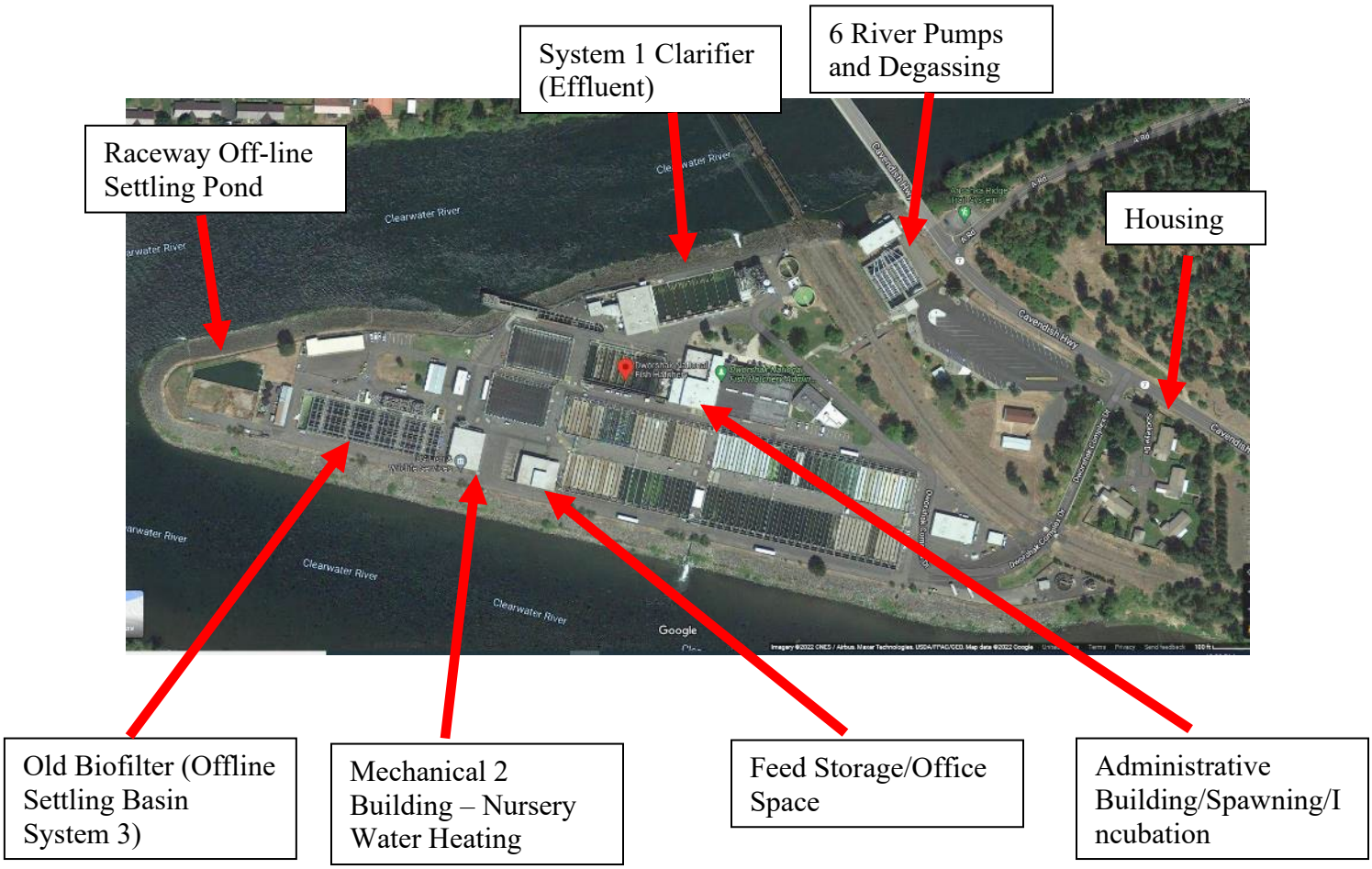
2008	0.01%
2009	0.62%
2010	0.01%
2011	0.37%
2012	0.75%
2013	0.01%
2014	0.35%
2015	0.13%
2016	0.13%
2017	0.06%
2018	0.09%
2019	0.12%
2020	0.30%
AVG	**0.27%**

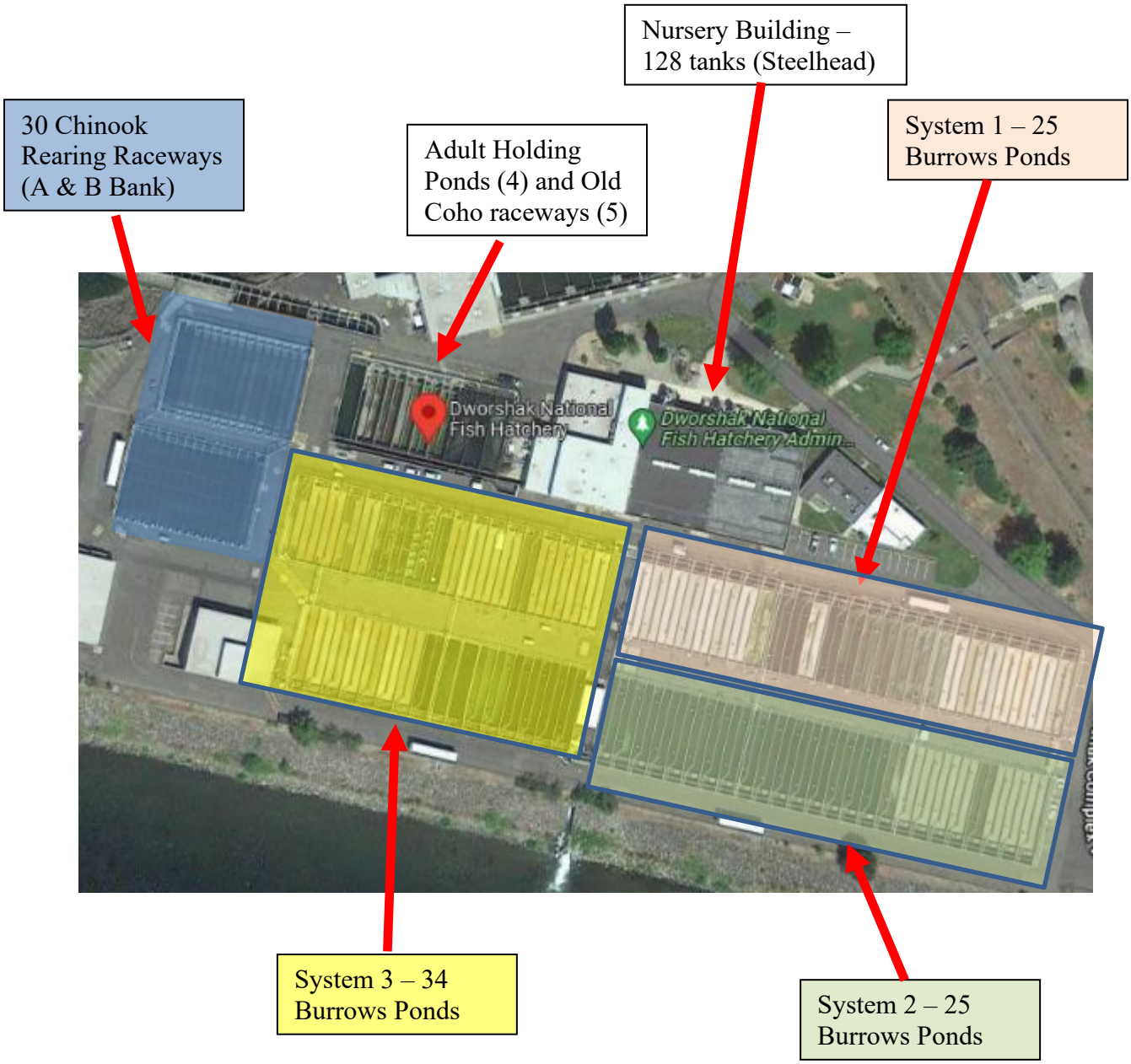
2.2 Biological Opinion

The seven Clearwater River hatchery programs are included as part of the proposed action collect adult broodstock at numerous locations throughout the Clearwater River Subbasin. Release of hatchery smolts also occurs at numerous locations throughout the subbasin (Figure 1). Juvenile release targets include approximately 3 million steelhead, 6 million Chinook salmon, and 500,000 coho salmon. (BIOP 2017)

To meet adult mitigation goals, the original annual production from Chinook Salmon hatcheries in the Clearwater drainage was approximately 1.35 million smolts. This level of production assumed that about 0.87% of smolts released would return to LGR but actual SAR's have averaged less than half of that value. To offset these below anticipated SARs, attempts have been made to increase production from Chinook Salmon hatcheries in the Clearwater drainage and annual releases now total approximately 6,380,000 smolts (Spring and Summer runs combined, including new production) and 925,000 parr and pre-smolts. (AOP 2022)

2.3 Infrastructure





Generally, steelhead are reared in 50 Burrows Ponds (80' x 16' x 2.3' = 3000 ft3) in Systems 1 and 2 and an additional 9 Burrows Ponds in System 3 at 35,000 to 40,000 smolts per Burrows Pond to 5.8 fpp.

Coho are reared in 6 Burrows Ponds in System 3 at 85,000 smolts per Burrows Pond to 20 fpp.

Spring Chinook are reared in 30 raceways (8' x 80' x 2.6' = 1664 ft3) at 55,000 smolts per raceway.

An additional 500,000 spring Chinook for the Southern Resident Killer Whale (SRKW) program are reared in 5 Burrows Ponds at 100,000 per pond to 20 fpp.

2.3.1 Hatchery Water Supply

In 2013-2014 the main supply was overhauled with 6 new energy efficient pumps rated at 200 hp each. Those pumps replaced 6, 250 hp pumps that were originally rated at 15,500 GPM each for a total flow of 93,000 GPM or 207 CFS. However, at the time of their replacement, impeller wear and performance at low river levels was below their original rating.

