Climate Induced Hatchery Upgrades

Crystal Lake Hatchery

Alternatives Analysis Submittal

Final Report
Revision No. 3

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Revision Log

Revision No.	Date	Revision Description
0	2/16/2024	65% Draft Submittal
1	8/14/2024	Draft Final Submittal
2	10/31/2024	Final Submittal
3	1/31/2025	Final Submittal to CDFW, ADA Accessible Document

Appendices

The appendices that accompany this document are not ADA compliant. For access to the following appendices, contact Fisheries@wildlife.ca.gov. If assistance is needed for an ADA compliant version of the appendices, please include that in the email.

- Appendix A. Site Visit Report
- Appendix B. Bioprogramming
- Appendix C. Concept Alternative Drawings
- Appendix D. Design Criteria TM
- Appendix E. Alternatives Development TM
- Appendix F. Cost Estimates
- Appendix G. Meeting Minutes
- Appendix H. LEED and NZE Evaluations

Executive Summary

McMillen, Inc. (McMillen) was retained by the California Department of Fish and Wildlife (CDFW) to provide an assessment of 21 CDFW fish hatcheries throughout the State of California in the context of their vulnerability to the effects of climate change. Climate modeling was performed by Northwest Hydraulic Consultants (NHC).

Crystal Lake Hatchery has an aging infrastructure and deficiencies that need to be addressed in the near future in order to meet fish production goals. Insufficient early and midgrade rearing space, low oxygen levels throughout the 500 feet of raceways, inoperable flow meter on the Rock Creek water supply, undersized and old pipe at the Rock Creek water supply, lack of a permanent spawning building, lack of water flow control for the raceways, and general aging infrastructure of the concrete, valves, pipes, and so on throughout the hatchery are all items that have been noted to hinder current production. The effects of which will magnify with climate change.

The preferred alternative for hatchery upgrades includes replacing the 24-inch supply pipe from the Rock Springs source to the hatchery, replacing existing concrete raceways with circular culture tanks supplied with partial recirculating aquaculture systems (PRASs), adding early rearing circular culture tanks with PRASs, and moving the broodstock into new concrete raceways with an attached spawning building. All rearing spaces would be covered with a solid roof and include predation netting and fencing on the sides. Additionally, the intake structures would be modified to allow for debris management and potential spring source water collection.

The Class 5 Opinion of Probable Construction Cost (OPCC) for constructing the preferred alternative upgrades can be found in the table below (Table 6-2 provides the full Class 5 OPCC). The table also includes the estimated cost of photovoltaic systems to offset the energy consumption of the new equipment and to maintain zero net energy. These upgrades would not significantly affect fire or flood risks at the facility, and all work would occur within already developed areas. Operationally, CDFW would need to update feeding, harvesting, and water quality monitoring protocols to accommodate the transition to partial recirculating aquaculture systems with circular tanks. These proposed upgrades would provide a solid foundation for CDFW to sustain fish production at the hatchery, even as climate change increasingly disrupts current and future operations.

Total Cost Estimate	$77,540,000
Photovoltaic for ZNE	$13,225,000

1.0 Introduction

1.1 Project Authorization

McMillen, Inc. (McMillen) was retained by the California Department of Fish and Wildlife (CDFW) to provide a climate change evaluation for 21 hatcheries operated by CDFW throughout the State of California. The contract for this Climate Induced Hatchery Upgrade Project (Project) was executed on March 21, 2023.

1.2 Project Background

California relies on CDFW hatcheries to provide recreational fishing opportunities for the public and for the conservation of endangered or threatened species. However, climate change threatens the business-as-usual production of fish with the existing CDFW hatchery infrastructure. Climate change impacts have already affected many CDFW hatcheries, resulting in altered or inconsistent operation schedules, lowered production, and emergency fish evacuations. These climate impacts include increasing water and air temperatures, changes to groundwater availability, low flows and water shortages, increased flood and fire risks, and other second-hand impacts associated with each of these categories (i.e., emerging pathogens and non-infectious diseases, low adult salmon returns, decreased worker safety, etc.).

A total of 21 hatcheries were visited by McMillen to evaluate the existing infrastructure and fish production operations. During these visits, McMillen assessed the existing hatchery infrastructure deficiencies and replacement needs. The assessment was used to aid in determining the potential upgrades for each hatchery that would maintain the existing program production goals for the various species reared at each facility while providing conceptual alternatives for climate resilience. Climate change has had an impact worldwide and will continue to affect CDFW's statewide fish production operations. Developing technologies and methods to meet fishery conservation and sport fisheries is critical to CDFW's goal of maintaining hatchery productivity while conserving precious cold-water supplies for native species.

We have based our detailed work plan to achieve the following project objectives stated in the Request for Proposals (RFP). As presented in Sections 2 and 3 of our proposal, we have intentionally comprised our team of experts in all required disciplines with experience in fish husbandry and hatchery engineering and design to successfully meet all CDFW's project goals.

- **Objective 1:** Review the state of each facility via data collection, review of documents, site visits, and discussions with hatchery personnel. Identify climate change impacts that are likely to negatively impact operations at each hatchery over the next 40 years.
- **Objective 2:** Develop cost effective and programmatically viable alternatives that will maintain current fish propagation goals given climatic impacts in the future.
- **Objective 3:** Assess the risks of each alternative to natural biological systems, environmental conditions, husbandry techniques for fish health and fish safety, and potential impacts to water quality.
- **Objective 4:** Determine the short- and long-term economic costs for the modifications to each hatchery in current year dollars. Account for construction, permitting, design, operational, and maintenance costs within the overall economic analysis. Prioritize the list of alternatives and associated hatcheries based on limited annual hatchery budgets.
- **Objective 5, Phase 2 Work:** Provide complete designs with issued for construction drawings and specifications for projects at as many hatcheries as are feasible. The focus shall be on those hatcheries that are deemed most susceptible to negative climate change impacts identified from the evaluation in the four previous objectives.

1.3 Project Purpose

The purpose of the Project is to determine the CDFW hatcheries and the existing infrastructure conditions that are most susceptible to reduced fish production attributable to climate change and provide a prioritization of the hatcheries for improvements. With input from CDFW, designs for climate change resiliency upgrades will be advanced for as many facilities as is feasible.

1.4 Project Location Description

Crystal Lake Hatchery is located approximately 64 miles northeast of Redding, CA (Figure 1-1).

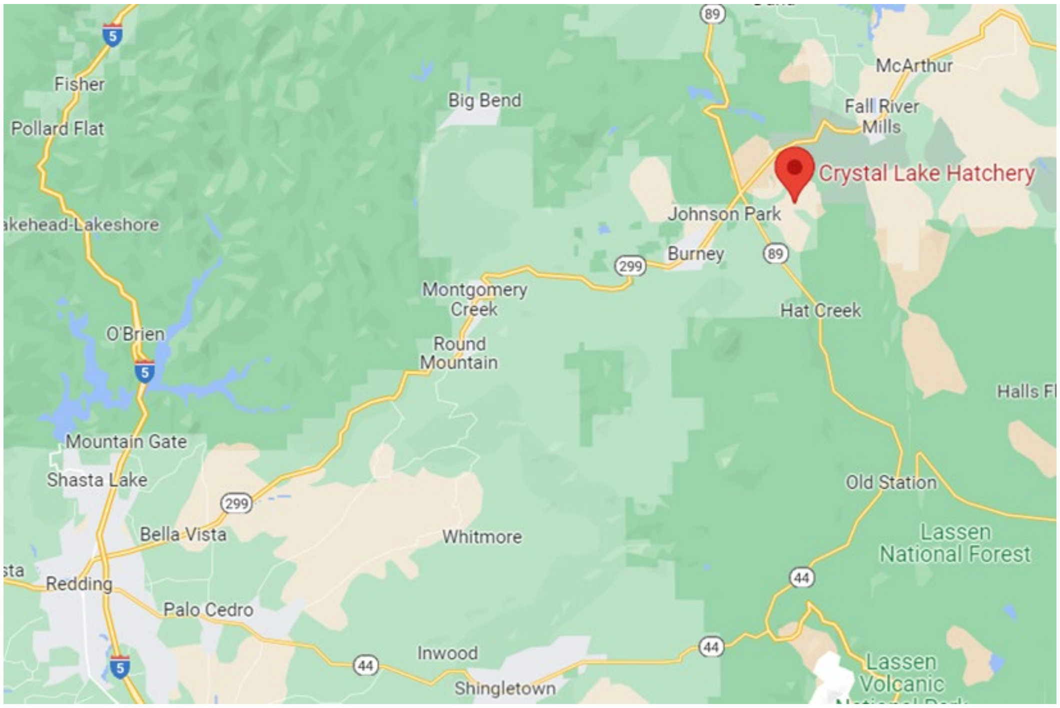

Figure 1-1. Hatchery Vicinity Map.

The Crystal Lake Hatchery raises Rainbow Trout (*Oncorhynchus mykiss*) and Brown Trout (*Salmo trutta*) with a production goal of approximately 400,000 pounds. The hatchery utilizes a spring-fed gravity flow-through system for the early rearing tanks (i.e., troughs and deep tanks) and for the raceways. The exception to the use of this system is for a mid-pond aeration station located below the upper raceway that increases oxygen levels for a portion of the water before flowing by gravity to the lower raceways. The general hatchery facilities are shown in Figure 1-2. See the Site Visit Report (Appendix A) for more details and photos regarding the existing hatchery facilities.

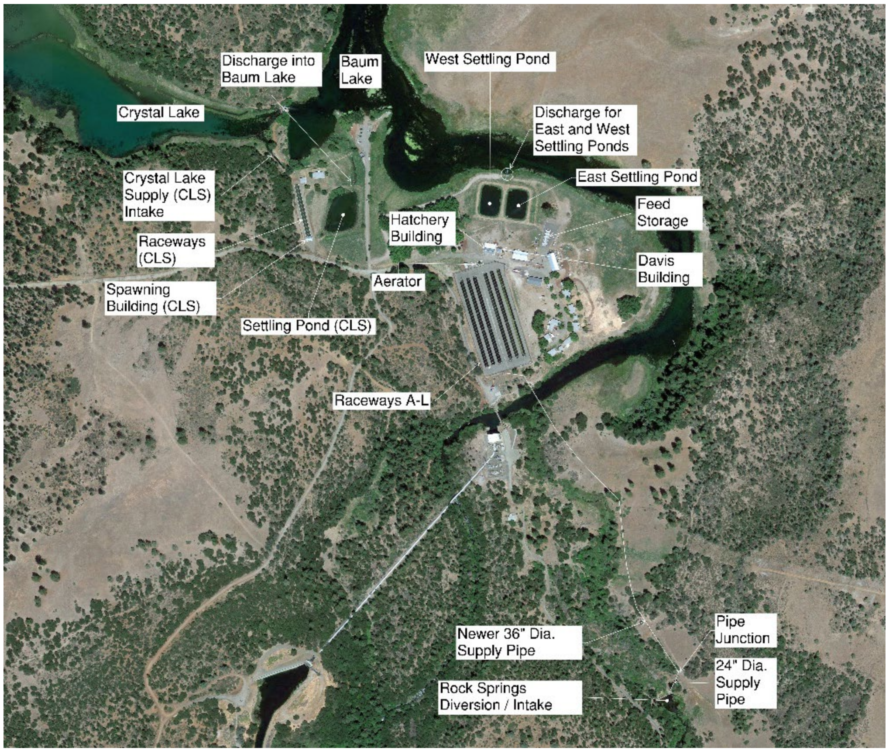

Figure 1-2. Crystal Lake Facilities Layout. Google Earth image date: 7/14/2022.

2.0 Bioprogram

2.1 Production Goals and Existing Capacity

2.1.1 Inland Fisheries

California's hatchery production goal for inland trout is based on sport fishing licenses sold in the previous calendar year. This requirement sets a production goal for CDFW hatcheries to produce and release 2.75 pounds of trout per sport fishing license sold. The requirement stipulates that most released fish be of a catchable size (two fish per pound) or larger and requires CDFW to achieve this goal in compliance with certain policies, including the Strategic Plan for Trout Management. Currently, CDFW achieves approximately 35% of the required production based on sport fishing license sales. CDFW is also required, to the extent possible, to establish and maintain native wild trout stocks and protect native aquatic and nonaquatic species. CDFW currently utilizes a trout triploid program (sterile trout) to avoid genetic impacts to native trout populations through the stocking program.

The Capacity Biological Program (Capacity Bioprogram) for the facility was developed for the Site Visit Report (Appendix A) and provides the total numbers of fish and biomass that can be produced for all rearing tanks based on tank volume, operational water flows, and size of the fish. The calculations utilize the density and flow indices previously identified for the preliminary bioprograms, which encompass water temperature and elevation criteria to ensure oxygen levels appropriately align with production. This information is available in the Site Visit Report (Appendix A). The calculations include a 10% safety factor to provide a 90% maximum capacity based on both the density index (DI) and flow index (FI) requirements identified. The Crystal Lake Hatchery produces several strains (i.e., Colorado, West Virginia, and Eagle Lake strains) of Rainbow Trout and Brown Trout. The annual production goal at the Crystal Lake Hatchery is 400,000 lbs (800,000 fish total) of catchable Rainbow Trout at 2 fish per pound (fpp), as provided by CDFW in the initial questionnaire. There are two Brown Trout allotments with the annual production goal of 1,100 lbs (110,000 fish) and 10,000 lbs (100,000 fish). The fish production goal and rearing capacity determined by the Capacity Bioprogram is shown in Table 2-1.

Table 2-1. Production Capacity of Various Rearing Units at the Crystal Lake Hatchery per the Capacity Bioprogram (Appendix A).

Rearing Unit (max. fish size)	Total Capacity (Fish)[a]	Limiting Factor
California Troughs (250 fpp/2.15 inches)	46,323	Rearing Volume
Deep Tanks (250 fpp/2.15 inches)	192,435	Rearing Volume
Total Hatchery Building (250 fpp/2.15 inches)	238,758	Rearing Volume
Raceways (2 fpp/10.8 inches)	532,998	Water Flow
Crystal Ponds (2 fpp/10.8 inches)	88,833	Water Flow

[a] This is an estimate of 90% production capacity to allow for a buffer in circumstances where more flexibility is needed for hatchery operations.

2.2 Bioprogram Summary

The Capacity Bioprogram in the Site Visit Report (Appendix A) demonstrates the total capacity of each rearing area at the Crystal Lake Hatchery for several stages of fish production. The capacity of each rearing area (-10% to provide an additional safety factor), limited by water flow or available rearing volume, is shown in Table 2-1. At a high level, the total capacity for the Crystal Lake Hatchery falls short of the production goal shown in Table 2-1; though, nuances of the timing of egg arrivals and fish stocking allows for annual production to exceed this total capacity. Details about the various rearing areas and infrastructure are discussed in the Site Visit Report, found in Appendix A.

In this current report, we developed an initial Production Bioprogram (Appendix B) to illustrate the potential maximum production that the facility is capable of while remaining within the limits set by the Capacity Bioprogram.