The new pumps supply 11,500 gpm each or approximately 69,000 gpm total river water supply to the Burrows Ponds, Chinook raceways, and Holding Ponds. In addition, 6400 gpm (minimum) is available from the reservoir water supply source. Additional water is available from Clearwater Fish Hatchery during early spring and summer months to get steelhead to 60 fpp and beat IHN susceptibility. Current water supplies are fully allocated and indicate a slight overage of pump rating:

Dworshak Water allocation

Location	Ponds	GPM	Total (gpm)
Steelhead	59	700	41,300
Coho	6	700	4,200
SRKW	5	700	3,500
Raceways	30	475	14,250
Holding Pond	4	1750	7,000
			70,250

3 Operations

3.1.1 Broodstock Collection

Adults are crowded from a fish trap at the end of the fish ladder into a crowding channel, moved into a channel basket, and placed into an anesthetic bin. Spring Chinook salmon adults are anesthetized with MS-222. Spinal columns of ripe females are severed using a pneumatic knife. The females are then placed on a table for 1-20 minutes for blood drainage. The ventral side is then cut open using a spawning knife and eggs are collected in disinfected colanders. After ovarian fluid is drained, the eggs are poured into a clean bucket Milt from ripe males is stripped into Styrofoam cups and a one-percent saline solution is added to assist in milt motility. The milt

solution is poured onto the eggs and swirled for more complete fertilization. After sufficient time is elapsed for fertilization to take place (one to two minutes), the eggs are rinsed of sperm, blood, and other organic matter. After rinsing, eggs are placed in Heath incubator trays at approximately 3,500 eggs per tray (1 female). In the tray is a 75 mg/l iodophor solution buffered with sodium bicarbonate. Eggs are maintained in this solution for approximately 30 minutes as a precaution against horizontal disease transmission. The egg trays are then pushed into the incubator, flushing the iodine. Water flow rate is approximately five gallons/minute and incubation temperature averages 43 F. Chinook spawning involves a male:female ratio of 1:1.

3.1.2 Holding Ponds

A fish ladder from the North Fork of the Clearwater River traps returning adults at the hatchery. The holding pond at the top of the ladder is 15'x 75' x 8' = 9000 ft3.

The facility has a total of 9 holding ponds. Four holding ponds are used for adult holding and 5 holding ponds were converted to Coho rearing raceways and are currently empty.

3.1.3 Incubation

The Hatchery incubation has 1,740 trays and a useable number of 1,856. There are a total of 116 stacks. These are for all production programs, spring Chinook (3M eggs), Steelhead (2.9M eggs), and Coho (1.5M eggs).

Spring Chinook eggs are initially loaded at 1 female/tray ~ 3,500 eggs/tray green eggs. After enumeration, eggs are returned to the tray at 5,000 eggs/tray. Water flow for the trays is approximately 5 gallons/minute and formalin treatments are conducted 3x weekly.

Dworshak has a large water chiller unit that is used to chill reservoir water supplies to approximately 37 F. This serves two purposes. First, it is used to match development of different spawn takes. Secondly, it is used to delay swim-up and feeding so that outdoor rearing and water supplies are not overlapping between brood years. Generally, release of spring Chinook smolts takes place in March and April and ponding of first-feeding fry occurs on May 1st at 1550 Temperature Units (TUs).

3.1.4 Early Rearing

All early rearing occurs in 8'x 2.6' x 80' raceways (1664 ft3). Initial ponding occurs in the top 1/3 of the raceway and fingerlings are moved to ½ and full raceway length throughout the summer to a maximum of 100 fpp for marking purposes.

Steelhead early rearing occurs in 128 nursery tanks (20 x 3 x 3' = 180 ft3).

3.1.5 Outdoor Rearing

Steelhead are reared in 59 outside Burrows Ponds (36K smolts/Burrows Pond), each with a volume of 3,000 cubic feet.

Chinook salmon are reared in 30 outdoor raceways, each of which has a volume of 1,664 cubic feet. Raceways are in two-banks of 15 raceways each (A & B Banks). Water is re-used from A-bank to B-bank raceways and additional fresh water is added at B-bank. Current protocols use 700 gpm in A-bank raceways and add an additional 250 gpm "new" water into B-bank raceways. All raceways are equipped with Low-head Oxygenation systems to increase Nitrogen de-gassing capacity and increase Oxygen supply as needed.

Raceways have been ponded at either 45,000 or 65,000 juveniles (100 fpp) after marking. Current protocols pond at 55,000 smolts per raceway for a final Density Index of 0.3 DI at a condition factor of 3. Fish will remain in the same individual raceways for the remainder of their rearing cycle at Dworshak.

The NPTH on-site release group early reared at DNFH will be transferred to NPTH in mid-August at ~200 fpp and marked/tagged there. The NPTH Lapwai Creek release group early reared at DNFH will be transferred to NPTH in September, within one week after marking/tagging at DNFH in September. DNFH program fish will also be marked/tagged in September (~100 fpp), and then moved to their final raceways at final densities.

B-Bank Raceway LHO's

3.1.6 Release

Chinook smolts are released onsite into the North Fork Clearwater river at 20 fish per pound. Releases are done at night to avoid additional bird predation.

A split timing release study has been initiated over the past two release cycles (Release Year 2021 and 2022). A portion of spring Chinook from Dworshak and Clearwater facilities have been released at the end of March and the remainder released in mid-April approximately 2-weeks later. The goal of this study was to examine survival to Lower Granite Dam trends and transportation and survival rates through the rest of the migration corridor.

Results of this study suggest that travel times to Lower Granite Dam are significantly longer for "early" released smolts and approach almost 2-weeks. It appears that early released fish are not migrating at release and delay downstream migration to the point that arrival at Lower Granite Dam is within 3-days for early and late released smolts.

3.1.7 NPDES

Significant efforts have gone to ensuring Dworshak is compliant with NPDES permits. Current operations are compliant and NPDES permitting tier is 500,000 to 1,000,000 pounds of annual fish production.

3.1.8 Marking

Chinook marking occurs in August and September at 100 fpp by Columbia River Fish and Wildlife Conservation Office staff.

3.1.9 Chinook Smolt Size at Release and Adult Returns

A sensitivity analysis was explored using adult returns from release years 2016-2020 for Dworshak and Clearwater Hatcheries into the North Fork Clearwater river. On average, larger smolts (16 fpp) from Clearwater Hatchery returned at a higher rate (0.23%) compared to smaller smolts (20 fpp) from Dworshak (0.14%).

However, rearing smolts to a larger size significantly reduces the infrastructure capacity of the facilities. We calculated that rearing Dworshak smolts larger (16 fpp) would reduce the rearing capacity at Dworshak from 2.15 M (Raceways and SRKW Burrows Ponds) to 1.83M.

Likewise, we estimated that decreasing the size of smolts reared at Clearwater from 16 fpp to 20 fpp would result in an increased number of smolts to 4.4 M from 3.8M.

Based on SAR data, rearing smolts at a smaller size would return an additional 503 adults on average and reduce Clearwater Fish Hatchery pounds produced by 17,500 lbs.

Sensitivity Analysis of Dworshak vs Clearwater returns, Release Years 2016-2020 in the North Fork Clearwater River

Release Year	DWO SAR	CRW SAR	Adults DWO 16 fpp	Adults CRW 16 fpp	Adults DWO 20 fpp	Adults CRW 20 fpp	Total 20 fpp	Total 16 fpp	Difference
2020	0.41	0.42	7,704	15,998	8,815	18,040	26,855	23,702	3,153
2019	0.24	0.05	878	1,824	5,160	10,560	15,720	2,702	13,018
2018	0.13	0.09	1,685	3,499	2,795	5,720	8,515	5,184	3,331
2017	0.06	0.11	2,079	4,316	1,290	2,640	3,930	6,395	(2,465)
2016	0.17	0.46	8,385	17,412	3,655	7,480	11,135	25,797	(14,662)
Ttl/Avg*	0.27	0.31	16,968	35,234	17,630	36,080		**AVG**	**503**

* Ttl/Avg only includes 2016, 2019, and 2020 due to high TDG issues at Dworshak NFH

Sensitivity Analysis of Size at release and total weight at Dworshak and Clearwater Hatcheries

Size	DWO Smolts	CRW Smolts	Total	CRW Lbs
20 fpp	2,150,000	4,400,000	6,500,000	220,000
16 fpp	1,830,000	3,800,000	5,630,000	237,500
			Difference	17,500

3.1.10 Steelhead Smolt Size at Release and Adult Returns

Steelhead reared at the Dworshak National Fish Hatchery average 5.8 fish per pound (fpp) and steelhead smolts reared at Clearwater Fish Hatchery average 4.5 fpp.

Work by Brian Leth, Idaho Department of Fish and Game, analyzed adult returns from steelhead releases at the Red House Hole. Larger smolts (4.5 fpp) have an estimated relative Smolt to Adult (SAR) benefit (4.5 fpp / 5.8 fpp) of 1.43. In other words, 1.43 adults return from 4.5 fpp smolts compared to 1 adult from 5.8 fpp smolts.

Red House Hole Steelhead Releases SARs to Lower Granite PBT Estimate

Hatchery	Brood Year	Smolts Released	1-Oc	2-Oc	3-Oc	Total LGD return	SAR-Rel to LGD	Relative SAR
CFH	2010	229,509	111	701	0	812	0.35%	0.93
CFH	2011	179,433	369	1,927	0	2,296	1.28%	1.27
CFH	2012	208,673	48	1,289	43	1,380	0.66%	1.01
CFH	2013	224,416	838	3,285	229	4,352	1.94%	1.14
CFH	2014	224,554	158	420	0	578	0.26%	1.38
CFH	2015	232,066	593	1,150	0	1,743	0.75%	1.56
CFH	2016	238,476	70	361	0	431	0.18%	1.34
CFH	2017	233,792	114	1,929		2,043	0.87%	2.80
DNFH	2010	438,393	266	1,393	0	1,659	0.38%	
DNFH	2011	403,894	360	3,668	45	4,073	1.01%	
DNFH	2012	399,753	350	2,221	37	2,608	0.65%	
DNFH	2013	418,067	934	6,042	162	7,138	1.71%	
DNFH	2014	484,298	43	842	17	902	0.19%	
DNFH	2015	424,642	530	1,508	0	2,038	0.48%	
DNFH	2016	402,027	118	423	0	541	0.13%	
DNFH	2017	417,333	89	1,212		1,301	0.31%	
Average						2118	0.70%	1.43

However, updated SAR data to Red House from the Nez Perce Tribe (Bill Young, personal communication), shrinks the 4.5 fpp benefit to 1.14:

Red House SAR data for Dworshak and Clearwater

Brood Year	CRW 4.5 fpp	DWO 5.8 fpp	Relative SAR
2010	0.35%	0.52%	0.68
2011	1.28%	1.23%	1.04

2012	0.66%	0.52%	1.27
2013	1.94%	1.46%	1.33
2014	0.26%	0.17%	1.51
2015	0.75%	0.65%	1.16
2016	0.18%	0.18%	1.00
2017	0.87%	0.76%	1.15
			1.14

However, this analysis is incomplete because rearing smaller smolts results in more total smolt rearing capacity of the hatchery facility while maintaining the same Density Index. Taking into account the increased smolt capacity of rearing 5.8 fpp smolts, the relative benefit of rearing larger, 4.5 fpp smolts is lost (0.99 relative SAR). Switching to 5.8 fpp would save 32,000 pounds of production at Clearwater Hatchery.

Relative benefit of rearing Clearwater River Steelhead to 4.5 fpp

	Size at Rel (FPP)	Number Produced	Density Index	Adults Produced	Relative Benefit at 4.5 FPP
CFH	4.5	843,000	0.30	6,238	**0.99**
CFH	5.8	998,400	0.30	6,315	
DNFH	5.8	2,100,000	0.27	13,282	**0.99**
DNFH	4.5	1,773,137	0.27	13,121	

Steelhead Adults DWO/CRW

Total at 4.5 FPP	19,359
Total at 5.8 FPP	19,597
Difference	**-237**

SAR	0.7%
Rel. SAR	1.17

	DWO Lbs	CRW lbs
4.5 fpp	187,333	394,030
5.8 fpp	172,138	362,069
	Difference	31,961

4 Operational/Infrastructure Changes for Program Efficiency

4.1.1 Install Shade Structure over Chinook Raceways

McCall Fish Hatchery has the most successful Smolt to Adult survival rates (0.85%) of all the LSRCP Chinook programs. The program has a lower Density Index criteria (0.21), but higher Flow Index criteria (1.96 at 39F and 5,000 ft). McCall has also had covered (shaded) rearing since inception. A SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis of installing a similar shade structure over the Chinook rearing raceways at Dworshak was completed in 2021:

Strengths

- Shading benefits smolt growth (Pickering 1987 - https://www.sciencedirect.com/science/article/abs/pii/0044848687902262)
- Shade structure will reduce predation of production fish.
- Aquatic Invasive Species/Disease contamination and spreading by predators from raceway to raceway.
- Baffle installation is effective because sunlight is eliminated resulting in less staff for cleaning efforts and reduced fish disturbance
- Less overhead disturbance to fish from birds and less staff interaction by reduction of cleaning and feeding activities which reduces fish stress, which in turn reduces susceptibility to fish pathogens and increased survival.
- Extends epoxy coating lifespan of raceways and concrete lifespan.
- Replaces existing bird net structure and removable shade cloth panels, which must be replaced periodically.
- Improves working conditions for staff by cooling the work area significantly (tested at DNFH with shade cloth).
- Improves safety by reducing staff sun exposure during summer months, and slip/fall risk during snow or ice accumulations during winter months
- Significantly reduces algae growth on pond walls and floors. Less algae means:
    - Reduced labor costs to remove it.
    - Reduced trapped fish waste and uneaten feed (which gets caught in algae filaments) which significantly improves the fishes rearing environment.
    - Reduced Workman's Compensation claims for staff injured as a result of removing algae day after day and year after year, through repetitive motion physically removing it with brushes, or by lifting/carrying heavy salt sacks for salt treatments of algae. Both approaches to algae control are physically demanding and lead to injury and WC claims.
    - Budget savings when salt use is reduced or eliminated.
- May reduce fish susceptibility to Steatitis when fed rancid feed accidentally.

Weaknesses

- Cost potential of $4.1M
- Reduces resources available for other infrastructure and program needs
- Labor for install/removal/cleaning of baffles for marking and release
- Does not address Chinook needs in Salmon basin (5% of return goals in 2021)

Opportunities

- Opportunity to increase adult Chinook returns
- Current SAR rates are below target (0.87) and have room to improve
- Potential of 4 to 8 million increase in early rearing Spring Chinook fingerlings (100 fpp) for later transfer to grow-out facilities by using Chinook raceways as "early rearing" environment
- LHO's are already installed leaving only baffle installation for "Michigan-style" raceway conversion. DNFH is already experimenting with baffles and is generally in favor of baffles for all raceways, since the reduced labor for cleaning, and better feed conversion when starting fish on feed, outweighs the increased labor to install, clean, and remove baffles annually.
- Opportunity to demonstrate that addition of LHO's, roof structure, and baffles can dramatically improve fish performance in and from standard raceways, which are common in the LSRCP program and Pacific Northwest. These investments are relatively inexpensive when compared to replacing raceways with some other rearing tank type from scratch.
- Opportunity to demonstrate to the COE the feasibility and benefits of a roof/shade structure over rearing vessels at DNFH. The algae and other issues found in the raceways are also found in the burrow's ponds used for ESA listed B steelhead rearing. Roof/shade structure benefits for spring Chinook would also benefit the steelhead program.

Threats

- Catastrophic failure potential (Carson NFH rain on snow event example)
- Increased incidence of Gyrodactylus has been anecdotally noted at covered facilities
- LSRCP Program buy-in for large project

Total cost of implementation: $4.1M

4.1.2 Increase 500,000 spring Chinook smolts if SRKW funding falters

LSRCP currently supports production of an additional 500,000 Southern Resident Killer Whale (SRKW) spring Chinook smolts at Dworshak by allowing water supplies for the raceways to be utilized for this program. If the SRKW program funding falters, LSRCP could pick up this production.

Total cost: $154,159 annually for fish food, marking, etc. and $135,150 for Burrows Pond rental (5) through COE/NPT/USFWS Cost Allocation process.

4.1.3 New Pipeline for Water Supply of Dworshak/Clearwater facilities

The Idaho Governor Brad Little's Salmon Workgroup (Idaho Governor's Workgroup 2020) identified an additional pipeline to the Clearwater Hatchery as dramatically enhancing operations to both the Clearwater and Dworshak hatcheries. A presentation to the Northwest Power and Conservation Council in 2022 identified that the new pipeline could produce an addition 1.6 million spring Chinook smolts that would return an additional 6,000 adult Chinook salmon (IDFG estimates). In addition, Dworshak hatchery could produce an additional 1.8 million spring Chinook smolts that would return an additional 10,000 adult Chinook salmon (NPT estimates).

Current LSRCP estimates (Asset Management Plan 2022) are a total project cost of $61.2M to replace the Clearwater pipeline.

Also in 2022, the Corps of Engineers released a Scoping Document Report that outlined a pipeline to solve numerous issues at Dworshak:

1. IHN disease concerns from North Fork water supply
2. River Intake structure compliance issues
3. Elimination of complex electrical infrastructure, water heating and backup generators

The scoping project selected two, 4-foot diameter steel pipes (primary and secondary) inside the Penstock 6 location at the Dam to the turbine location. Once head pressure was reduced, the remaining piping would be buried HDPE on the south side of the North Fork of the Clearwater River.

Total water supply would be 216 cfs (108 cfs primary and 108 cfs secondary) to allow fish production in all 84 Burrows Ponds, 30 raceways and provide Holding Pond and ladder/attraction water.

The total project cost was estimated at $49M and an additional $13M for turbines on the pipeline to generate electricity.

5 Options Discussed

The Corps of Engineers (COE) owns the Dworshak National Fish Hatchery. The US Fish and Wildlife Service (USFWS) through Lower Snake River Compensation Plan owns the 30 Chinook raceways by Real Estate Agreement with the COE. Shared assets at Dworshak NFH are jointly managed through annual agreements and funded through a cost allocation process between the USFWS/Nez Perce Tribe/COE.

The following concepts are not currently being pursued because they involve COE assets not within the scope of the Lower Snake River Compensation Plan:

5.1.1 Convert Dworshak to Chinook and Clearwater to Steelhead

Dworshak and Clearwater both rear steelhead and Chinook smolts. There are some benefits to this arrangement:

1) Risk of catastrophic failure is spread between two facilities

2) Staff experience rearing both steelhead and Chinook smolts

Spreading both species across these two facilities has multiple opportunity costs:

1) Risk of catastrophic IHN failure of steelhead at Dworshak NFH on river water supplies continues

2) Water heating to achieve 60 fpp on steelhead smolts before introduction to river water exceeds 11.5M kwh or the equivalent of $1.15M annually at $0.10/kwh (Dworshak does not currently pay electric costs)

3) Releasing Chinook smolts later in mid-April is challenging because rearing space is needed for the subsequent brood year.

4) Dworshak Chinook eggs/fry are chilled to temperatures of 37 F and colder to slow growth during winter months

5) Clearwater steelhead/Chinook compete with each other at both facilities as staff choose between size targets for each species and limited water supplies/temperatures

6) Dworshak and Clearwater are underutilized by 15% because of balancing between multiple species at each location

7) Dworshak and Clearwater produce 18% less Chinook adults and 14% less Steelhead adults than could be achieved by focusing on one species.

Numerous political and social constraints factor in the decision on what Dworshak and Clearwater facilities annually produce. This report will focus mainly on the biological criteria rather than those obstacles to implementation.

Converting all steelhead production to Clearwater Fish Hatchery on reservoir water supplies to avoid IHN risks. Max production would be achieved in March annually at 3,500,000 steelhead smolts at 5.8 fpp and a corresponding DI of 0.28 (assuming use of A-E banks) and a FI of 2.31 at 41 F. Piper (1982) specifies a maximum FI of 2.52 at 41 F and 1000 feet of elevation to maintain dissolved oxygen concentrations above 5 ppm. If higher dissolved oxygen levels are desired, Low-Head Oxygenation systems can be installed in E-bank raceways (see Clearwater report). Early rearing of approximately 843,000 steelhead would still occur at Dworshak NFH

on the 6400 gpm of reservoir water supplied to their nursery building. This would accommodate early steelhead takes without robbing additional water from final rearing at Clearwater Fish Hatchery. Limited water heating would be needed to match size of Clearwater steelhead at 100 fpp in July. 843,000 steelhead would be targeted for rearing in the existing Clearwater A&B 1-11 raceways (currently Chinook) to keep fingerlings transferred from Dworshak isolated in one area of the facility. Clearwater would likely need additional labor resources for feeding to meet 5.8 fpp size targets.

Dworshak would maintain Coho production in 6 Burrows Ponds and convert remaining Burrows Ponds (78) to spring Chinook production at 100,000 smolts/Burrows Pond. Maximum production would occur in April at 7,800,000 spring Chinook at 20 fpp and a DI of 0.32 and FI of 1.36. Total flow required is 54,600 gpm (700 gpm per Burrows Pond) and 10,200 gpm for early rearing of Chinook/Coho in raceways. Limited chilling would be required to match Chinook egg takes and releases could occur in mid-April to May to shorten travel times to Lower Granite Dam.