2.2.1 Criteria

The methods and reasoning used to determine the criteria associated with biological programming for the Crystal Lake Hatchery can be found in Appendix A. For reference, the established criteria are shown in Table 2-2. To model the production cycle schedule for the

Production Bioprogram, several assumptions were made and included in Table 2-2 as well. Additional assumptions include the following:

- CDFW will continue the production of Eagle Lake Rainbow Trout collected directly from Eagle Lake via trapping efforts and from hatchery broodstock. The Crystal Lake Hatchery will also continue to produce Pit River Rainbow Trout and Brown Trout.
- The rearing vessel volumes for the California troughs (18) and deep tanks (12) will be combined and used for the early rearing projections.
- The aeration tower for the lower raceways will remain fully operational to restore oxygen levels to saturation.
- CDFW will have the ability to have Rainbow Trout eggs available throughout the year by either purchasing eggs from private vendors or through CDFW's own photoperiod programs to maximize fish production at the facility.
- There will be optimal conditions for egg development and fish growth given the existing water temperatures at the facility.

Klontz (1991) provided optimal growth rates for Rainbow Trout at designated water temperatures. The growth rate is assumed to be the following: Rainbow Trout 0.0219 inches per day and Brown Trout 0.0159 inches per day. Survival rates were provided in the questionnaire completed by Crystal Lake Hatchery staff. CDFW provided additional timing and rearing duration information that closely correlates to growth projections provided by Klontz (1991).

Table 2-2. Criteria Used for the Production Bioprogram. Criteria are Discussed in Detail in Appendix A.

Criteria	Value
Density Index (DI)	0.5
Flow Index (FI)	1.70
Water Temperature-Rock Creek	Consistent 51° F
Water Temperature-Crystal Lake	37° to 58° F

Table 2-3. Survival Assumptions Used for the Production Bioprogram.

Species	Survival
Rainbow Trout	Egg-to-fry: 92% Fry-to-juvenile (250 fpp): 80% Juvenile-to-outplant (2 fpp): 80%
Eagle Lake Rainbow Trout (Trapped)	Egg-to-fry: 76% Fry-to-juvenile (250 fpp): 85% Juvenile-to-outplant (2 fpp): 70%
Eagle Lake Rainbow Trout (Hatchery)	Egg-to-fry: 84% Fry-to-juvenile (250 fpp): 80% Juvenile-to-outplant (2 fpp): 80%
Pit River Rainbow Trout	Egg-to-fry: 82% Fry-to-juvenile (250 fpp): 32% Juvenile-to-outplant (2 fpp): 32%
Brown Trout	Egg-to-fry: 92% Fry-to-juvenile (250 fpp): 70% Juvenile-to-outplant (10 fpp): 70%

2.2.2 Production Bioprogram

This bioprogram (Appendix B) is meant to view hatchery operations at a high level and does not capture the nuances of the specific timing of fish transfers, grading, sorting, or stocking. The model is meant to show an example of how production may occur given the criteria and assumptions outlined in the previous section. This program incorporates the two groups of Eagle Lake Rainbow Trout (i.e., wild broodstock trapped at the lake and hatchery broodstock), the Pit River Rainbow Trout, and Brown Trout into their typical schedules with two additional groups of production Rainbow Trout (RBT) added into the production cycle to stagger and maximize production for the facility. The lower raceways are 100% serial reuse with the water from the upper raceways. The aeration tower located between the upper and lower raceways utilizes pumps and an aeration tower with a perforated screen to aerate the water before it passes through the lower raceways. The aeration tower can operate with one or two pumps, depending on flow requirements. Each pump is capable of pumping 7 cfs for a total of 14 cfs of reconditioned water. The total flow rate for the raceways is 18 cfs, leaving 4 cfs of flow untreated for the lower raceways. For the bioprogramming, all water for the lower raceways was considered reconditioned with oxygen levels at saturation for FI calculations. Additionally, one raceway is designated exclusively for broodstock and is unavailable for fish production. A second raceway is used seasonally for broodstock as younger year classes are cycled into the broodstock program as older broodstock are stocked out (i.e., 3-year-old females and two-year-old males).

2.2.2.1 Trapped Eagle Lake Rainbow Trout

Assuming that eggs are received around March 1, it takes approximately 60 days from fertilization (i.e., green eggs) to first feeding using the hatchery's average water temperature of 49°F. The first feeding would be initiated approximately May 1. Using 4,218 fpp (0.84 inches) as a standard size for Rainbow Trout at feed initiation, growth was projected throughout the rearing cycle. These fish should reach approximately 250 fpp (2.2 inches) at the end of June (Table 2-4). This is a critical stage as early rearing space is limited in the California troughs and deep tanks and the fish must be transferred into raceways at this time. The projection numbers used in the growth modeling were calculated based on the preferred size of the young fish (i.e., 250 fpp) before being transferred into the raceways; therefore, production goals for this group of fish will not be achieved due to the early rearing space limitations. The standard hatchery practice has been to move the fish into the raceways at a smaller size than optimal to make space for the next group of fish in need of the early rearing tanks. In this exercise, it is assumed that approximately 375,000 eggs are incubated, 280,000 fry are hatched from those eggs, and 240,000 juvenile fish are transferred to the raceways based on survival rates provided by Crystal Lake Hatchery staff. The 240,000 juveniles can initially be reared in a single 500-foot raceway, and as they grow, this group of fish will require four raceways to meet their rearing requirements (Table 2-4). Flow is the limiting factor for maximizing production in the raceways. This group of fish will remain in the raceways and achieve the catchable size (i.e., 2 fpp) the following July with a total rearing time of approximately 16 months.

Table 2-4. End of Month Production Information for the Trapped Eagle Lake Rainbow Trout (ELT-T) Bioprogram Including Realized DI and FI Values.

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Early Rearing-May	CA Troughs + Deep Tanks Combined	30	735.0	1.50	280,000	381.0	1.2	0.26	0.47
June	CA Troughs + Deep Tanks Combined	30	250.0	2.20	240,000	960.0	1.2	0.45	0.81
Jul	Raceways	1.0	108.0	2.80	233,538	2,162.4	3.0	0.05	0.57
Aug	Raceways	1.0	58.0	3.50	228,000	3,931.0	3.0	0.07	0.83
Sep	Raceways	1.0	36.0	4.10	222,462	6,179.5	3.0	0.10	1.12

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Oct	Raceways	1.0	22.0	4.80	216,924	9,860.2	3.0	0.14	1.53
Nov	Raceways	2.0	15.0	5.50	211,386	14,092.4	6.0	0.09	0.95
Dec	Raceways	2.0	10.6	6.20	205,848	19,419.6	6.0	0.10	1.16
Jan	Raceways	2.0	7.7	6.90	200,310	26,014.3	6.0	0.13	1.40
Feb	Raceways	3.0	5.8	7.50	195,690	33,739.7	9.0	0.10	1.11
Mar	Raceways	3.0	4.6	8.10	190,152	41,337.4	9.0	0.11	1.26
Apr	Raceways	3.0	3.7	8.80	184,614	49,895.7	9.0	0.13	1.40
May	Raceways	3.0	3.0	9.50	179,076	59,692.0	9.0	0.14	1.56
Jun	Raceways	4.0	2.5	10.20	173,538	69,415.2	12.0	0.11	1.26
Jul	Raceways	4.0	2.0	10.80	168,000	84,000.0	12.0	0.13	1.44

2.2.2.2 Hatchery-Origin Eagle Lake

Assuming that eggs are received around January 1, it takes approximately 60 days from fertilization (i.e., green eggs) to first feeding using the hatchery's average water temperature of 49°F. The first feeding would be initiated approximately March 1. Using 4,218 fpp (0.84 inches) as a standard size for Rainbow Trout at feed initiation, growth was projected throughout the rearing cycle. These fish should reach approximately 250 fpp (2.15 inches) at the end of April (Table 2-5). This is a critical stage as early rearing space is limited for the facility in the California troughs and deep tanks, and the fish must be transferred into raceways at this time. The projection numbers used in the growth modeling were calculated based on the preferred size of the young fish (i.e., 250 fpp) before being transferred into the raceways. In this case, the production goal for this group is not constrained by rearing volume since the initial ponding numbers were aligned with the DI values to ensure the fish would not be overcrowded in the early rearing tanks. A portion of the early rearing tanks may be left vacant and could be available for Brown Trout, which overlap with the ELT-H group during the early rearing cycle. It is assumed that approximately 235,000 eggs are incubated, 187,500 fry are hatched from those eggs, and 150,000 juvenile fish are transferred to the raceways based on survival rates provided by Crystal Lake Hatchery staff. The 150,000 juveniles can initially be reared in a 200-foot section of a 500-foot raceway, and as they grow, this group of fish will require three raceways to meet their flow requirements. Flow is the limiting factor for maximizing production in the raceways. This group of fish will remain in the raceways and achieve the catchable size (i.e., 2 fpp) the following May with a total rearing time of approximately 16 months.

Table 2-5. End of Month Production Information for the Hatchery-Origin Eagle Lake Rainbow Trout (ELT-H) Bioprogram Including Realized DI and FI Values.

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Early Rearing-Mar/Apr	CA Troughs + Deep Tanks Combined	20	250.0	2.20	150,000	600.0	0.8	0.42	0.76
May	Raceways	0.4	109.0	2.80	147,684	1,354.9	3.0	0.08	0.36
June	Raceways	0.4	128.0	3.50	145,377	1,135.8	3.0	0.05	0.24
Jul	Raceways	1.0	34.0	4.20	143,070	4,207.9	3.0	0.07	0.74
Aug	Raceways	1.0	22.0	4.80	140,763	6,398.3	3.0	0.09	0.99
Sep	Raceways	1.0	15.0	5.50	138,456	9,230.4	3.0	0.11	1.25
Oct	Raceways	2.0	10.6	6.20	136,149	12,844.2	6.0	0.07	0.77
Nov	Raceways	2.0	7.7	6.80	133,842	17,382.1	6.0	0.09	0.95
Dec	Raceways	2.0	5.9	7.50	131,535	22,294.1	6.0	0.10	1.10
Jan	Raceways	2.0	4.5	8.20	129,228	28,717.3	6.0	0.12	1.30
Feb	Raceways	3.0	3.6	8.80	126,921	35,255.8	9.0	0.09	0.99
Mar	Raceways	3.0	2.9	9.50	124,614	42,970.3	9.0	0.10	1.12
Apr	Raceways	3.0	2.4	10.20	122,307	50,961.3	9.0	0.11	1.24
May	Raceways	3.0	2.0	10.80	120,000	60,000.0	9.0	0.12	1.38

2.2.2.3 Brown Trout

Assuming eggs are received in November, it takes approximately 75 days from fertilization (i.e., green eggs) to first feeding using the hatchery's average water temperature of 49°F. The first feeding would be initiated approximately February 1. Using 4,218 fpp (0.84 inches) as a starting size for Brown Trout at feed initiation, growth was projected throughout the rearing cycle. These fish should reach approximately 211 fpp (2.30 inches) at the end of April (Table 2-6); therefore, staff will need to transfer these fish when they reach 250 fpp to avoid exceeding the DI of 0.50. This is a critical stage as early rearing space is limited for the facility in the California troughs and deep tanks.

The two allotments for Brown Trout are 110,000 fish at 100 fpp and 100,000 fish at 10 fpp, and the early rearing space limitation (DI) prevents increasing the number of fish to achieve this goal. However, if these eggs are received in a staggered fashion (e.g., 2-3 weeks), it allows more fish to be held in the early rearing tanks. Additionally, if fish are moved into the raceways at a smaller size, which is the current standard practice to maximize fish production at the facility, the Brown Trout production goal could be met.

In late April, the Brown Trout will need to be transferred into a raceway, and all fish can initially be reared in a 200-foot section of a 500-foot raceway. The projection numbers used in the growth modeling were calculated based on the preferred size of the young fish (i.e., 250 fpp) before being transferred into the raceways. In this exercise, it is assumed that approximately 370,000 eggs are incubated, 342,000 fry are hatched from those eggs, and 240,000 juvenile fish are transferred to the raceways based on survival rates provided by the Crystal Lake Hatchery staff. The 240,000 juveniles can initially be reared in a 200-foot section of a 500-foot raceway, and as they grow, this group of fish may require additional rearing space depending on the size and timing of when the 110,000 allotment (100 fpp) is stocked out.

Fish remaining on-station after the transfer can be reared in a 300-foot section of a 500-foot raceway. Using the full 500 feet of raceway, which has historically been used for Brown Trout, is recommended if this space is available. Flow is the limiting factor for maximizing production in the raceways. This group of fish will remain in the raceways and achieve the sub-catchable size (i.e., 10 fpp) in January.

Table 2-6. End of Month Production Information for the Brown Trout Bioprogram Including Realized DI and FI Values.

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Early Rearing Feb/Mar	CA Troughs + Deep Tanks Combined	30	446.0	1.8	261,000	585.2	1.2	0.34	0.61
Apr	CA Troughs + Deep Tanks Combined	30	211.0	2.3	240,000	1,137.4	1.2	0.50	0.92
May	Raceways	0.6	120.0	2.8	231,840	1,932.0	3.0	0.08	0.51
Jun	Raceways	0.4	73.5	3.2	113,680	1,546.7	3.0	0.08	0.36
Jul	Raceways	0.4	48.0	3.7	105,520	2,198.3	3.0	0.10	0.44
Aug	Raceways	0.4	33.0	4.2	97,360	2,950.3	3.0	0.12	0.52
Sep	Raceways	0.4	24.0	4.7	89,200	3,716.7	3.0	0.13	0.59
Oct	Raceways	0.6	17.9	5.2	81,040	4,527.4	3.0	0.10	0.65
Nov	Raceways	0.6	13.5	5.7	72,880	5,398.5	3.0	0.11	0.70

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Dec	Raceways	0.6	10.7	6.2	64,720	6,048.6	3.0	0.11	0.72
Jan	Raceways	0.6	8.5	6.6	56,560	6,654.1	3.0	0.11	0.75

2.2.2.4 Pit River Rainbow Trout

Assuming that eggs are received around December 1, it takes approximately 60 days from fertilization (i.e., green eggs) to first feeding using the hatchery's average water temperature of 49°F. The first feeding would be initiated approximately February 1. Using 4,218 fpp (0.84 inches) as a standard size for Rainbow Trout at feed initiation, growth was projected throughout the rearing cycle. These fish should reach approximately 250 fpp (2.15 inches) at the end of March (Table 2-7). This is a critical stage as early rearing space is limited in the California troughs and deep tanks, and the fish must be transferred into raceways at this time.

Specific to this group of fish, once they are transferred from the early rearing tanks, they are raised in the Crystal Pond raceways on the Crystal Lake water supply. No other fish are reared on the Crystal Lake water supply due to the presence of *Ceratanova shasta* (C. *shasta*) in the water. The Pit River Rainbow Trout survival rate is better than the other groups of fish reared on the Crystal Lake water supply. The Crystal Lake water temperatures fluctuate throughout the year; therefore, monthly growth rates have been adjusted to account for this variability.

The projection numbers used in the growth modeling were calculated based on the preferred size of the young fish (i.e., 250 fpp) before being transferred into the raceways. As discussed previously, the Pit River Rainbow Trout and Brown Trout early rearing cycles overlap to a degree that typically results in the Brown Trout being transferred into the raceways at a smaller size than desired. In this exercise, it is assumed that approximately 715,000 eggs are incubated, approximately 586,000 fry are hatched from those eggs, and 187,500 juvenile fish are transferred to the Crystal Ponds based on survival rates provided by Crystal Lake Hatchery staff. The 187,500 juveniles can initially be reared in a single Crystal Pond raceway (300 ft), and as they grow, this group of fish will be reared in the 200- to 300-foot Crystal Pond raceways. These are the only group of fish reared on the Crystal Lake water supply due to the presence of *C. shasta*, so there are no conflicts with the rearing of other groups of fish in the Crystal Pond raceways. This group of fish will remain in the Crystal Pond raceways and achieve the catchable size (i.e., 2 fpp) in late April or May with a total rearing time of approximately 16 months.

Table 2-7. End of Month Production Information for the Pit River Rainbow Trout Bioprogram Including Realized DI and FI Values.

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Early Rearing Feb/Mar	CA Troughs + Deep Tanks Combined	30	250.0	2.10	187,500	750.0	1.2	0.36	0.66
Apr	Crystal Ponds	1	114.0	2.80	177,693	1,558.7	3.0	0.06	0.41
May	Crystal Ponds	1	54.0	3.60	167,886	3,109.0	3.0	0.10	0.64
Jun	Crystal Ponds	1.0	31.0	4.30	158,079	5,099.3	3.0	0.13	0.88
Jul	Crystal Ponds	1.0	16.0	5.40	148,272	9,267.0	3.0	0.19	1.27
Aug	Crystal Ponds	2.0	9.4	6.40	138,465	14,730.3	6.0	0.13	0.85
Sep	Crystal Ponds	2.0	6.8	7.10	128,658	18,920.3	6.0	0.15	0.99
Oct	Crystal Ponds	2.0	5.1	7.90	118,851	23,304.1	6.0	0.16	1.10
Nov	Crystal Ponds	2.0	4.1	8.40	109,044	26,596.1	6.0	0.18	1.18
Dec	Crystal Ponds	2.0	3.6	8.80	99,237	27,565.8	6.0	0.17	1.16
Jan	Crystal Ponds	2.0	3.1	9.30	89,430	28,848.4	6.0	0.17	1.15
Feb	Crystal Ponds	2.0	2.7	9.70	79,623	29,490.0	6.0	0.17	1.13
Mar	Crystal Ponds	2.0	2.4	10.10	69,816	29,090.0	6.0	0.16	1.07
Apr	Crystal Ponds	2.0	2.0	10.80	60,000	30,000.0	6.0	0.15	1.03

2.2.2.5 Rainbow Trout 1 and 2

Rainbow Trout 1 and 2 (RBT-1, RBT-2) model two additional groups of Rainbow Trout production fit into the hatchery logistics around the Eagle Lake(s), Pit River, and Brown Trout groups. There are existing conflicts with early rearing between the Eagle Lake Hatchery-origin and Brown Trout, and between the Brown Trout and the Pit River Rainbow Trout. Assuming that eggs are received around September 1 for RBT-1 and eggs are received around June 1 for RBT-2 and it takes approximately 60 days from fertilization (i.e., green eggs) to first feeding using the hatchery's average water temperature of 49°F, the first feedings would be initiated approximately November 1 and August 1, respectively. Using 4,218 fpp (0.84 inches) as a standard size for Rainbow Trout at feed initiation, growth was projected throughout the rearing cycle. These fish should reach approximately 250 fpp (2.15 inches) at the end of December and September (Table 2-8). This is a critical stage as early rearing space is limited for the facility in the California troughs and deep tanks, and these groups will need to be transferred into the raceways at approximately the end of December (RBT-1) and September (RBT-2).

The projection numbers used in the growth modeling were calculated based on the preferred size of the young fish (i.e., 250 fpp) before being transferred into the raceways. In this exercise, it is assumed that approximately 326,000 eggs are incubated, 300,000 fry are hatched from those eggs, and 240,000 juvenile fish are transferred to the raceways based on the assumed survival rates. The 240,000 juveniles can initially be reared in a single 500-foot raceway, and as they grow, this group of fish will require additional raceways. There are not enough raceways at the facility to rear these two groups to a catchable size; however, if 60,000 fish are stocked out from each of these two groups at approximately 11 fpp (sub-catchable) at the end of June (RBT-1) and the end of March (RBT-2), it allows the remaining fish for each group to be reared to the catchable size in three raceways per group. Flow is the limiting factor for maximizing production in the raceways. These groups of fish will remain in the raceways and achieve the catchable size (i.e., 2 fpp) the following January (RBT-1) and October (RBT-2) with a total rearing time of approximately 16 months.

Table 2-8. End of Month Production Information for the Rainbow Trout RBT-1 and RBT-2 Bioprogram Including Realized DI and FI Values.

RBT-1 Nov/Dec	RBT-2 Aug/Sep	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Early Rearing	Early Rearing	CA Troughs + Deep Tanks Combined	30	250.0	2.1	240,000	960.0	2.0	.47	0.51
Jan	Oct	Raceways	1.0	114.0	2.8	236,308	2,072.9	3.0	.05	0.55
Feb	Nov	Raceways	1.0	58.0	3.5	232,616	4,010.6	3.0	.08	0.85
Mar	Dec	Raceways	1.0	36.0	4.2	228,924	6,359.0	3.0	.10	1.12
Apr	Jan	Raceways	2.0	22.0	4.8	225,232	10,237.8	6.0	.07	0.79
May	Feb	Raceways	2.0	15.0	5.5	221,540	14,769.3	6.0	.09	1.00

RBT-1 Nov/Dec	RBT-2 Aug/Sep	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Jun	Mar	Raceways	2.0	11.0	6.1	217,848	19,804.4	6.0	.11	1.21
Jul	Apr	Raceways	2.0	7.7	6.8	154,156	20,020.3	6.0	.10	1.09
Aug	May	Raceways	2.0	5.9	7.5	150,464	25,502.4	6.0	.11	1.26
Sep	June	Raceways	3.0	4.5	8.2	146,772	32,616.0	9.0	.09	0.99
Oct	Jul	Raceways	3.0	3.6	8.8	143,080	39,744.4	9.0	.10	1.11
Nov	Aug	Raceways	3.0	2.9	9.5	139,388	48,064.8	9.0	.11	1.25
Dec	Sep	Raceways	3.0	2.4	10.1	135,696	56,540.0	9.0	.12	1.39
Jan	Oct	Raceways	3.0	2.0	10.8	132,004	66,002.0	9.0	.14	1.51

2.2.2.6 Summary

It should be noted that the FIs and DIs at the end of each month for RBT-1 and RBT-2 are within the criteria specified in Table 2-2. This provides additional flexibility to reduce flows for smaller fish or hold fish in a raceway for longer to accommodate other logistical needs. Ultimately, production is limited by the water flow available in each raceway when fish reach a catchable size.

This staggered production creates maintenance windows to depopulate and clean rearing areas, while producing approximately 898,568 fish weighing 324,667 pounds annually at the facility. These totals include the stocking of the 110,000 Brown Trout at 100 fpp and 60,000 Rainbow Trout from both RBT-1 and RBT-2 at 11 fpp to avoid exceeding the FI as these groups of fish grow larger.

This does not meet the production goal of the facility (1,000,000 fish and 400,000 pounds), but it maintains production within recommended DI and FI criteria for the water temperatures at the facility. There is flexibility within the program to rear fish in the hatchery building to a larger size if required, but flows limit the total number of fish transferred to the raceways to reach a catchable size. Once fish reach the target stocking size, they should be stocked out relatively soon to open rearing space for the next cohort of fish and because the FI criteria will be exceeded as fish continue to grow.

Water demand will be the highest in May and July as seen in Figure 2-1. The water flow specified in Figure 2-1 is meant to show the flow requirement assuming all rearing areas are supplied with the maximum water flow. Figure 2-1 does not include the flows for the Crystal Lake water supply since the only fish being reared on this water supply is the Pit River Rainbow Trout. In practice, once fish have been transferred from the hatchery building to the raceways, they will likely not require the maximum water flow initially, providing additional flexibility for water use in other rearing areas as necessary. However, water flow/oxygen will become the limiting factor in maximizing production in the raceways. Note that the different colored blocks in the following figure correspond to the months for when each species is in either the deep tanks or in the raceways, along with noting when eggs are received and incubated.

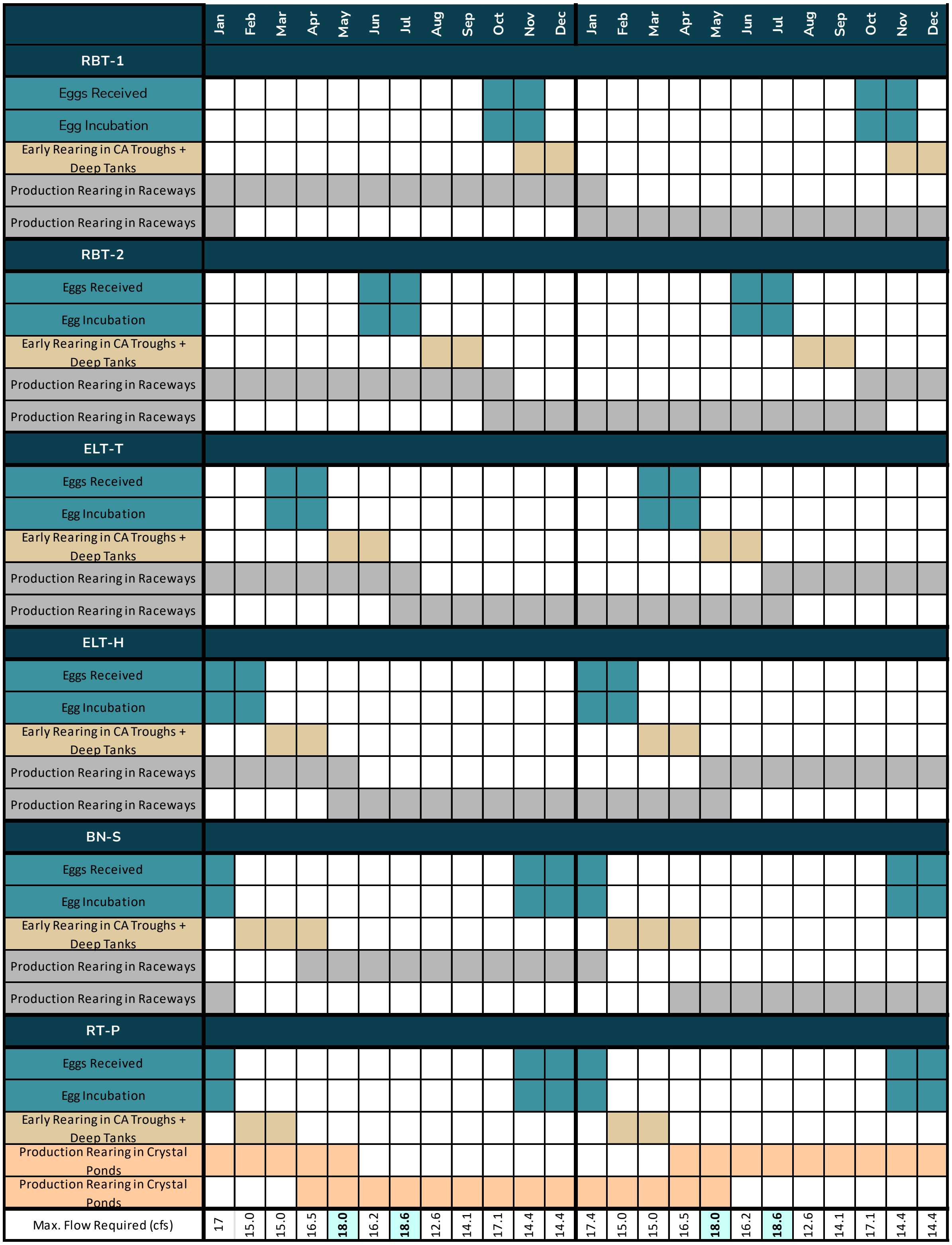

Figure 2-1. Production Rearing Schedule Over 2 Years with Peak Water Demand Occurring Annually in May and July (as highlighted in the Max Flow Required row).

3.0 Climate Evaluation

3.1 Introduction

In this section, climatic and hydrologic projections of conditions at the hatchery are presented for the next 20 years (2024-2043) and the following 20 years (2044-2063). These time horizons are referred to as the near-future period and the mid-century period, respectively. These projections inform the project team of potential needs for adaptive changes. Air temperature projections inform of potentially hazardous working conditions, and water temperature projections inform of risks to fish rearing.

3.2 Water Sources

Crystal Lake Hatchery uses two water sources:

Rock Creek Springs. The main part of the hatchery takes in 11.6 million gallons per day (mgd; about 18 cfs) from Rock Creek Springs. This water flows through the Upper and Lower Raceway Series and the hatchery building. The Upper Series, like the Lower Series, consists of six raceways, and each raceway has five 100-foot rearing ponds. With regards to water temperatures, the Site Visit Report (see Appendix A) states as follows: "Per CDFW, the water temperatures utilized for production for all species at the Crystal Lake Hatchery is consistent year-round at a temperature of 51°F with a couple degrees of variability throughout the year." Also, "water supply has been stable throughout drought periods."

Crystal Lake. The Brood Pond Series is located separately on the northern part of the hatchery. It receives 4.0 mgd (about 6 cfs) of water from Crystal Lake, through a canal that feeds two concrete raceways. Each raceway consists of three 100-foot rearing ponds. Crystal Lake is supplied by spring water. The Site Visit Report states: "…a good cold-water source with temperatures that drop into the upper 30's [°F] in the winter on occasion, but also provides good growth temperatures in the mid to upper 50's [°F] range in the summer."

3.3 Methodology for Climate Change Evaluation

This study uses future climatic and hydrologic projections based on global climate model (GCM) simulations associated with the data set known as CMIP5, which was part of the fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC 2014). The projections in this report are based on results from 10 different global climate models under the RCP4.5 scenario of future greenhouse gas emissions, which represents a future with modest reductions in global emissions compared to current levels.

An ensemble of 10 global climate models (GCMs), listed in Table 3-1, is used for capturing a wide range of plausible climate projections. Since this project's future time horizon is limited to 40 years, the dominant source of uncertainty in climate projections is expected to be the natural variability of the earth's climate (and the variability present in every GCM model run), with the second major source of uncertainty being differences between GCMs. Using this ensemble will simultaneously address both uncertainty sources. The selection of 10 GCMs was based on tests of their ability to accurately simulate California climate, following the study of 35 CMIP5 models by (Krantz et al., 2021).