Current smolt production at Dworshak and Clearwater Fish Hatcheries

Facility	Species	Numbers	FPP	SAR	Adults	Total
Dworshak	STT	2,100,000	5.8	0.69%	14,490	21,150
Clearwater	STT	843,000	4.5	0.79%	6,660	
Dworshak	SCS	2,150,000	20	0.20%	4,300	13,270
Clearwater	SCS	3,900,000	16	0.23%	8,970	

Converting Clearwater Hatchery to all steelhead would result in an increase of adult steelhead of 3,000 (0.69% SAR) or 14% more steelhead adults from baseline. Converting Dworshak to all spring Chinook production would result in an increase of adult Chinook of 2,330 (0.20% SAR) or 18% more Chinook adults from baseline.

Smolt production by switching Dworshak and Clearwater to single-species rearing

Facility	Species	Numbers	FPP	SAR	Adults	Net Adult Benefit	Adult Increase
Dworshak	SCS	7,800,000	20	0.20%	15,600	2,330	18%
Clearwater	STT	3,500,000	5.8	0.69%	24,150	3,000	14%

Total cost of implementation: $450,000 to skim coat/epoxy 30 remaining Burrows Ponds, $288,000 for additional fish food and $97,000 for additional marking/tagging/etc. for 970,000 additional spring Chinook.

5.1.2 Convert Dworshak to Steelhead and Clearwater to Chinook

Another exercise can be done by switching Clearwater Hatchery to Chinook production and Dworshak Hatchery to steelhead production. In this example, we also switched coho (600,000 smolts) to Clearwater Hatchery assuming that Dworshak would solely manage for steelhead.

Because of early-rearing reservoir water bottlenecks (limited to 9,000 to 12,000 gpm to 60 fpp from piping restriction), Dworshak could rear 3,024,000 steelhead. The size of steelhead is also limited to 5.8 fpp for later takes because winter water temperatures are limited by the ambient temperature of the North Fork Clearwater River (41-45 F).

Clearwater was limited to 7,800,000 Chinook at 20 fpp with a Density Index criteria of 0.30 for final rearing. Raceways A1-11 and B1-2 were used for early earing to 100 fpp of Chinook and Coho leaving them unusable for final rearing. Density indices for those raceways were capped at 0.40 DI (for small fish).

The net expected result from this switch is an increase of 2,330 adult Chinook and a net decrease of 284 adult steelhead.

Smolt production by switching Dworshak and Clearwater to single-species rearing

Facility	Species	Numbers	FPP	SAR	Adults	Net Adult Benefit	Adult Increase
Dworshak	STT	3,024,000	5.8	0.69%	20,866	-284	-1%
Clearwater	SCS	7,800,000	20	0.20%	15,600	2,330	18%

5.1.3 Convert Burrows Ponds to Mixed Cell Rearing

A trial conversion of Burrows Ponds to Mixed Cells was completed in 2010 at Dworshak National Fish Hatchery. Mixed Cells need less water (600 gpm compared to 700 gpm) than Burrows Ponds and are "self cleaning" if algae is controlled.

Conversion of all Burrows Ponds to Mixed Cells at Dworshak would free an additional 7,000 gpm of water (70 current BP's from 700 gpm to 600 gpm) that could then water-up almost 12 additional mixed cells (82 of 84 available ponds).

If that additional rearing space was used for Chinook at 20 fpp it could potentially rear an additional 1.2M Chinook smolts annually.

Total Cost of Implementation: 82 Burrows Ponds converted to Mixed Cells at $50K each is $4.1M. Ideally, existing bird netting would be replaced with shade structure to eliminate algae growth – Total cost of $8M for shade structure. Annual rearing costs of $180,000 for additional 1.2M Chinook.

5.1.4 Cross Connect and Increased Pumping Capacity

Dworshak staff have identified an opportunity to connect effluent from the Chinook raceways to the trapping pond and adult ladder. This effort could reduce the amount of water needed for the holding ponds from 7000 gpm to 3000 gpm.

Alternatively, current pumps could be increased from 200 hp to 250 hp. This project could increase total water capacity to 90,000 gpm (15,000 gpm per pump).

Water required for all 84 Burrows Ponds (700 gpm each) is 58,800 gpm, Raceways are 21,000 gpm (700 gpm each), and Holding Ponds/Ladder is 9,000 gpm (1,000 gpm each).

Total Cost: TBD

5.1.5 Increase incubation space

To accommodate additional spring Chinook while maintaining Coho production, incubation tray space will need to be increased as well as "double-traying" females during green egg production. Eyed egg production will remain at 5,000 eggs per tray.

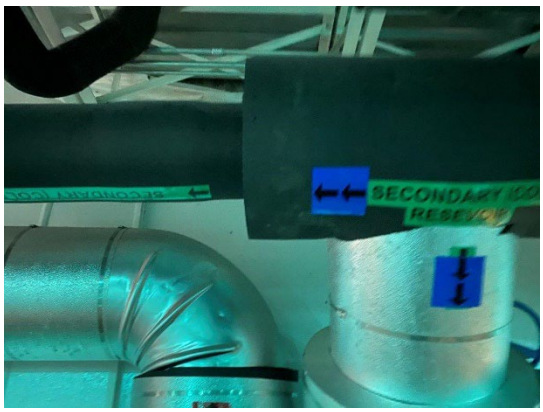
Incubation expansion opportunities include adding a "mixing" tray to the top of the stack. This will add an additional 116 trays to total capacity. Old trays are on inventory at Dworshak for this project:

In addition, Dworshak could add 20 more full stacks (160 trays) at the end of E/F Bank:

Add Additional Stacks

Total incubation with both expansions would be 136 stacks with 2,176 useable trays. Total simultaneous capacity is 4,352 females (double-trayed) green eggs and 10.9M eyed eggs (5,000 eggs/tray).

Additional water supplies are also needed to expand from 450 gpm maximum to 680 gpm (5 gpm/stack). Additional water could be secured by increasing the current 6" PVC pipe in the Nursery to a 10" PVC pipe prior to splitting for the "Secondary Incubation" and "Chiller Supply".



Total cost for incubation expansion is estimated at $20,000 ($2,000 per stack) and $20,000 for 10" PVC pipe in Nursery (in-house maintenance project).

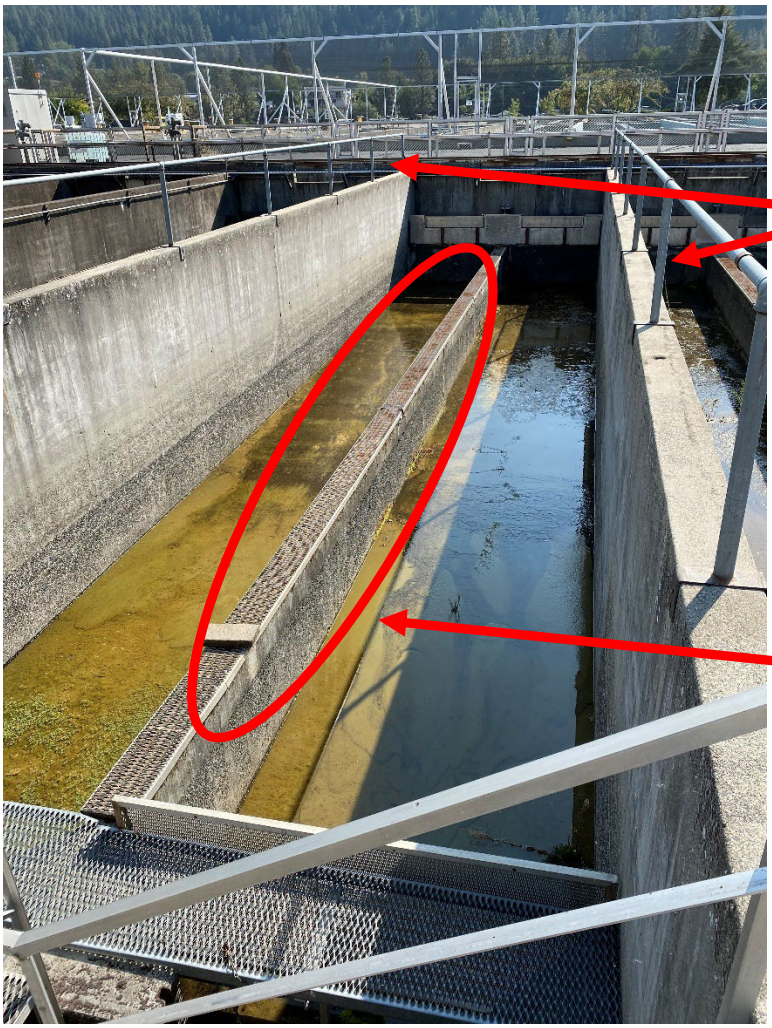
5.1.6 Holding Ponds

Current holding pond water need is 7,000 gpm to run holding ponds and the fish ladder/trapping pond. By using all of System 3 Burrows Ponds, water can be re-used from System 3 to the holding ponds. This operation was utilized in 2012 when 2.5 million spring Chinook were transferred to Dworshak from Clearwater Fish Hatchery.

In addition, an opportunity exists for rearing/acclimation in the 5 empty holding ponds. These ponds were converted to "Coho" raceways in the late 1990's. They were abandoned because cleaning effluent could not be diverted to a settling basin. The cleaning problem could be solved by installing 5 vacuum systems (to avoid priming issues) for periodic cleaning of the ponds. Effluent could be diverted to the System 1 clarifier (temporarily) during cleaning operations.

Rearing would remain at "deep" levels (8 feet?) and 9,000 cubic feet per rearing unit. Modification to existing screen channels would need to extend to accommodate a second set of screens on top of existing screens. Each holding pond could accommodate 100,000 spring Chinook smolts to 16 fpp at a max DI of 0.12 and FI of 1.11 at 41 F.

Bolt in additional channel for extending screens to 10 foot total depth (2 foot jump height)



Total project cost is estimated at $50,000 per holding pond for modifications using in-house labor - $250,000 total and $75,000 for annual feed/marking costs.

5.1.7 Net Pen Culture in Dworshak Reservoir

Net Pens in Quinalt Lake on the Quinalt Indian Reservation

Dworshak Reservoir offers a unique opportunity to explore net pen culture for salmonids. To expand rearing opportunities for spring Chinook salmon, 30' x 30' x 15' net pens could be purchased an anchored near Dent Acres approximately 17 miles up-reservoir from the Dam and intake for Clearwater Fish Hatchery.

A NPDES permit is already in-place for Dworshak reservoir for nutrient enhancement for the purpose of improving Kokanee size structures. That permit could provide a starting point to examine the potential of net pen aquaculture in the reservoir.