Table 3-1. List of Global Climate Models Used in This Study.

No.	GCM	Research Institution
1	ACCESS-1.0	CSIRO, Australia
2	CanESM2	Canadian Centre for Climate Modelling and Analysis, Canada
3	CCSM4	National Center for Atmospheric Research, United States
4	CESM1-BGC	National Science Foundation, Department of Energy, and National Center for Atmospheric Research, United States
5	CMCC-CMS	Centro Euro Mediterraneo per Cambiamenti Climatici, Italy
6	CNRM-CM5	Centre National de Recherches Météorologiques / Centre Européen de Recherche et Formation Avancées en Calcul Scientifique, France/European Union
7	GFDL-CM3	NOAA Geophysical Fluid Dynamics Laboratory, United States
8	HadGEM2-CC	Met Office Hadley Centre, United Kingdom
9	HadGEM2-ES	Met Office Hadley Centre, United Kingdom
10	MIROC5	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies, Japan

Hydrologic projections utilize daily timestep results from the VIC hydrologic model (Figure 3-1) that was driven by the projected daily climate time series. VIC divides the watershed into grid cells (about 5x7 km in this study) where properties of the soil column and land cover and all major fluxes of water and energy are represented. Soil infiltration capacity is spatially variable within each grid cell, and baseflow is represented as a non-linear function of soil water storage.

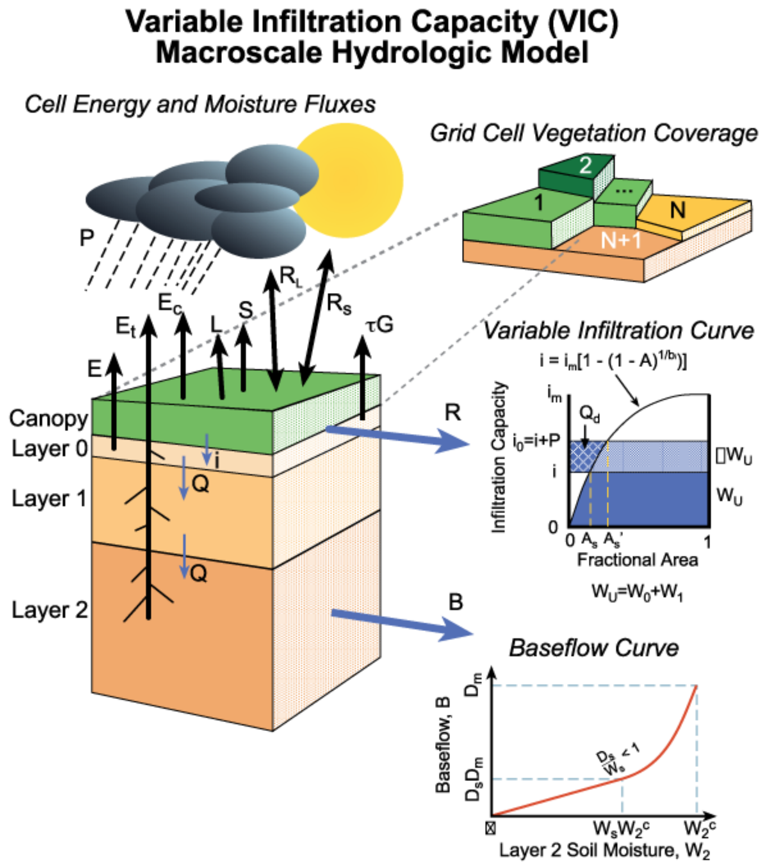

Figure 3-1. The VIC Hydrologic Model (University of Washington Computational Hydrology Group, 2021).

The methodology used for obtaining projections of climate, water temperature, hydrology and flood risk is summarized in Figure 3-2. The sections below provide additional detail, as well as discussion of fire risk:

1. **Projections of climatic variables** (air temperature, precipitation and evapotranspiration) were based on simulations by the 10 selected CMIP5 global climate models (GCMs). The GCM projections were statistically downscaled (using different methodologies) by a consortium of research institutions and made publicly available for all of California at a grid cell spatial resolution of 1/16° x 1/16° (about 5 km x 7 km) (Vano et al., 2020). In this report, the downscaling methodology named “Localized Constructed Analogs” (LOCA) is used. The choice of the LOCA data set was guided by its proven ability to represent extreme values of the downscaled climatic variables (important to this study) and because the hydrologic projections made available by the same research consortium (item (2) below) used the LOCA-downscaled climate projections. The difference between greenhouse gas emissions scenarios is small for a time horizon of

20 years; therefore, it is sufficient to use one greenhouse gas emissions scenario in this study, and the moderate scenario RCP4.5 is used.

2. **Projections of water temperature** of the natural spring water that is source to the hatchery were obtained using empirical relationships developed in this project between daily observations of air temperature and water temperature. The observed temperature data for the spring water were provided by the hatchery, while the air temperature corresponded to the Soldier Mountain meteorological station record, combined with the publicly available Livneh gridded data set (Livneh et al., 2013) for the grid cell containing the hatchery. The Livneh data allowed extending the record back to the reference period 1984-2003 and obtaining estimates of maximum daily temperatures (Tmax). Methods for developing such relationships between air and water temperature were previously applied successfully in climate vulnerability assessments conducted for Washington state hatcheries (McMillen, Inc, 2023; USFWS, 2021). The empirical relationship specific to this hatchery site was used to obtain projected water temperatures from the projected air temperatures increases determined from item (1) above.
3. **Projections of wildfire risk** at each hatchery site were evaluated at a high level based on the projections by Westerling (2018), which are available through the California government Cal-Adapt.org website (Cal-Adapt 2023). In addition to the risk that fire poses to the facility, it has the effect of reducing soil permeability, increasing peaks of runoff and stream flows that impact flooding and water quality, and potentially decreasing groundwater recharge.

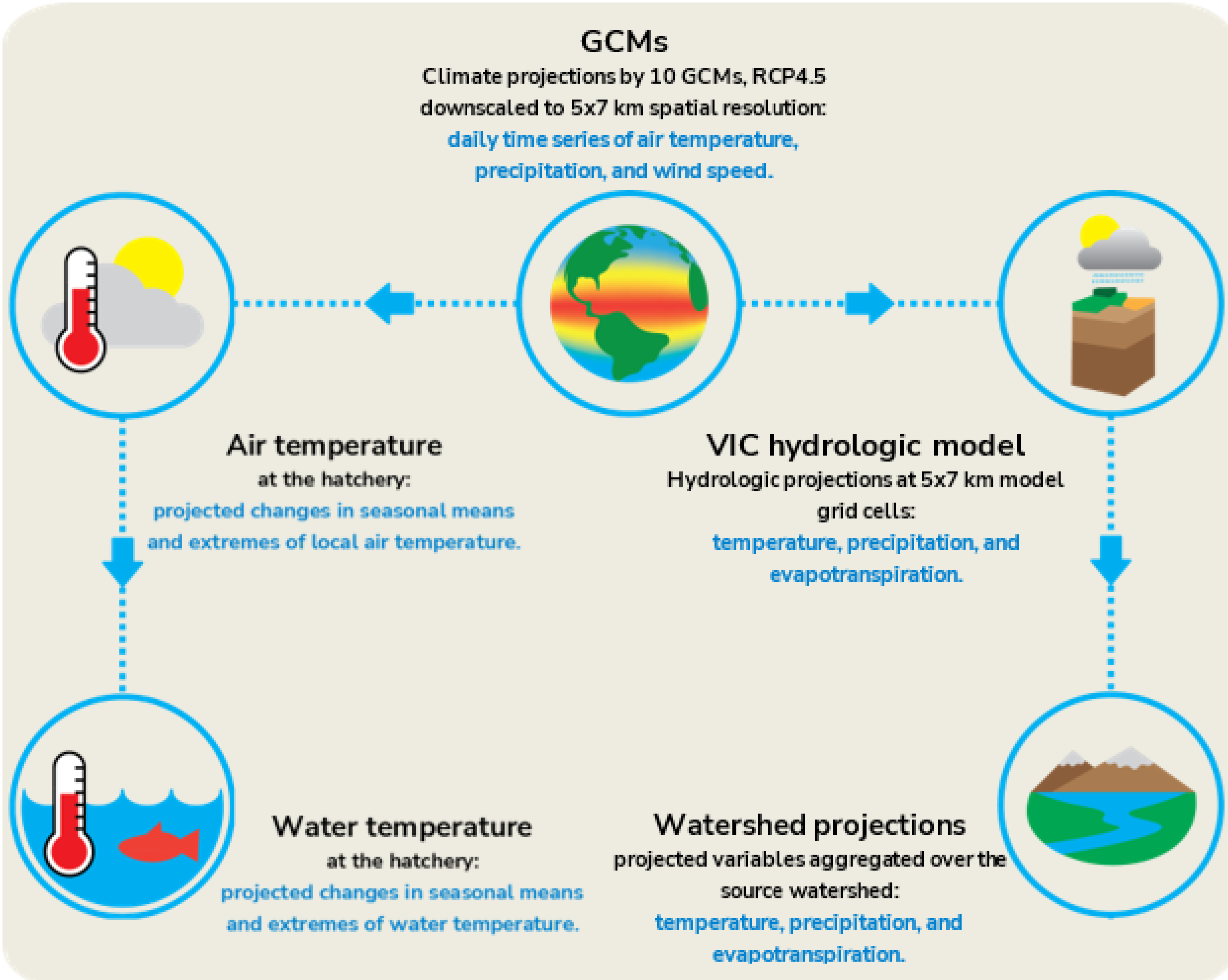

Figure 3-2. Methodology for Obtaining Projections.

3.4 Uncertainty and Limitations

It is important to acknowledge the uncertainty associated with these and any projections of climate and hydrology. While there is a need to provide climate projections for a variety of planning purposes, the underlying projections of climate change are subject to large and unquantifiable uncertainty.

The projections of air temperature, water temperature, precipitation, evapotranspiration, and wildfire risk developed in this work should therefore be considered as plausible representations of the future, given the best current scientific information, and do not represent specific predictions. The actual future realizations of these variables over the areas studied will differ from any of the projections considered here, and their differences compared to historical climate may be greater or smaller than the differences in the projections considered.

3.5 Projected Changes in Climate at the Hatchery Site

3.5.1 Air Temperature

Figure 3-3 displays the simulated mean daily air temperature (solid lines) and its range from minimum to maximum (shaded areas) for each day of the year, at the hatchery. The near-future time period and the reference period are represented in red and blue, respectively. All data are simulated by the ensemble of 10 GCMs for each time period. Higher peaks of daily temperature are seen for the near future compared to the reference period, while the historical period has lower minima.

Table 3-2 and Table 3-3 list the projected mean seasonal air temperature for two future time periods, and the temperature change relative to the reference period. All time horizons, including the reference period, are simulated by the ensemble of 10 GCMs. The lowest and highest of the 10 GCM daily projections define the lower and upper limits of the shaded areas in Figure 3-3, and are given in Table 3-2 and Table 3-3. Table 3-4 and Table 3-5 list the projected percentiles of highest air temperature in each day (Tmax) for two future time periods, relative to the reference period. All time horizons, including the reference period, are simulated by the ensemble of 10 GCMs.

At the hatchery site, mean annual air temperature is projected to rise by 2.2°F in the near-future period compared to the reference period (1984-2003), and by an additional 1.2°F in the mid-century period. The season with the most warming is the summer (Figure 3-3 and Table 3-2 and Table 3-3) and the highest temperature rises are projected to occur in the hottest days (Table 3-4 and Table 3-5). Days with maximum daytime temperatures representing the 75th percentile (i.e., the upper quartile of temperatures) are projected to warm by 2.9°F in the next 20 years, relative to the reference period. The 97th percentile of the daytime maximum temperature is projected to rise by even more, 3.1°F, reaching 106.1°F. These projected temperatures represent potentially hazardous outdoor working conditions at the hatchery.

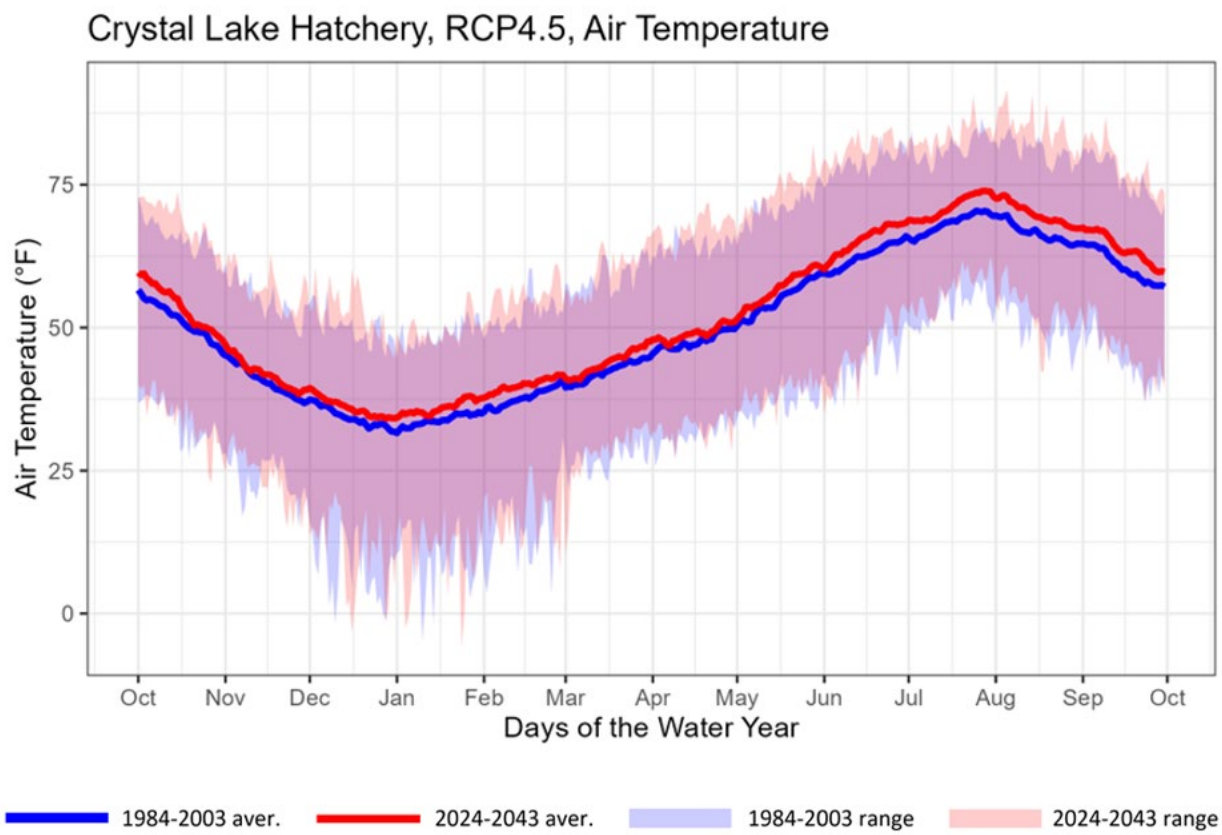

Figure 3-3. Mean Daily Air Temperature and Range for Each Day of the Year.

Table 3-2. Projected GCM 2024-2043 Mean Seasonal Air Temperature (change relative to 1984-2003).

GCM	Annual	Winter (DJF)	Spring (MAM)	Summ. (JJA)	Fall (SON)
Ensemble mean	57.1°F (+2.2°F)	39.5°F (+2.0°F)	52.7°F (+1.6°F)	74.9°F (+3.1°F)	56.3°F (+2.0°F)
Lowest	56.9°F (+2.0°F)	38.6°F (+1.1°F)	51.8°F (+0.7°F)	73.4°F (+1.6°F)	55.2°F (+0.9°F)
Highest	57.8°F (+2.9°F)	40.4°F (+2.9°F)	53.8°F (+2.7°F)	75.8°F (+4.0°F)	57.5°F (+3.2°F)

Table 3-3. Projected GCM 2044-2063 Mean Seasonal Air Temperature (change relative to 1984-2003).

GCM	Annual	Winter (DJF)	Spring (MAM)	Summ. (JJA)	Fall (SON)
Ensemble mean	58.3°F (+3.4°F)	40.7°F (+3.2°F)	53.8°F (+2.7°F)	75.9°F (+4.1°F)	57.7°F (+3.4°F)
Lowest	57.6°F (+2.7°F)	39.7°F (+2.2°F)	52.5°F (+1.4°F)	74.5°F (+2.7°F)	57.0°F (+2.7°F)
Highest	59.2°F (+4.3°F)	42.0°F (+4.5°F)	54.7°F (+3.6°F)	77.9°F (+6.1°F)	58.6°F (+4.3°F)

Table 3-4. Projected GCM 2024-2043Percentiles of Highest Air Temperature in Each Day (T_{max}) (change relative to 1984-2003).

GCM	3rd perc.	25th perc.	50th perc.	75th perc.	97th perc.
Ensemble mean	45.8°F (+2.2°F)	58.2°F (+1.6°F)	73.4°F (+1.8°F)	91.9°F (+2.9°F)	106.0°F (+3.1°F)
Lowest	44.3°F (+0.7°F)	57.5°F (+0.9°F)	72.7°F (+1.1°F)	91.2°F (+2.2°F)	104.7°F (+1.8°F)
Highest	47.6°F (+4.0°F)	60.0°F (+2.5°F)	74.5°F (+2.9°F)	92.2°F (+3.2°F)	107.2°F (+4.3°F)

Table 3-5. Projected GCM 2044-2063 Percentiles of Highest Air Temperature in Each Day (T_{max}) (change relative to 1984-2003).

GCM	3rd perc.	25th perc.	50th perc.	75th perc.	97th perc.
Ensemble mean	48.0°F (+3.4°F)	60.1°F (+2.5°F)	75.7°F (+3.1°F)	93.0°F (+4.1°F)	106.9°F (+4.0°F)
Lowest	48.2°F (+1.6°F)	59.0°F (+1.4°F)	74.9°F (+2.3°F)	91.9°F (+2.9°F)	105.6°F (+2.7°F)
Highest	49.8°F (+5.2°F)	61.4°F (+3.8°F)	76.4°F (+3.8°F)	94.8°F (+5.9°F)	108.3°F (+5.4°F)

3.5.2 Water Temperature

Once-weekly water temperature observations were provided by the hatchery for the period from 2018 through 2022. This record contains an error, in that the data for 2018 and 2019 are identical. It is not known whether these data rightfully belong to 2018 or 2019. In Figure 3-4, top panel, it is assumed the data belong to 2018, while in the bottom panel it is assumed to belong to 2019. The x axis represents the daily mean air temperature recorded at Soldier Mountain meteorological station, provided by the hatchery, is used. The red points indicate data from the summer season. The blue dashed curve plotted on both figure panels is the same, showing that, whichever of the two figure panels is the correct one, it is adequately fit by this curve. The blue dashed curve represents a Mohseni empirical-statistical model for the dependence of mean daily water temperature from mean daily air temperature. On its upper end, this Mohseni curve approaches a limit value of 51.5°F. Therefore, the projected 3.1°F rise in mean summer temperature is unlikely to bring mean daily water temperature above the range observed in recent years, displayed in Figure 3-4.

The blue dashed curve corresponds to the logistic model of Mohseni et al. (1998; 1999). Equation 3-1 was fitted for the mean daily water temperature and separately for the maximum daily water temperature (i.e., the temperature of the hottest hour of each day), yielding the blue dashed curves in Figure 3-4, shown on the top and bottom panel, respectively.

Equation 3-1

$$\mathrm{T_{water}} = \mu + \frac{\alpha - \mu}{1 + e^{\gamma \cdot (\beta - T_{air})}}$$

In Equation 3-1, T_{air} is the air temperature; μ and α represent the minimum and maximum water temperature, respectively; β is the air temperature at the inflection point of the "S"-shaped curve; and γ is a function of the slope around the inflection point, given by $\gamma = 4 \cdot \text{slope}/(\alpha - \mu)$.

For the mean daily water temperature, the fitted parameters (blue dashed curve in the top panel of Figure 3-4) are the following: μ=32℉, α=95℉; β=68℉; and slope=0.84. For the maximum daily water temperature, the fitted parameters (blue dashed curve in the bottom panel of Figure 3-4) are the following: μ=32℉, α=100℉; β=68℉; and slope=0.84.

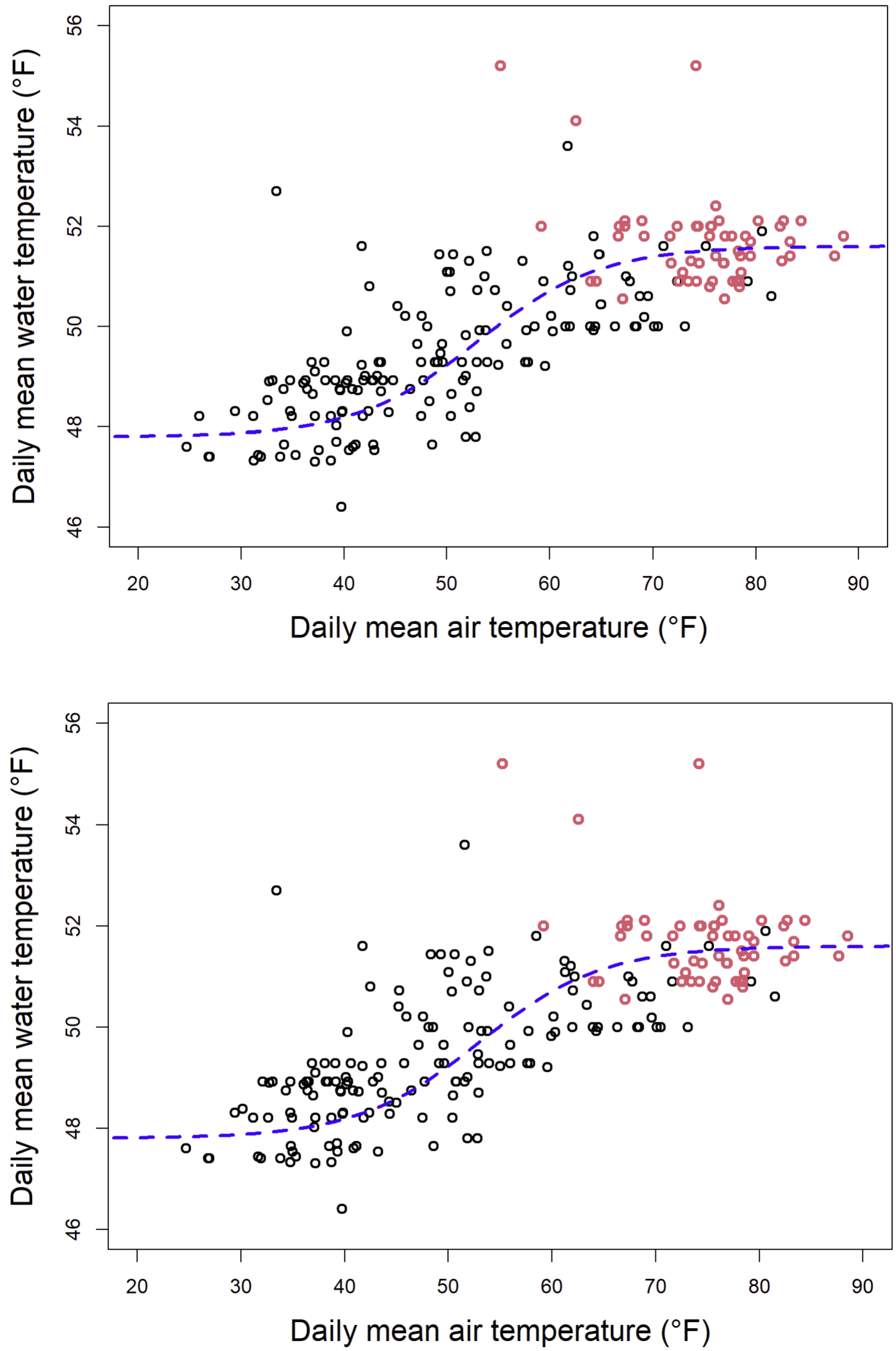

Figure 3-4. Water Temperature's Dependence on Air Temperature. Top panel: Assuming the 2018 data is correct. Bottom panel: Assuming the 2019 data is correct. On both panels, the blue dashed logistic curve represents Equation 3-1 fitted to the data.

3.5.3 Precipitation Minus Evapotranspiration Over the Watershed

Projected annual precipitation minus evapotranspiration aggregated over the Rock Creek springs area is projected to change relatively little in the next 20 years (Figure 3-5, Table 3-6, and Table 3-7) and incur moderate changes in the mid-century period (an annual increase by 11%, shown in Table 3-7). In Figure 3-5, Table 3-6, and Table 3-7, all time periods, including the reference period, are simulated by the ensemble of 10 GCMs.

This variable is an indicator of future direction of change in groundwater recharge rates but has large associated uncertainty given that precipitation in California is subject to great natural variability, experiencing large departures from the mean in any given year or multi-year period. Mimicking this natural variability, precipitation projections for the next 20 years vary widely between different GCM runs and are subject to great uncertainty.

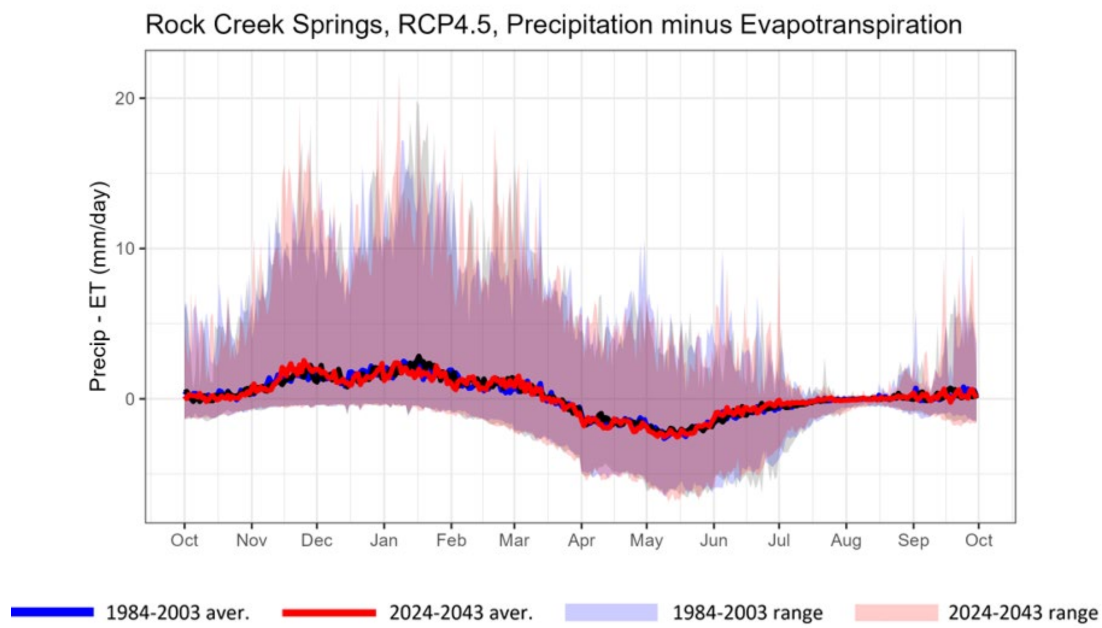

Figure 3-5. Mean Daily Precipitation Minus Evapotranspiration and Range for Each Day of the Year at the Hatchery Site.

Table 3-6. Projected GCM 2024-2043 Change in the Seasonal Total Precipitation Minus Evapotranspiration (relative to 1984-2003).

GCM	Annual	Winter (DJF)	Spring (MAM)	Summ. (JJA)	Fall (SON)
Ensemble mean	+1%	-4%	+6%	-23%	+7%

Table 3-7. Projected GCM 2044-2063 Change in the Seasonal Total Precipitation Minus Evapotranspiration (relative to 1984-2003).

GCM	Annual	Winter (DJF)	Spring (MAM)	Summ. (JJA)	Fall (SON)
Ensemble mean	+11%	+10%	+8%	-17%	-11%

3.5.4 Wildfire Risk

Historical wildfires have been documented in the vicinity of the hatchery, including some large fires in the surrounding uplands, such as the historical Dixie Fire of 2021, 20 miles north of the facility. Smaller fires of less than 15,000 acres are common in the immediate vicinity of the hatchery but have not occurred since 2014. Landcover varies from grassland in the immediate vicinity of the hatchery to hardwood and coniferous in the upper watershed. Fuel recovery rates post-fire vary from several years in grasslands to more than 10 years in hardwood and coniferous forests. Figure 3-6 shows known historical fires within the vicinity of the watershed, as well as the probability of future fires occurring.

Expressing wildfire risk as a percent chance of occurring at least once in a decade, the projected wildfire risk at the hatchery site is between 25% and 35% through mid-century. Fire risk across the watershed is 26% probability of fire occurring through 2060, then increasing to 36% through 2099. It should be noted that low probability areas can still have large devastating fires, such as the Dixie Fire (>900,000 acres), occurring in a predicted low probability area in the 2020-2029 map.

Existing concerns at the hatchery include increased runoff and turbidity in Rock Creek. If a large fire were to occur in the surrounding area, then soil erosion potential would increase until the burn scar heals. Warmer streamflow temperatures are possible in the years following fire until tree canopies reestablish. There is also risk to the hatchery facilities as well given the occurrence of frequent but small fires in the immediate vicinity of the hatchery.