Each net pen could accommodate approximately 64,000 spring Chinook smolts to 16 fpp (4,000 pounds total). An experimental sized system would link 30 net-pens with 1.9 million smolts. This system could be expanded for program needs as needed.

Total cost is estimated at $53,000 per net pen or $1.59M total installation cost based on estimates from Quinalt Lake net pens. Annual operation costs are estimated at $285,000 annually.

6 References

Annual Operation Plan (AOP). 2022. Annual Operation Plan for Salmon and Steelhead Production Programs in Clearwater River Basins. Prepared by Idaho Department of Fish and Game, Nez Perc Tribe, and U.S Fish and Wildlife Service. Accessed September 26, 2022. https://www.fws.gov/media/annual-operations-plan-clearwater

BIOP. 2017. Biological Opinion. National Marine Fisheries Service Authorization for the Continued Operation of the Clearwater Steelhead, Spring/Summer Chinook Salmon, and Coho Salmon Hatchery Programs—Idaho (Clearwater River Basin)—Biological Opinion. Accessed September 26, 2022. https://www.fws.gov/sites/default/files/documents/FWS%20Biological%20Opinion%20Clearwater%20Basin%20Hatchery%20Programs%2012-15-2017.pdf

Hatchery Genetic Management Plan (HGMP). 2010. Dworshak National Fish Hatchery Spring Chinook Salmon. U.S. Fish and Wildlife Service. Clearwater Subbasin, Idaho. December 20, 2010. Accessed September 26, 2022 https://www.fws.gov/sites/default/files/documents/Dworshak%20HGMP%202010%20Final.pdf

Idaho Governor's Workgroup. 2020. Policy Recommendations from Idaho Governor Brad Little's Salmon Workgroup. December 2020. Accessed September 26, 2022: https://species.idaho.gov/wp-content/uploads/2020/12/Idaho-Salmon-Workgroup-Report-December-2020.pdf

Peltz, Larry. 2014. History of Steelhead Production at the Dworshak National Fish Hatchery. A review based on Annual Reports. U.S. Fish and Wildlife Service, Dworshak National Fish Hatchery.

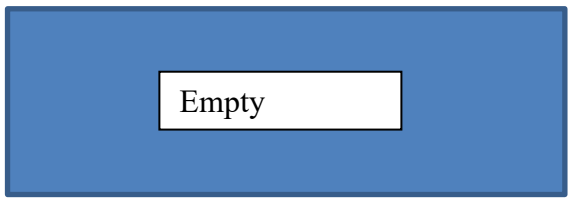
Piper, Robert G. 1982. Fish Hatchery Management. United States Department of the Interior. Fish and Wildlife Service. Washington, D.C.

U.S. Fish and Wildlife Service (USFWS). 2009. *Dworshak, Kooskia, and Hagerman National Fish Hatcheries. Final Report, June 2009*. Hatchery Review Team, Pacific Region. U.S. Fish and Wildlife Service, Portland, Oregon.

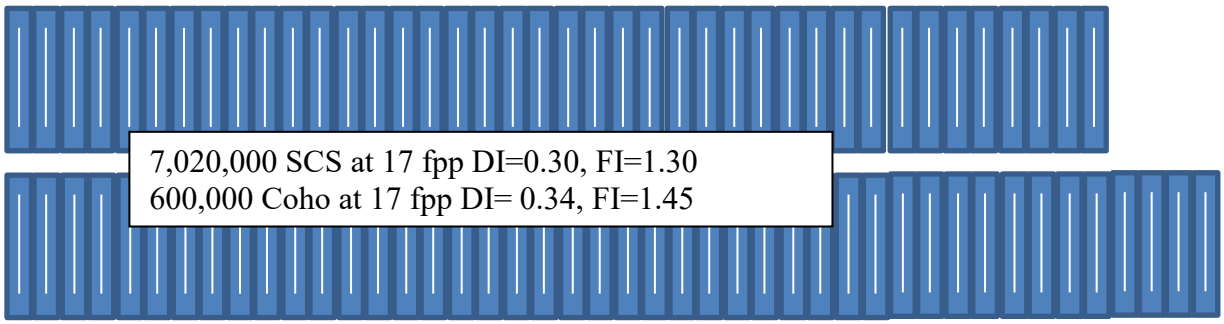
7 Appendix A. Monthly Production Strategy–Dworshak National Fish Hatchery

7.1.1 January

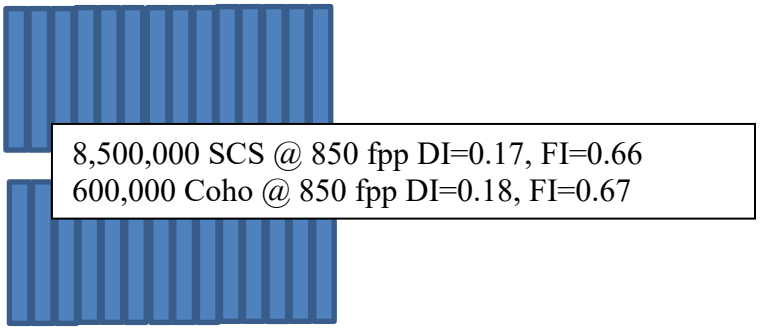
Nursery Rearing – 128 tanks (20 x 3 x 2')



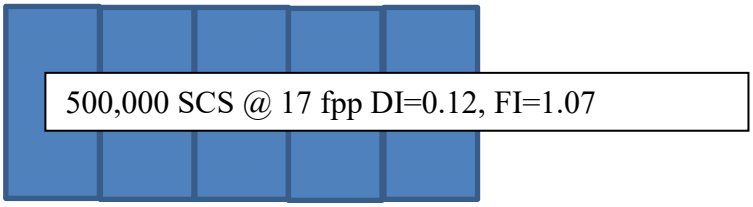
Burrows Ponds Rearing – 84 Ponds (3000 cuft and 700 gpm each)



Raceways – 30 Ponds (1664 cuft and 700 gpm each)

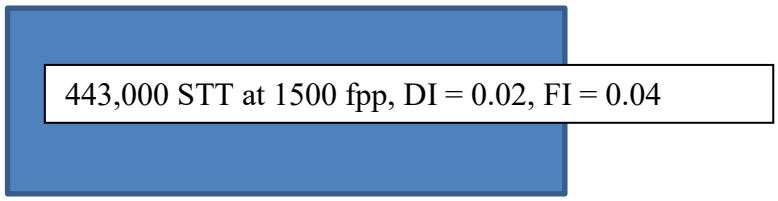


Holding Ponds – 5 Ponds (9000 cuft and 1000 gpm each)

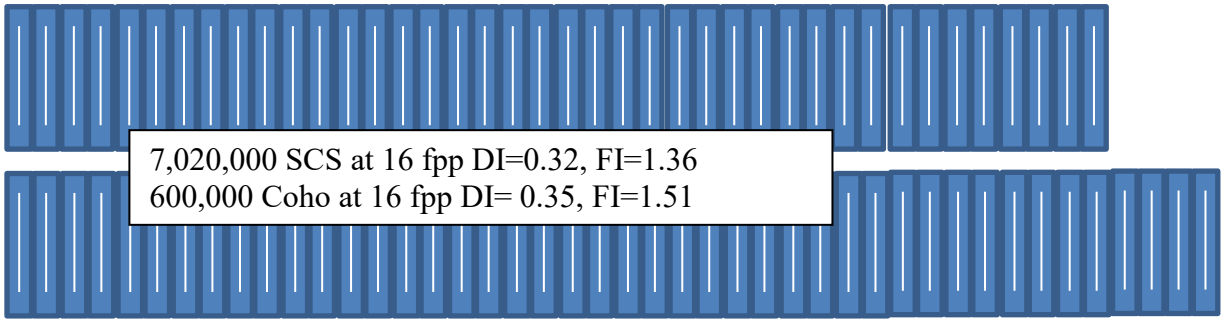


7.1.2 February

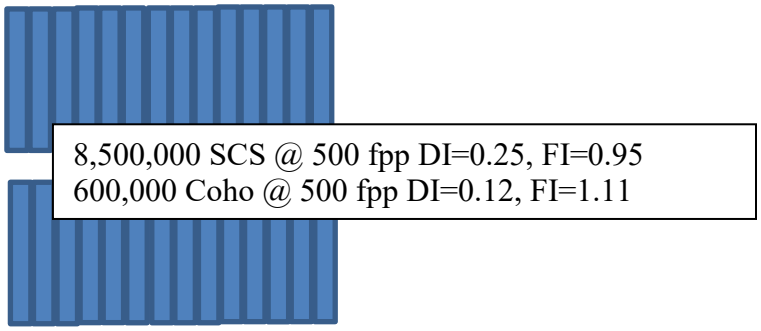
Nursery Rearing – 128 tanks (20 x 3 x 2')



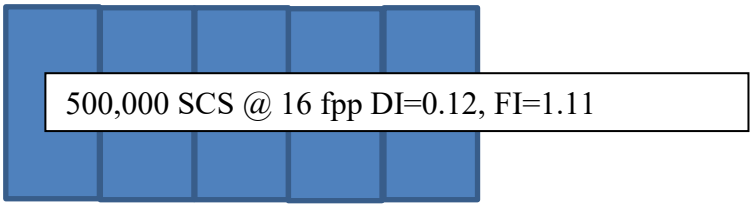
Burrows Ponds Rearing – 84 Ponds (3000 cuft and 700 gpm each)



Raceways – 30 Ponds (1664 cuft and 700 gpm each)

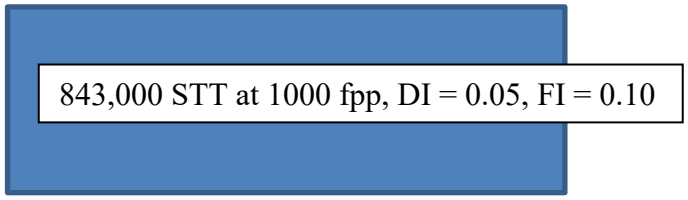


Holding Ponds – 5 Ponds (9000 cuft and 1000 gpm each)

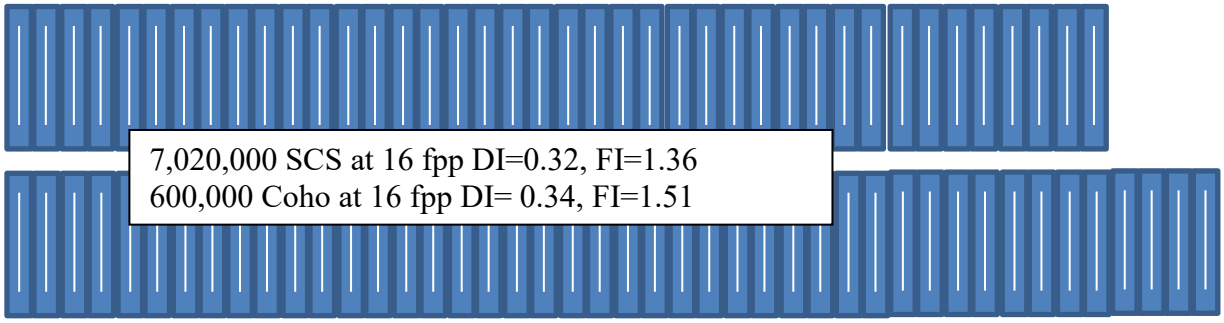


7.1.3 March

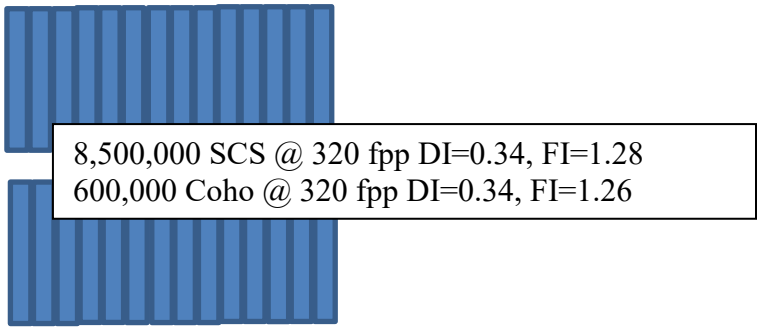
Nursery Rearing – 128 tanks (20 x 3 x 2’)



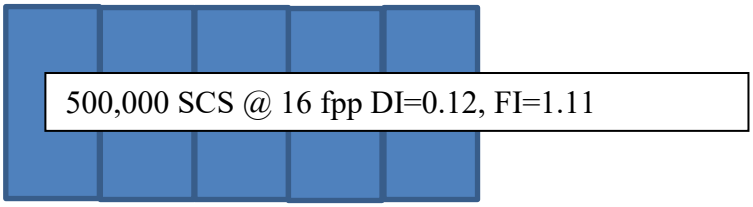
Burrows Ponds Rearing – 84 Ponds (3000 cuft and 700 gpm each)



Raceways – 30 Ponds (1664 cuft and 700 gpm each)

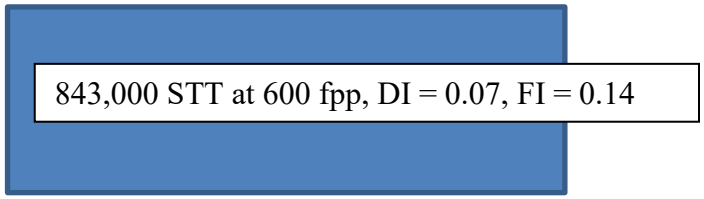


Holding Ponds – 5 Ponds (9000 cuft and 1000 gpm each)

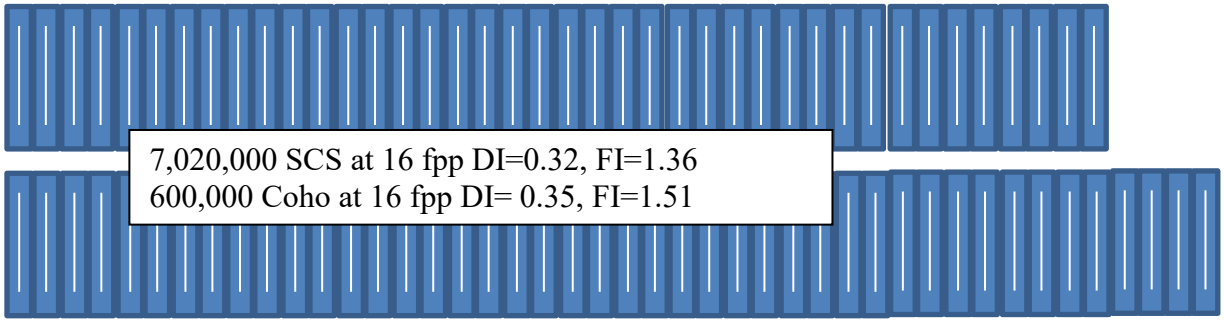


7.1.4 April

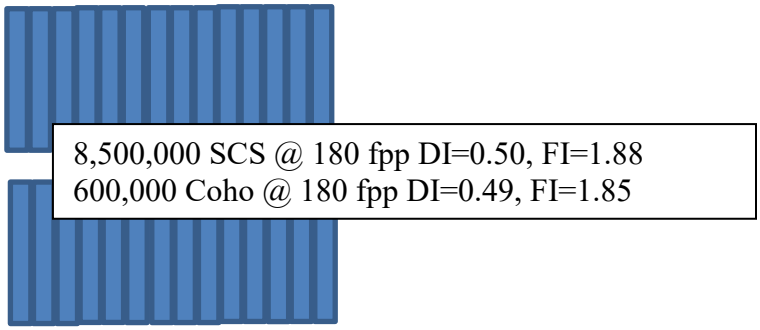
Nursery Rearing – 128 tanks (20 x 3 x 2')



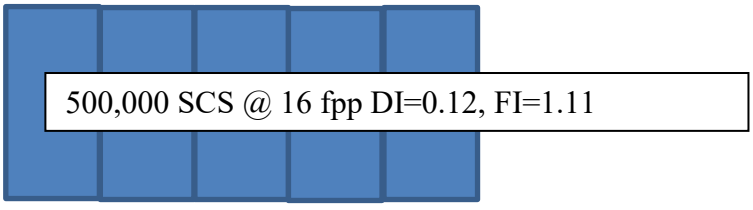
Burrows Ponds Rearing – 84 Ponds (3000 cuft and 700 gpm each)



Raceways – 30 Ponds (1664 cuft and 700 gpm each)

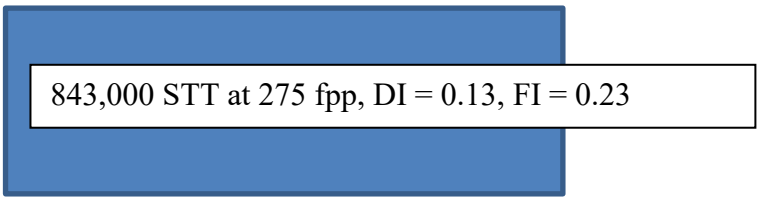


Holding Ponds – 5 Ponds (9000 cuft and 1000 gpm each)

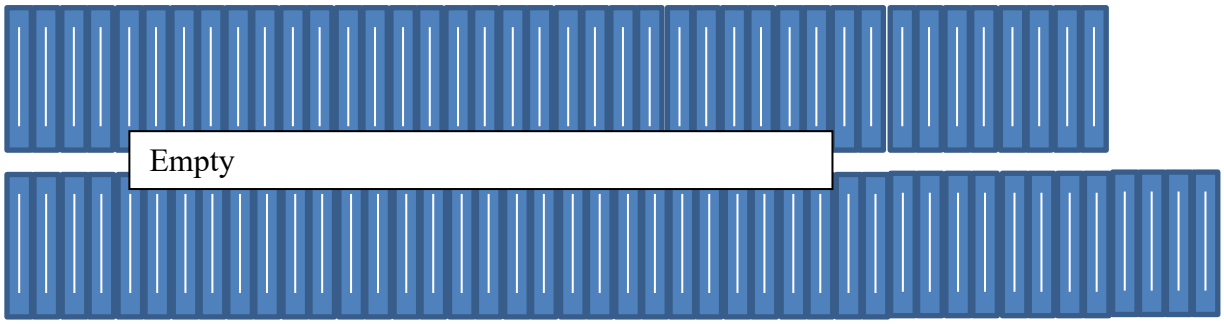


7.1.5 May

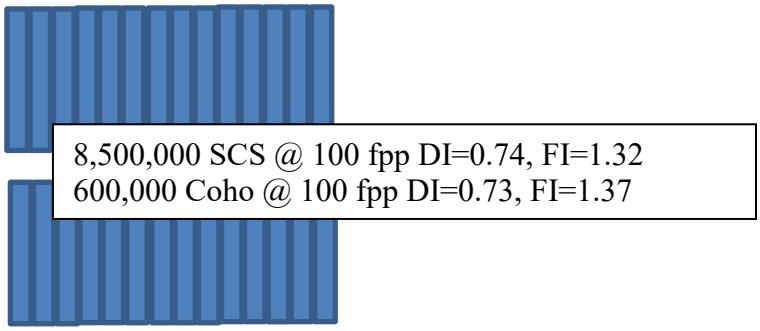
Nursery Rearing – 128 tanks (20 x 3 x 2')



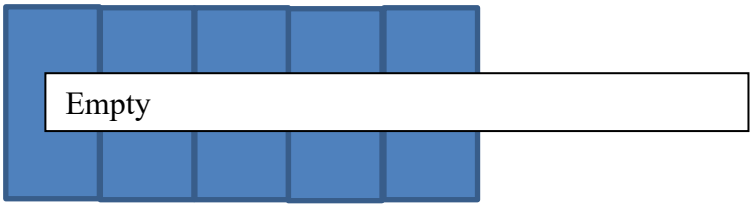
Burrows Ponds Rearing – 84 Ponds (3000 cuft and 700 gpm each)



Raceways – 30 Ponds (1664 cuft and 700 gpm each)

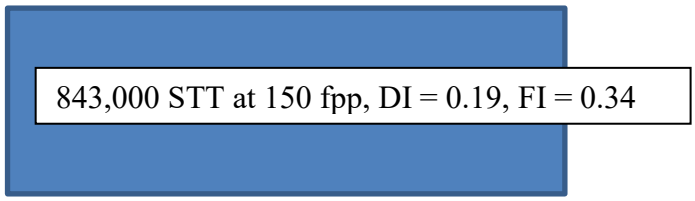


Holding Ponds – 5 Ponds (9000 cuft and 1000 gpm each)