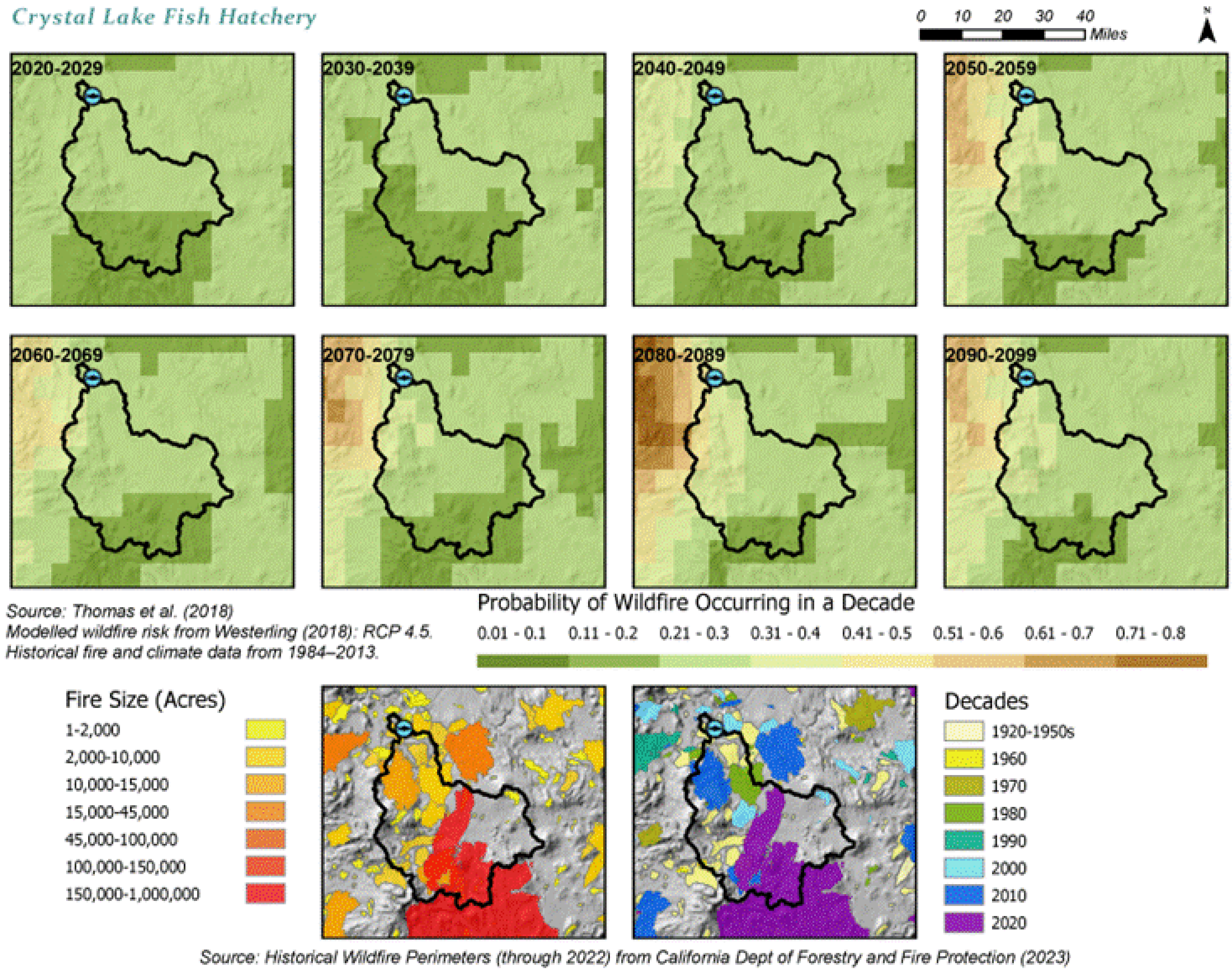

Figure 3-6. Wildfire Risk as Probability of Future Occurrence, and Known Historical Fires.

3.6 Conclusions

Significant increases in air temperature are expected for the Crystal Lake Hatchery location. Mean annual air temperature is projected to rise by 2.2°F in the next 20 years (2024-2043) and by an additional 1.2°F in the mid-century period (2044-2063), compared to the reference period (1984-2003). The summer will experience the most warming, and the largest temperature increases are projected to occur on the hottest days. Days with temperatures representing the 75th percentile and 97th percentile of daily temperatures are projected to warm by 2.9°F and 3.1°F, respectively, in the next 20 years, relative to the reference period.

According to the Soldier Mountain observations of air temperature used in this study, combined with gridded air temperatures for the reference period 1984-2003, the 75th and 97th percentiles of peak daytime temperature (i.e., the temperature at the hottest time of day) were 89.0°F and 102.9°F. For the near-future period (2024-2043), these percentiles are projected to rise to 91.9°F and 106.0°F, respectively. Such an increase in the peak air daytime temperature requires adaptation measures for protection of hatchery workers against heat stroke and other health effects of heat exposure. Roads and roofs may also need to be replaced using more heat-resistant and reflective materials.

Observations show that mean daily water temperature rarely rises above 51.5°F, a temperature at which it no longer responds to further air temperature increase. Therefore, atmospheric warming is not expected to elevate summer water temperature beyond the range observed in recent years.

The hatchery is at significant risk of wildfires. There is a history of large fires in the watershed and surrounding uplands and, given the absence of fire at these locations since year 2014, there is increasing risk of fire in the near future. The projected chance of at least one wildfire occurring in a 10-year period at the hatchery site and watershed as a whole is estimated as 25%-35% through mid-century. Post-fire conditions also pose risks to the hatchery, including scar-induced flooding, turbidity, debris, and warmer waters due to loss of riparian tree shade.

4.0 Existing Infrastructure Deficiencies

While the Crystal Lake Hatchery is an operational facility, multiple facility deficiencies were identified during the site visit and are described in Section 4 of the Site Visit Report (Appendix A). Section 5.4 of the Site Visit Report identified potential technologies and solutions needed to address specific deficiencies that would allow the hatchery to meet production goals and provide protection against climate change. The identified hatchery deficiencies include the following:

- Insufficient early and midgrade rearing space
- Low oxygen levels throughout the 500-foot raceways
- Inoperable flow meter on the Rock Creek water supply
- Undersized and old pipe at Rock Creek water supply
- Lack of permanent spawning building
- Lack of water flow control for the raceways
- General aging infrastructure such as the concrete, valves, and pipes throughout the hatchery

Biosecurity deficiencies and potential solutions for addressing them were identified in Sections 3.0 and 3.2 of the Site Visit Report, respectively. These measures include treating the incoming water for the hatchery building with filtration and UV, covering outdoor rearing vessels with solid roof structure and enclosing sides, and fully enclosing the Davis Building for early rearing. The details of the existing deficiencies are further expanded upon in Section 4.1 and Section 4.2.

4.1 Water Process Infrastructure

4.1.1 Inadequate Flow to Maintain Oxygen Levels in the Raceways

Rock Creek Spring serves as the main water source for the hatchery, delivering approximately 18 cfs. The water enters the facility with oxygen levels around saturation. The water is then used as serial reuse in the upper and lower raceways. Each set of raceways is 500 feet long. The oxygen levels quickly become depleted in the raceways to the point where the tail end of the lower raceways can only support very low fish densities. The maximum density in the raceways is around 0.15 because of the oxygen and flow limitations, which limits the total production numbers at the hatchery. This problem is exacerbated during the summer months when the long raceways experience significant heat gain. The hatchery currently maximizes the available flow and cannot increase the amount of incoming water.

4.1.2 Lack of Treatment on Incoming Water to the Hatchery Building

The incoming water to the hatchery building comes from Rock Creek Spring. The spring water is relatively biosecure. However, it is open to the environment for the first 650 feet from the spring to the diversion dam where the flow enters a pipe. The hatchery does see some increase in sediment during storm events, and this is a potential pathway for pathogens to enter the hatchery building. Eggs and fry in the hatchery building are at the stage when they are the most susceptible to pathogens. Untreated water entering the hatchery building presents an increased biosecurity risk.

4.1.3 Pathogens in Crystal Lake Water Supply

The hatchery has two concrete raceways that receive its water supply from Crystal Lake. The incoming water has no treatment, and Crystal Lake has *C. shasta*, which results in high mortalities for fish reared in the raceways. The hatchery only rears the Pit River Rainbow Trout in these raceways because they are more resilient to *C. shasta* compared to other fish. The hatchery allotment for Pit River Rainbow Trout is 60,000 fish; however, the hatchery sees an overall survival rate of 32% for the Pit River Trout. *C. shasta* is a myxosporean parasite, and an ultraviolet (UV) dosage of 30 mJ/cm^2 will kill 99.9% of the parasite in the incoming water.

4.2 Rearing Infrastructure

4.2.1 Limited Early Rearing Space

The existing hatchery building is limited in early rearing space. Currently there is a bottle neck in the hatchery building during peak production that requires the hatchery to move young fish out to the raceways at a smaller size than desired because there are more fish coming out of incubation requiring rearing space in the troughs and deep tanks. The fish perform better in the raceways once they reach a larger size because the younger fish are more susceptible to stress and pathogens. Additionally, the smaller fish are not as adept at handling the higher flows required for the larger fish that are also in the raceways.

4.2.2 Aging Intake Pipe for Rock Creek Water Supply

The Rock Creek water supply is diverted into a 36-inch ductile iron pipe that then connects to a 24-inch spiral steel pipe. The spiral steel pipe is old, and the condition is unknown. The hatchery does not have a secondary pipeline or alternative water source for the raceways, so if this incoming pipe were to fail, the hatchery would lose its water supply to the hatchery building and the upper and lower raceways. In this scenario, it would be expected that all fish production on the Rock Creek water supply would be lost.

4.2.3 No Dedicated Spawning Space for the Rock Creek Water Supply

Crystal Lake Hatchery spawns Pit River Rainbow Trout and West Virgina Rainbow Trout. Currently, the hatchery uses the spawning building on the Crystal Lake water supply for the Pit River Rainbow Trout and holds and spawns the West Virginia stock out of Raceway A on the Rock Creek water supply without any established infrastructure. The Crystal Lake water supply is positive for *C. shasta*, as discussed previously. The hatchery has biosecurity measures in place to prevent the spread, but there is still the potential for the pathogen to spread throughout the hatchery. There is no spawning area on the Rock Creek water supply.

4.2.4 Exposure and Predation Issues in Raceways

Both the upper and lower raceways are enclosed in chain-link fencing but still experience predation. In addition to the losses associated with predation, these predators also increase the risk of pathogens. Birds and other animals can carry diseases and cause stress in the fish which can result in fish loss. In addition to predation, the open environment of the raceway allows for prolonged exposure to sunlight, especially during the summer months. As mean and maximum ambient air temperatures continue to rise in the future, reducing the solar effects on water temperature in the hatchery will be critical to maintain temperatures within the range for salmonids. Prolonged exposure to sunlight and UV rays warms the water, can cause sunburn on the fish, and damages the infrastructure.

4.2.5 Damaged Flow Meter on the Rock Creek Water Supply

The hatchery has a flow meter located on the Rock Creek water supply pipeline. However, the flow meter is broken and no longer provides flow data. The hatchery has no way to monitor the incoming flow and can only use experiential knowledge to set flows in the raceways. The flow meter control box shows signs of aging and is difficult to open.

5.0 Alternative Selected

During the site visit, several deficiencies were identified that currently limit the hatchery's ability to meet fish production goals. These deficiencies have been summarized in Section 4.0 of this report. The Alternatives Development TM (see Appendix E) provides a discussion of alternative technologies that may be used to address the existing deficiencies and potentially expand production, improve biosecurity, and increase operational efficiencies. The following section presents a summary of the preferred alternative that would best utilize the alternative technologies to respond to the existing deficiencies, maximize fish production, and respond to the climate change projections described in Section 3.0.

5.1 Alternative Description

5.1.1 Rock Springs Intake

Rock Creek is the main water source for the Crystal Lake Hatchery. Water is delivered to the hatchery from a concrete structure located approximately 2,000 feet to the south of the Hatchery. Water is diverted into a 36-inch ductile iron pipe for approximately 110 feet before transitioning to a 24-inch spiral steel pipe. The concrete structure and 36-inch pipe were installed in 2015. The 24-inch steel pipe was installed in 1964.

The preferred alternative is to replace the 24-inch-diameter spiral steel section of the water supply with a 36-inch ductile iron pipe to allow for increased flow and to limit the potential for air pockets and burping, which currently affect the hatchery when flows are adjusted. Additionally, the non-functional flow meter located on the 24-inch pipe would be replaced allowing the hatchery to manage flows entering the hatchery.

The Rock Creek intake is open to the environment for the first 200 yards after the source spring. This area is protected as a natural environment of the Shasta Crayfish (*Pacifastacus fortis*; a threatened species). However, this open area creates biosecurity concerns as it is open to the environment. Animals have access to the spring and during rain events runoff flows into this area. It is recommended that, in addition to replacing the incoming pipeline, microscreen drum filtration and UV disinfection should be installed to treat the entirety of the water entering the facility. The drum filter will provide filtration for a particle size of 40 microns, and UV disinfection should be selected to provide a minimum dosage of 126 mJ/cm^2. This will ensure *Flavobacterium* spp. and *C. shasta* does not enter the facility and will treat several other common aquaculture pathogens. Additionally, UV disinfection will be required at a higher dosage (170 mJ/cm^2) for the hatchery building for egg incubation to control *Saprolegnia* and for early fish rearing in the hatchery building; therefore, a separate UV system will be included for that purpose.

5.1.2 Crystal Lake Intake

Water from Crystal Lake contains the pathogen *C. shasta*, a myxosporean parasite. A disinfection treatment process is required to kill the parasite. The most common treatment process is UV irradiation. C. *shasta* requires a UV dosage of 30 mJ/cm^2; however, because the water is surface water, it will likely have a low UV transmittance (UVT). This will require either solids removal prior to the UV unit or an oversized UV unit to handle the low UVT. Either option would be challenging to install with the current intake.

Pit River Rainbow Trout are raised in the two raceways using water from Crystal Lake and have a higher resistance to the parasite; however, the Pit River Rainbow Trout still experience a survival rate of 32%. While the raceways on the Crystal Lake supply are isolated from other hatchery operations, the potential spread of *C. shasta* is still a biosecurity concern.

It is the preferred alternative to abandon the Crystal Lake water supply and to create additional rearing space for the Pit River Rainbow Trout supplied with Rock Creek water. If constructed in conjunction with the addition of the PRASs throughout the hatchery (see Sections 5.1.6 and 5.1.8), there would more than enough water from the Rock Creek supply to supplement the 6 cfs that is currently being sourced from Crystal Lake.

5.1.3 Water Budget

Table 5-1 provides a water budget comparison between water requirements for the existing facility relative to the proposed preferred alternatives, including expanding intermediate rearing capabilities with PRAS, final rearing of Rainbow Trout using PRAS, and the addition of broodstock raceways on the Rock Creek water supply. The table does not include the Crystal Lake water supply since the preferred alternative does not include the use of the Crystal Lake source due to the presence of *C. shasta*.