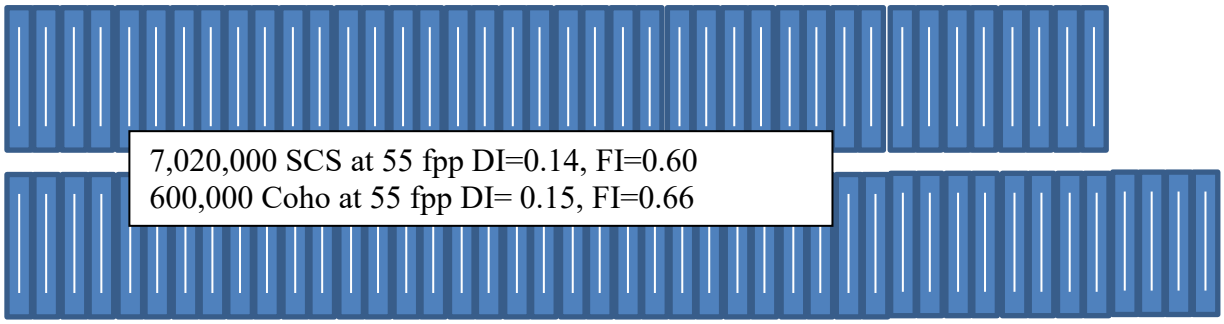


7.1.6 June

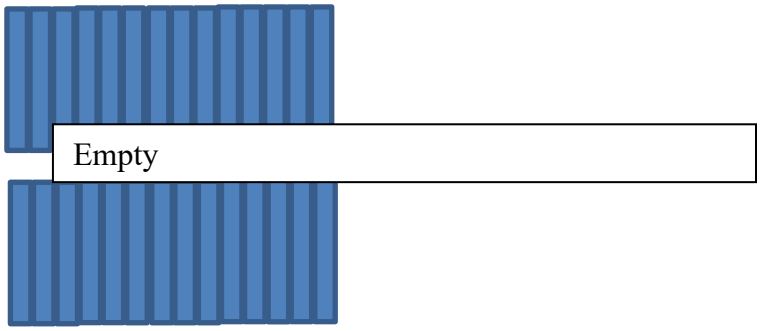
Nursery Rearing – 128 tanks (20 x 3 x 2')



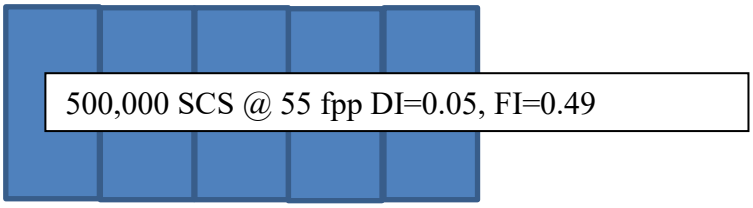
Burrows Ponds Rearing – 84 Ponds (3000 cuft and 700 gpm each)



Raceways – 30 Ponds (1664 cuft and 700 gpm each)

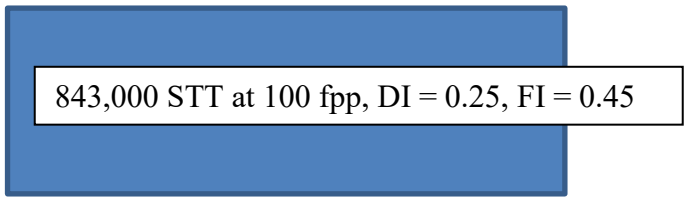


Holding Ponds – 5 Ponds (9000 cuft and 1000 gpm each)

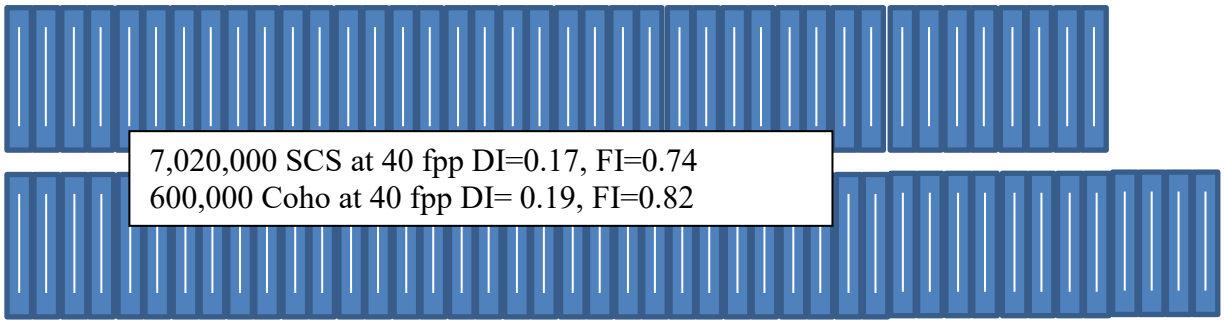


7.1.7 July

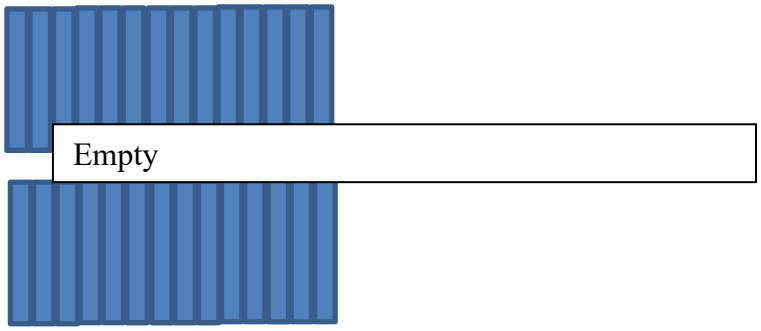
Nursery Rearing – 128 tanks (20 x 3 x 2')



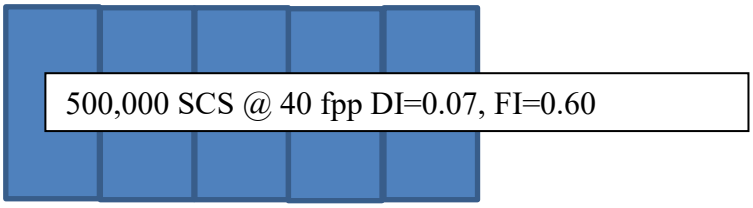
Burrows Ponds Rearing – 84 Ponds (3000 cuft and 700 gpm each)



Raceways – 30 Ponds (1664 cuft and 700 gpm each)

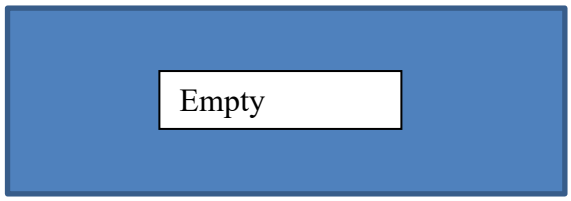


Holding Ponds – 5 Ponds (9000 cuft and 1000 gpm each)

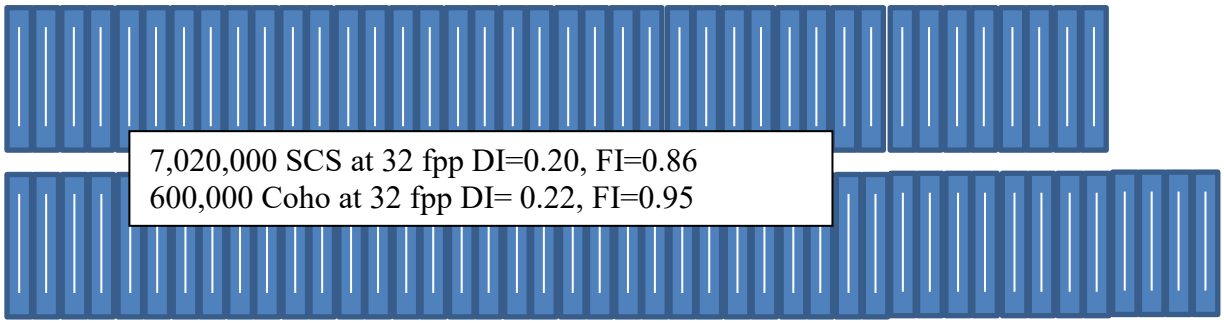


7.1.8 August

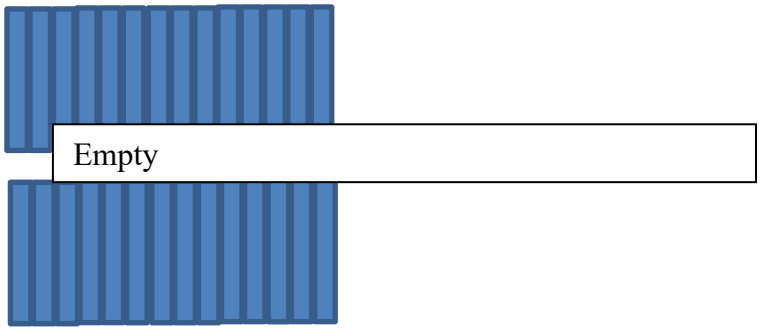
Nursery Rearing – 128 tanks (20 x 3 x 2')



Burrows Ponds Rearing – 84 Ponds (3000 cuft and 700 gpm each)



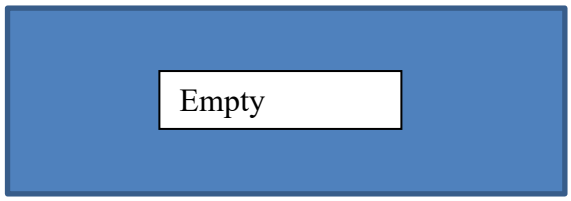
Raceways – 30 Ponds (1664 cuft and 700 gpm each)



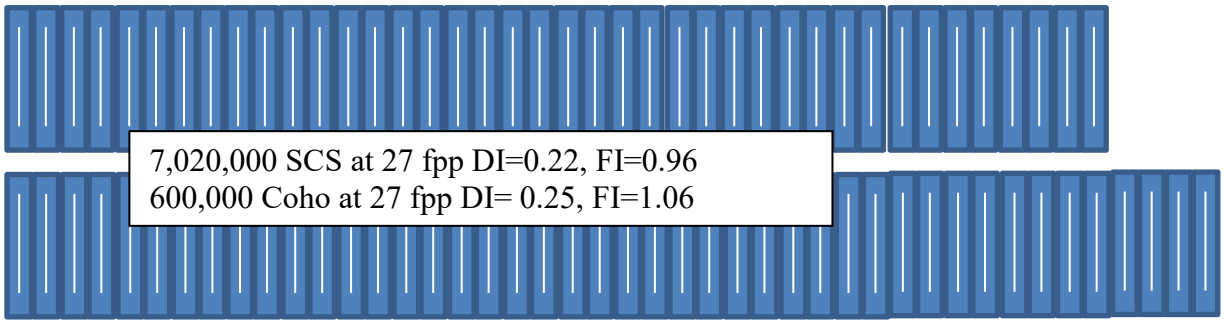
Holding Ponds – 5 Ponds (9000 cuft and 1000 gpm each)

7.1.9 September

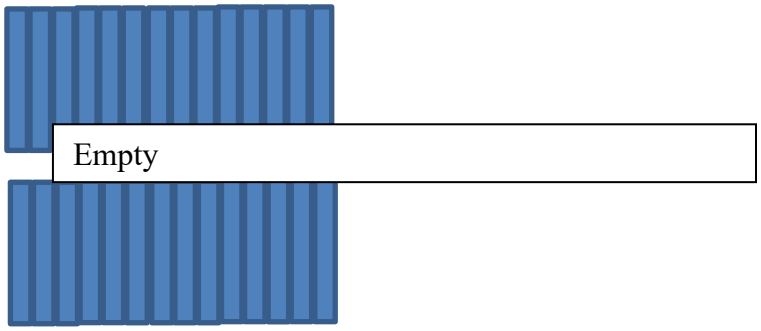
Nursery Rearing – 128 tanks (20 x 3 x 2')



Burrows Ponds Rearing – 84 Ponds (3000 cuft and 700 gpm each)



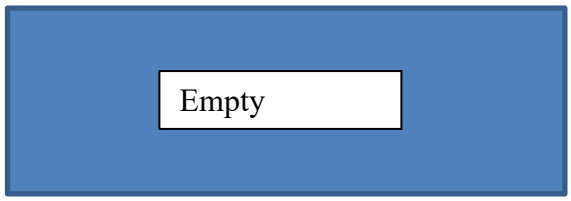
Raceways – 30 Ponds (1664 cuft and 700 gpm each)



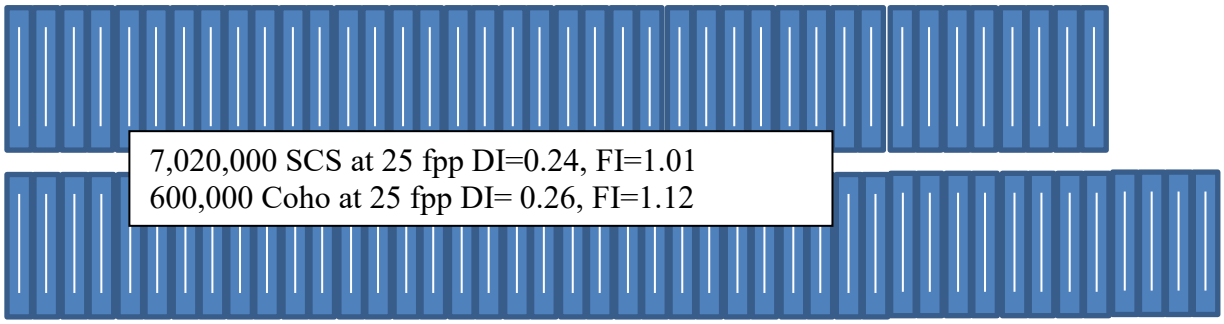
Holding Ponds – 5 Ponds (9000 cuft and 1000 gpm each)

7.1.10 October

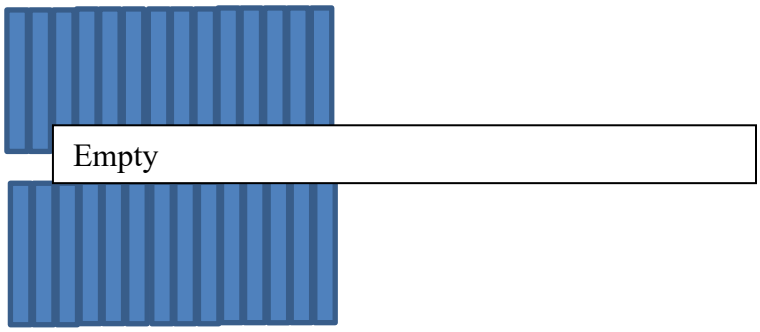
Nursery Rearing – 128 tanks (20 x 3 x 2')



Burrows Ponds Rearing – 84 Ponds (3000 cuft and 700 gpm each)



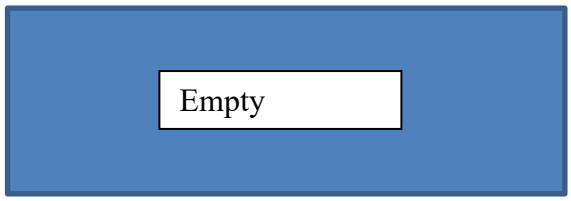
Raceways – 30 Ponds (1664 cuft and 700 gpm each)



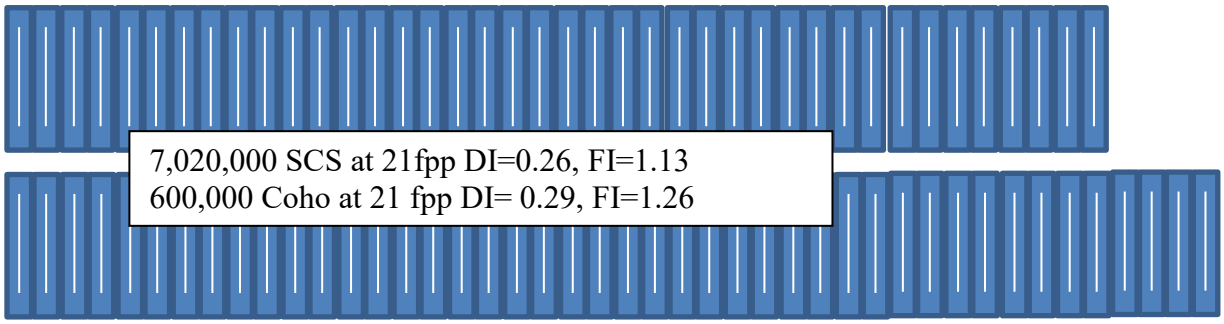
Holding Ponds – 5 Ponds (9000 cuft and 1000 gpm each)

7.1.11 November

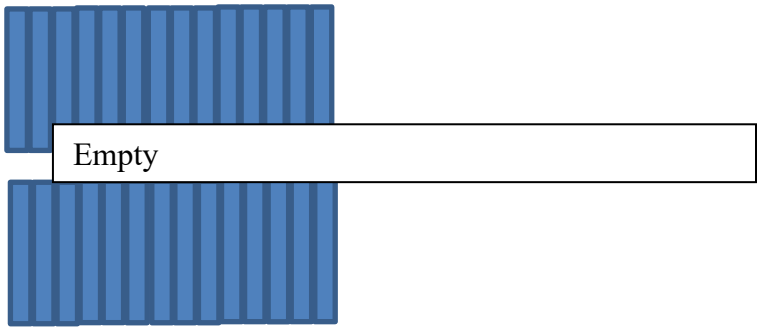
Nursery Rearing – 128 tanks (20 x 3 x 2')



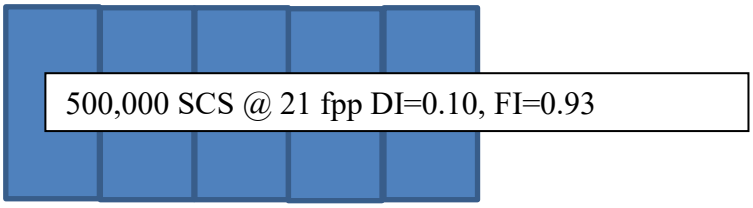
Burrows Ponds Rearing – 84 Ponds (3000 cuft and 700 gpm each)



Raceways – 30 Ponds (1664 cuft and 700 gpm each)

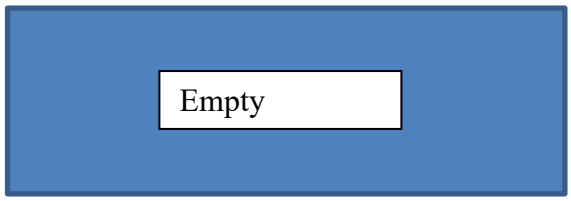


Holding Ponds – 5 Ponds (9000 cuft and 1000 gpm each)

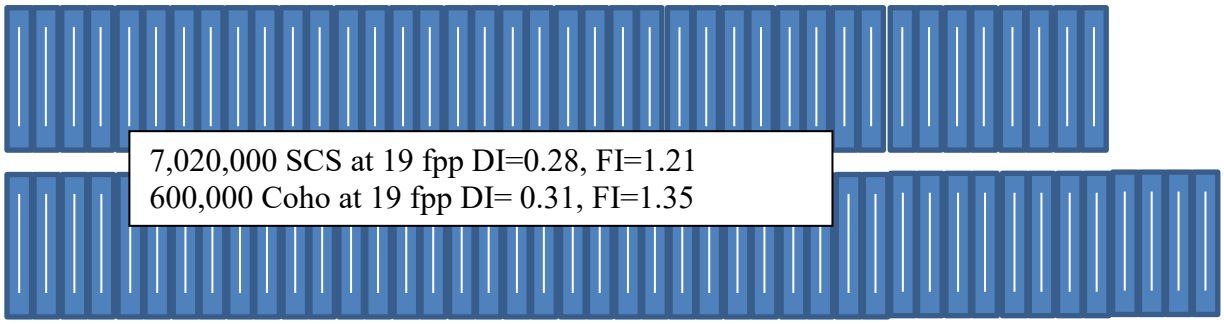


7.1.12 December

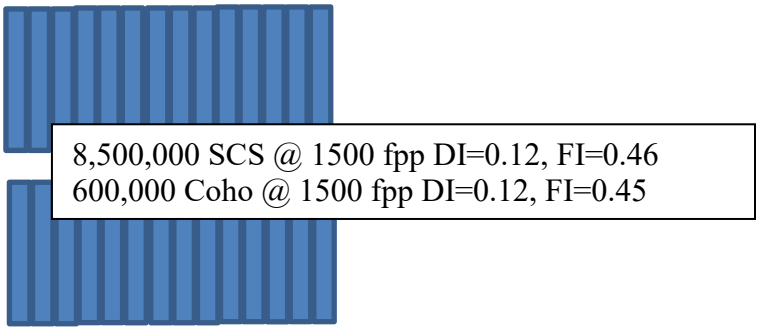
Nursery Rearing – 128 tanks (20 x 3 x 2')



Burrows Ponds Rearing – 84 Ponds (3000 cuft and 700 gpm each)



Raceways – 30 Ponds (1664 cuft and 700 gpm each)



Holding Ponds – 5 Ponds (9000 cuft and 1000 gpm each)