Water requirements for incubation and early rearing will remain the same utilizing jars, 12 deep tanks, and 18 troughs for a total of 690 gpm. The new intermediate rearing PRAS circular tanks address the limitation in early rearing volume at the hatchery, allowing young fish to be grown to a larger size before being transferred into final rearing tanks. This new water demand will require a total of 240 gpm of make-up water.

The upper and lower raceways will be replaced with PRAS circular tanks and will yield the largest water savings of 2,800 gpm. Raceways A and B have been used for broodstock holding. The addition of raceway style brood ponds will require 700 gpm per raceway for a total of 1,400 gpm. The previous water use for broodstock was included in the raceways category, so the 1,400-gpm requirement can be deducted from the PRAS savings from the raceways with 1,400 gpm to spare. Data for the water budget in Table 5-1 was generated from the information provided by CDFW in the questionnaire relative to maximum flow rates for the various rearing facility components. Overall, a decrease in the water flow requirement of approximately 1,160 gpm will occur with the implementation of the preferred alternatives.

Table 5-1. Water Requirements for the Existing and Proposed Facility Components.

Characteristics	Existing Facility Components Flow (gpm)	Proposed Facility Components Flow (gpm)
Incubation and Early Rearing	690	690
Intermediate Rearing PRAS	0	240
Raceways/PRAS Circulars	8,000	5,200
Brood Pond(s)	0[a]	1,400
Miscellaneous Water Use	300	300
Total GPM	**8,990**	**7,830**

[a] The broodstock are currently held in raceways A and B; therefore, the water use for broodstock is lumped under the raceways/PRAS Circulars category for the existing facility components.

5.1.4 Valving and Piping

Various valves and pipes across the hatchery site are more than 50 years old. Valves throughout the hatchery, such as at the heads of each raceway, have been left open and are not operated by hatchery staff due to the potential of breaking the aged valve.

The preferred alternative is to more closely inspect valves and pipes throughout the hatchery and to replace infrastructure that is leaking, not operable, heavily aged/worn, or likely to fail in the near future. Replacing valves and pipes would allow for better flow control and would allow for the hatchery to continue operating into the future.

5.1.5 Improve Oxygen Levels in Raceways

The raceways at Crystal Lake Hatchery operate as a serial reuse, and the water passes over the upper and lower raceways. By the time the water reaches the end of the lower raceways, the oxygen levels have decreased and dissolved carbon dioxide levels have increased. To mitigate this, the hatchery uses passive degassing to treat the flow. The hatchery treats 7 cfs of the total 18 cfs during normal operations. However, during peak production, the hatchery can treat 14 cfs. Even with the aeration tower providing passive degassing, the hatchery is still limited by oxygen levels in the lower raceways. To meet production goals, the hatchery needs to increase oxygen levels in the raceways.

The preferred alternative for increasing oxygen levels in the raceways depends on whether PRAS and circular tanks are introduced in place of the existing concrete raceways (see Section 5.1.8).

If the concrete raceways are replaced with PRAS and circular tanks, no additional mid-pond aeration will be needed. Each PRAS module will have a low-head oxygenator to maintain sufficient oxygen levels. The existing aerator between the upper and lower raceways could continue to be used elsewhere in the facility or removed, if not needed.

If the concrete raceways remain in place, the preferred alternative is to install low-head oxygenators (LHOs) in the upper and lower raceways to improve oxygen levels in the raceways. The LHOs will be placed at the head and midpoint in both the upper raceways. The existing aerator between the upper and lower raceways could continue to be used, depending on the effectiveness of the new LHOs. LHOs require an oxygen source, and it is recommended that a bulk liquid storage tank be placed onsite. The bulk storage tank will require a concrete pad, fencing, vaporizers, and supporting equipment. Typical agreements with local oxygen supply vendors include leasing the liquid bulk tanks, and, as a result, all maintenance done on the tank is completed by the oxygen supply company. The system will also require supply lines to the LHOs and oxygen flow meters. Installing LHOs in the raceways would increase oxygen levels and improve the overall water quality. Additionally, the hatchery may be able to increase production and maximize the use of the existing raceways. If the drop in the raceways is not sufficient for LHOs, a series of airlift systems would be installed as a secondary alternative.

5.1.6 Add PRAS Circular Tanks for Intermediate Rearing

The facility is limited in early rearing volume to achieve the appropriate size of young fish before transferring them to the raceways. The preferred alternative will provide circular tanks with PRAS, providing an intermediate rearing area after early rearing occurs in the troughs and deep tanks in the hatchery building. This will enable the hatchery to rear approximately 300,000 young fish to 100 fpp in an enclosed biosecure building.

A standard size for smaller dual-drain circular tanks is a 10-foot diameter with a 3-foot operating depth. Each 10-foot tank provides 235.6 ft^3 of rearing volume. A total of 16 tanks will provide an additional 3,770 ft^3 of intermediate rearing space. There will be a total of four PRAS modules with four tanks/module.

The total flow for each tank is based on hydraulic retention times (HRT). Typical HRT for 10-foot diameter circular tanks is less than 30 minutes to maintain water quality and ensure efficient solids flushing from the tank. For 10-foot diameter tanks, if each tank has a flow of

60 gpm, then the resulting HRT would be 29 minutes. The entire flow for a four tank PRAS module would be 240 gpm. If the system is operated at a 75% reuse rate, the total make-up flow per module would be 60 gpm. All four modules would require a total of 240 gpm of make-up water. The PRAS that is recommended to be installed to increase the intermediate rearing volume will require a total of 240 gpm of “new” water.

Each PRAS module would require microscreen drum filters (40 micron), CO_2 removal, LHO, and UV disinfection (126 mJ/cm^2). Appendix E covers the details for each treatment equipment. Additionally, the tanks and equipment should be covered with an open-sided roof structure with side enclosure to prevent predation.

Although installing circular tanks on a PRAS to increase the intermediate rearing capability at the hatchery will result in a slight increase in water use, there will be greater water savings if the raceways are also converted to PRASs, thus ensuring there is sufficient water for these additional intermediate rearing tanks. Dual-drain circular tanks provide a completely mixed environment as opposed to a linear tank/raceway that has a gradient of high to low dissolved oxygen (DO) along its length. This characteristic of circular tanks makes the entire volume available to the fish, as opposed to fish crowding at a raceway’s head end, thereby not using the entire raceway volume. Other benefits include the self-cleaning of fish waste, concentration of fish waste in a small center drain flow that can be continuously treated, and the capacity for providing exercise velocities for fish. Covering the tanks with a rigid roof structure will also reduce heat gain, and enclosing the sides will improve biosecurity.

Initial early rearing will still occur in the hatchery building deep tanks on single-pass water, allowing up to 240,000 fish to be reared until they reach approximately 250 fpp before being transferred into the PRAS module(s). The existing bottlenecks associated with the overlapping of the existing groups (i.e., ELT-H, Pit River Rainbow Trout and Brown Trout) of fish currently produced at the hatchery will be alleviated by the flexibility and isolation capability of the new PRAS system in conjunction with the existing early rearing tanks (i.e., troughs and deep tanks). The new system will be designed to allow up to 500,000 fish to be reared to 100 fish per pound (fpp) or 350,000 fish to be reared to 60 fpp at any given time while following the industry standards for fish culture. Therefore, any bath style treatments to administer vaccinations or therapeutic treatments for disease or parasites may be conducted prior to the fish being transferred into larger rearing vessels (e.g., raceways or larger PRAS circulars).

The new PRAS tanks will operate on 50-75% less water when compared to the single-pass flow-through type tanks used for early rearing at the facility. At this level of PRAS, a biofilter is not required, which reduces the complexity of the system. The self-cleaning benefits of the circular tanks should improve overall tank hygiene and reduce the bacterial loading remaining in the tanks, thus reducing the risk of bacterial infections (e.g., Bacterial Gill Disease, Bacterial Coldwater Disease).

A new photovoltaic power generation system would be included atop the PRAS circular tank cover structure to help offset the power requirements of the new hatchery infrastructure while also lowering the overall cost of operating the hatchery.

5.1.7 Davis Building Troughs

Provided additional early rearing will occur in the form of a new PRAS system, the preferred alternative is to abandon the Davis Building given its condition and limited production potential.

5.1.8 Replace Raceways with PRAS Circular Tanks

The existing raceways currently provide the hatchery with reliable rearing space; however, the raceways will likely reach the end of their expected life span in the next 10 to 20 years. The raceway concrete is already showing signs of aging and deterioration. The rough and cracked concrete surfaces are not ideal for fish rearing as the surfaces can irritate fish when they contact the walls, and cracks and spalling are difficult to disinfect.

To replace this aging infrastructure, the preferred alternative is to install circular tanks with PRAS. Both the upper and lower raceways consist of six concrete raceways that are each 500 feet in length. Each raceway is 10 feet wide and has a water depth of 3 feet. This provides a total of 12 raceways, and each raceway has 15,000 ft^3 of rearing space. The total rearing space for both the upper and lower raceways series is 180,000 ft^3. However, at Crystal Lake, the flow is the limiting factor rather than the rearing volume. Under current operations, the hatchery is not able to rear fish above a 0.15 density index due to limited flow and oxygen levels in the raceways.

The circular tanks can assume a higher density index because they are a completely mixed environment, and the treatment equipment will ensure high levels of oxygen are maintained throughout the tanks. Table 2-1 outlines the production goal and current capacity of the raceways. The production goal is 800,000 at 2 fpp, and this goal includes all Rainbow Trout reared on both the Rock Creek and Crystal Lake water sources.

A standard size of larger, dual-drain circulars is a 20-foot-diameter tank with a 6-foot operating depth. Each 20-foot tank provides 1,885 ft^3 of rearing volume. A total of 64 tanks would be required to meet the production goal. There will be a total of eight PRAS modules, each with eight tanks. This will provide 120,640 ft^3 of rearing volume and result in a maximum density index of 0.31.

Table 5-2. Comparison between the Existing Raceways and Proposed Circulars Tanks with PRAS.

Characteristics	Existing Raceway	Circulars
Max Number of Fish	532,998	800,000
Fish Size at Max	2 fpp at 10.8 inches	2 fpp at 10.8 inches
Density Index	0.14	0.31
Dimensions (ft)	500 ft long; 10 ft wide	20-ft diameter
Operating Depth (ft)	3	6
Volume Per Rearing Vessel (ft^3)	15,000	1,885
Number of Rearing Vessels	12	64
Total Volume Required (ft^3)	**180,000**	**120,640**

The total flow for each tank is based on hydraulic retention times (HRT). Typical HRT for circular tanks is between 30 to 45 minutes to maintain water quality and ensure efficient solids flushing from the tank. For 20-foot diameter tanks, if each tank has a flow of 325 gpm, then the resulting HRT would be 43 minutes. The entire flow for an eight tank PRAS module would be 2,600 gpm. If the system is operated at a 75% reuse rate, the total make-up flow per module would be 650 gpm. All eight modules would require 5,200 gpm (11.6 cfs) of make-up water. The raceways currently use 8,080 gpm (18 cfs). By installing PRAS, the hatchery would reduce their water use by 2,880 gpm. This extra flow could be used elsewhere in the hatchery or additional rearing space could be added in the future.

Each PRAS module would require microscreen drum filters (40 micron), CO_2 removal, LHO, and UV disinfection at 126 mJ/cm^2. Appendix E (Alternatives Development TM) provides detailed information for the equipment components required for each PRAS module. Additionally, the tanks and equipment should be covered with an open-sided roof structure with predator netting surrounding the open sides.

Installing circular tanks on PRAS in the raceways can reduce the overall water usage and rearing volume and improve water quality within the rearing environment. Dual-drain circular tanks provide a completely mixed environment as opposed to a raceway that has a gradient of high to low dissolved oxygen (DO) along its length. This characteristic of circular tanks makes the entire volume available to the fish, as opposed to fish crowding at a raceway's head end, thereby not using the entire raceway volume. This allows the hatchery to increase the maximum density index used in circulars and rear more fish. Other benefits include the self-cleaning of fish waste, concentration of fish waste in a small center drain flow that can be treated continuously, and the capacity for providing exercise velocities for fish. Covering the tanks with a rigid roof structure will also reduce heat gain and improve biosecurity.

A new photovoltaic power generation system would be included atop the PRAS circular tank cover structure to help offset the power requirements of the new hatchery infrastructure while also lowering the overall cost of operating the hatchery.

5.1.9 Adult Holding/Spawning Building

The facility holds and spawns captive broodstock in Raceway A on the Rock Creek water supply. Currently, there is not a designated spawning building for the broodstock held on the Rock Creek water supply (the Pit River Rainbow Trout Broodstock are held in the Crystal Pond raceways on the Crystal Lake water supply). The preferred alternative would be to construct an adult holding/spawning building adjacent to the raceways or alternative location on the Rock Creek water supply. A holding/spawning facility would separate production fish from broodstock. This would allow all 12 raceways to be used for fish production rather than two of them being used to hold broodstock. A specific broodstock holding facility would provide a controlled environment for spawning and may improve egg quality and survival while improving biosecurity by separating spawning and fish production activities. Although there is already a spawning building on the Crystal Lake water supply where the Pit River Rainbow Trout are held and spawned, a new broodstock holding facility could incorporate space to hold the Pit River Rainbow Trout broodstock and eliminate the use of the Crystal Lake water supply. This would enhance biosecurity by minimizing the risk of *C. shasta* and improve survival if the Pit River Rainbow Trout were reared on the Rock Creek water supply.

The preferred alternative for the brood ponds is to replace the concrete structure with new rectangular raceways, a crowding lane, and spawning building attached. The new configuration will be placed parallel to the lower raceways. This would provide broodstock holding for the West Virginia Rainbow Trout and the Pit River Rainbow Trout for Age 1- to 3-year classes for females and Age 1- and 2-year classes for males. The hatchery starts holds Age 0 to Age 3 broodstock (Age 3 females only). The combined numbers and biomass ranging from Age 0 fish to Age 3 broodstock at a maximum density index of 0.15, requires 8,687 ft^3 of rearing space. The two Rainbow Trout strains would require 17,374 ft^3 of rearing volume.

Each strain of Rainbow Trout will be held in a separate raceway for a total of two raceways. Each raceway will be 400 feet long, 10 feet wide, and have an operating water depth of 3 feet. Each raceway would require 700 gpm to operate within the FI of 1.7, including a 10% safety buffer for a total of 1,400 gpm. The water requirements were generated using the maximum possible biomass including Age 0 through Age 3 broodstock for the West Virginia and Pit River Rainbow Trout. This will provide 12,000 ft^3 of rearing volume per strain of Rainbow Trout and a total of 24,000 ft^3. The wall height of the raceway will be 5 feet to prevent the adults from jumping out and allow the hatchery to change the operating depth as needed. Raceway walls thickness will be 8 inches, and raceway floor thickness will be 10 inches.

A new photovoltaic power generation system would be included atop the adult holding raceways and spawning building tank cover structure to help offset the power requirements of the new hatchery infrastructure while also lowering the overall cost of operating the hatchery.

5.1.10 Upgrade Existing Settling Ponds

The Rock Springs Supply operates two settling ponds for treating effluent before discharge. The hatchery has reported no issues meeting the limits of the NPDES permit. However, they have experienced problems with muskrats digging holes and causing leaks in the ponds. Although the recommended changes will not increase the total flow of the facility, the upgrades will boost production, leading to a higher solids content in the effluent wastewater. Therefore, it is recommended that the hatchery add an additional settling pond.

The new settling pond will match the size of the existing ones. With three ponds, the hatchery staff can use two ponds at a time while keeping the third offline for cleaning and maintenance. The increased solids content will necessitate more frequent dredging and maintenance. Additionally, having an extra settling pond may provide greater flexibility to manage muskrat issues by allowing one pond to be drained as needed.

The new settling pond will be located west of the existing ponds. Water will be diverted to the existing intake structure and connected to the discharge point. This arrangement will enable the hatchery to maintain only one discharge monitoring location as required by the NPDES permit.

5.1.11 Backup Power Generator(s)

An electrical assessment will be conducted for the facility to include the existing electrical requirements along with additional components encompassing the suite of alternatives selected to determine the electrical requirements for the facility to appropriately size backup generators.

5.2 Pros/Cons of Selected Alternative

Table 5-3 provides a high-level summary of the pros/cons for Crystal Lake Hatchery’s selected alternative.

Table 5-3. Pros/Cons of Selected Alternative – Crystal Lake.

Description	Pros	Cons
Replace Rock Springs intake pipe and add filtration and UV disinfection.	• Secures source water from aging infrastructure. • Reduces risk of failure. • Reduces effects of "burping." • Reduces risk of disease and potential for *C. shasta* to impact fish on the Rock Creek supply. • Increases the UV disinfection dosage to 170 mJ/cm^2 for incubation and early rearing provides protection against *Saprolegnia* and improves water quality during early rearing when fish are most susceptible.	• Costs more due to installation costs and increases cost for operation/maintenance (UV bulb replacement, drum filter panels, etc.). • Disrupts hatchery operations during construction. • Adds equipment to maintain. • Increases complexity. • Increases power requirements (commercial and backup power).
Abandon Crystal Lake intake.	• Reduces risk of spreading disease. • Increases survival rates of Pit River Trout.	• Loss of facility. • Loss of alternate water source.
Replace valves and pipe throughout hatchery.	• Improves operability and control of flow. • Increases in hatchery infrastructure lifespan.	• Costs more due to installation costs. • Disrupts hatchery operations during construction.
Improve oxygenation levels in raceways.	• Provides excellent water quality in a completely mixed environment because PRAS includes LHOs and CO_2 strippers. • Provides a healthier rearing environment, even if the PRAS is not implemented, because LHOs will boost oxygen level to saturation.	• Costs more due to installation costs and increases cost for operation/maintenance. • If LHOs are a standalone solution, capital costs and the cost of oxygen will increase because LHOs need to be installed at multiple intervals. • Increases pumping onsite.

Description	Pros	Cons
Add PRAS circular tanks for intermediate rearing.	• Provides space for intermediate rearing that is not currently available. • Provides a healthier rearing environment for fish. • Reduces labor because it is self-cleaning. • Concentrates waste for effluent treatment for NPDES permit compliance. • Protects fish from sunburn and reduces heat gain because of the roof. • Protects fish from predation and improves biosecurity because of the roof and enclosed sides. • Allows fish to be vaccinated prior to transfer to larger rearing vessels (if necessary).	• Requires additional components (e.g., drum screen, UV, LHO, CO_2 removal). • Costs more due to installation costs and increases cost for operation/ maintenance (UV bulb replacement, drum filter panels, etc.). • Increases complexity. • Requires additional staff training . • Requires new water demand at the facility. • Increases power requirements (commercial and backup power). • Disrupts hatchery operations during construction (this is new, so production should be minimally impacted if at all).
Davis Building: abandon existing building and troughs.	• Decreases maintenance because there will be one less building/troughs to maintain (facility does not use at the present time).	• Requires some maintenance or removal cost.

Description	Pros	Cons
Replace upper and lower raceways with circular PRAS and solid roof.	• Reduces total water required and provide flexibility. • Improves water quality within rearing vessels. • Replaces aging infrastructure. • Improves flow control. • Provides a healthier rearing environment for fish. • Is self-cleaning. • Concentrates waste for effluent treatment for NPDES permit. • Protects against heat gain because of the roof. • Improves biosecurity and predation losses because of the enclosed sides.	• Costs more due to installation costs and increases cost for operation/maintenance (UV bulb replacement, drum filter panels, etc.). • Requires additional staff training. • Increases pumping onsite. • Requires additional components (e.g., drum screen, UV, LHO, CO_2 removal). • Increases complexity.
Build new adult holding raceways and spawning building.	• Improves biosecurity from *C. shasta* because the Crystal Lake water supply is not used. • Keeps all spawning and broodstock in one area. • Provides a functional facility to sort, handle, and spawn broodstock. • Provides a controlled environment for spawning, which produces better egg quality. • Allows raceways A and B to be used for producing catchable fish (if PRAS is not implemented).	• Adds cost. • Adds infrastructure and water requirements (offset if Raceways converted to PRAS). • Abandons the existing Crystal Ponds, spawning building and water supply.
Add backup power generator(s).	• Provides power to all life support systems in the event of a power outage. • Enables the hatchery to use modern technology to produce healthier fish.	• Increases cost. • Increases complexity. • Increases maintenance. • Increases the risk of fish loss if system fails in a power outage.

5.3 Alternatives for Short Term Improvements

If funding is not available to construct the preferred alternative, the following short-term improvements are recommended for continued hatchery operation.

5.3.1 Valving and Piping

Replacing the existing non-functional water meter located on the supply pipe will allow the hatchery to collect data on water use within the hatchery. Replacing the control valves on the water supply pipes will improve the ability of the hatchery to manage water.

5.3.2 Skim Coat Concrete Raceways

The concrete in both the upper and lower series raceways is approximately 40 years old and showing signs of aging. The underlying aggregate in the floor and walls of the raceways is exposed due to wear which creates an abrasive surface that can be harmful to fish as well as a surface that promotes algae growth. The rough aggregate is difficult for hatchery staff to clean efficiently. Adding a coating to the concrete can help alleviate the present issues and reduce the rate at which the concrete surface deteriorates.

5.3.3 Update and Repair Aeration Tower

The existing aeration tower regularly treats 7 cfs but can treat up to 14 cfs. However, the aeration tower provides oxygenation and gas stripping via passive aeration and therefore can only provide limited oxygenation. To increase efficiency, the aeration tower could be renovated to operate as a low-head oxygenation. The changes that would need to be made would be adding an oxygen source (LOX or oxygen generator), removing the interior media, adding chambers inside the aeration tower, and ensuring the bottom for the unit is submerged in water. If designed correctly, the updated oxygenation system would be able to oxygenate the water up to 130% to 150% saturation.

5.3.4 Hatchery Building to Include Intermediate Rearing Tanks

A pole barn style hatchery building would be constructed to incorporate a 16-tank PRAS to address the hatchery's early/intermediate rearing space limitation. The tank and equipment configuration will be the same as the preferred alternative discussed in Section 5.1.6.

A new photovoltaic power generation system would be included atop the new pole barn structure to help offset the power requirements of the new hatchery infrastructure while also lowering the overall cost of operating the hatchery.

5.4 Natural Environment Impacts

The proposed upgrades to the Crystal Lake Fish Hatchery should have negligible impacts on the natural resources in the surrounding area. All improvements would occur within currently developed areas, avoiding requirements for additional environmental or cultural permits not identified in Section 7.0. An exception may occur if any existing structures fall under the jurisdiction of California's Office of Historic Preservation (OHP).

5.4.1 Fire and Flood Risk

The recommended changes to the Crystal Lake Fish Hatchery will change the existing infrastructure and the number of rigid structures onsite; however, these changes are not anticipated to increase or decrease the fire risk. Based on the climate change evaluation, the projected fire risk at the hatchery site is between 25% and 35% through mid-century. Fire risk across the watershed will increase from 26% mid-century to 36% through 2099.

Flood potential increases with the increased incidence of fire; therefore, as fire risk increases, the risk of flooding also increases. The recommended changes to the Crystal Lake Fish Hatchery will slightly increase the total impervious surface of the site but decrease the impact of flooding on the facility. The existing raceways are already located on higher ground and at a lower risk of flooding since they are located out of the flood-prone areas. Fiberglass circular tanks will replace the raceways and provide additional flood protection as they will be installed with the tank tops at heights 30 to 36 inches above ground. The tank height will provide protection from overland flow entering the fish rearing vessels, and the ground will be graded to carry water away from the tanks to the extent feasible. The addition of broodstock raceways will be constructed within the existing raceway footprint outside of flood-prone areas. Baum Lake, Crystal Lake, and the watershed upstream of the hatchery all have water control structures to regulate flows and water levels within the watershed providing additional protection from flood events.

Additionally, upgrading the intake and piping, and replacing the valves will provide the hatchery with better flow control into the facility. The hatchery staff will be able to manage surges in flow and prevent flooding of the rearing vessels.

5.4.2 Effluent Discharge

The recommended changes to the hatchery do not include an overall increase in fish production goals at the Crystal Lake Fish Hatchery. This will ensure there will be no change to the NPDES permit requirements. The hatchery will continue to be able to meet the NPDES permit requirement. Installing dual-drain circular tanks and effluent treatment will concentrate the solids into a smaller effluent flow. Adding a third settling pond will provide the hatchery with additional capability for water treatment prior to discharging to Baum Lake and allow the hatchery to rotate between the three settling ponds to provide a work window for pond cleanout and maintenance.

It is important to note that changes to existing aquaculture programs (renovations, new construction) may trigger (administratively) the requirement for new and/or updated NPDES permits. Acknowledging that waste load (fish biomass) is not anticipated to change with the proposed alternatives, we assume that the increase in effluent removal efficiencies provided by the PRAS systems will result in net effluent “gains” to the overall aquaculture program.

5.5 Hatchery Operational Impacts/Husbandry

Brown Trout along with multiple groups (pulses) of Rainbow Trout will be produced starting at different times of the year to maximize production capability at the hatchery. Early rearing fish culture practices will continue as the hatchery has operated previously with single-pass flow-through in the troughs and deep tanks. As the fish outgrow the early rearing tanks, they will be transferred into the intermediate rearing PRAS circular tanks. A small fish pump (e.g., 2.5-inch-diameter hose) would minimize handling and stress on the fish as they are transferred. If enumeration of the fish is desired, a fish counter may be utilized in conjunction with the fish pump.

The intermediate rearing tanks enable the hatchery to raise the fish to a larger size before transferring them into the final rearing tanks. These tanks address the rearing volume limitations associated with the existing hatchery building and eliminate the bottlenecks between groups of fish, which previously forced hatchery staff to move fish into the raceways prematurely. As the fish approach their target rearing size of 100 fpp in the intermediate rearing tanks, they are pumped into a fish transfer tank and offloaded via gravity into the final rearing PRAS tanks. Linear distances from origin to destination rearing tanks will limit how fish can be transferred throughout the hatchery. The intermediate rearing tanks range from approximately 250 feet to 700 feet from the nearest and furthest final rearing PRAS tanks, respectively. Pumping fish these distances would require considerable amounts of hose and the space to store it. Additionally, Baum Road, the main entrance road to the facility lies between the intermediate rearing area and final rearing tanks, and pumping would require the hose to be placed across the road, blocking vehicle access. It is preferable to pump the fish into a fish transfer tank equipped with an oxygen system and off-load them directly into the final rearing tanks, which will be recessed into the ground at an elevation to allow fish to be flushed into the final rearing tanks via gravity.

Once the fish are in the final rearing PRAS circular tanks, the fish will be grown to their target release size at which time they will maximize the biomass and DI capacity of the system. Truck loading for fish release will continue as the hatchery has operated in the past, utilizing fish pumps and dewatering towers with a few minor adjustments unique to circular tanks relative to traditional raceways.

One of the benefits of this proposed design is to provide the means for staff to maintain fish health and welfare. The intermediate rearing tanks allow for administering chemical treatments as needed (e.g., coldwater disease) and selection of captive broodstock prior to the fish transferring into the final rearing tanks.

5.5.1 PRAS Circular Tank Operations

The intermediate and final rearing tanks will operate as PRAS systems, reusing up to 75% of their water flow. The hydraulic self-cleaning characteristics of the circular tanks will reduce labor associated with tank cleaning. Additional tank sweeper systems are also available and can further reduce staff labor associated with maintaining tank hygiene. Staff time will be required for monitoring PRAS components, including routine water quality checks, flow adjustments, and monitoring LHO and CO_2 systems to ensure a high-quality rearing environment. Staff will make routine flow adjustments as fish grow to maintain a maximum velocity of approximately two body lengths/second (or as required for fisheries management objectives). Seine nets, clamshell crowders, or other crowder types can be used to concentrate fish for collection and handling.

Transfer of fish between tanks and for truck loading will utilize fish pumps and hosing to minimize handling and stress on the fish and decrease physical labor for staff transferring fish between tanks or loading trucks. For transferring fish into other rearing tanks requiring enumeration, a fish counter can be included at the receiving tank to obtain an accurate inventory of the fish. For fish being loaded onto a transport tanker for stocking, a dewatering tower will allow for the removal of the water through a screen prior to the fish entering the fish transport tanker. This is consistent with current hatchery practices as well as industry standards and practices, and allows the hatchery to quantify fish biomass based on water displacement in the fish transport tanker. The return of the water from the dewatering tower to the PRAS module sump will be necessary to maintain the water balance within the PRAS module. Another option is to increase the fresh make-up water flow to compensate for this water loss in the module during the fish pumping process.

5.5.2 PRAS Equipment

The PRAS provides tremendous benefits in reducing the water flow requirements to produce large numbers/biomass of fish while maximizing water quality. However, these systems are more complex and require additional skillsets to monitor and maintain the equipment to ensure reliable system operations for successful fish production. Given the staggered production cycle including Brown Trout and using multiple groups of Rainbow Trout, the PRAS modules will not all be occupied at the same time, providing maintenance windows and opportunities for cleaning and disinfection. All PRAS components should be programmed into the facilities maintenance and management system to schedule, perform, and document preventative and corrective maintenance.

5.5.3 Feeding

Early rearing feeding techniques in the troughs and deep tanks can continue using the hatchery's standard feeding practices. Hatchery staff will need to transition away from the blower-style feeding systems typically used for linear raceways to a feeding system designed for circular tanks. Fish can be fed in circular tanks utilizing the simplest of methods ranging from hand-feeding to automated systems, and the techniques may vary depending on the size of the circular tanks and staff preferences. In addition to staff preferences, there are pros and cons associated with the various feeding options. Hand-feeding requires more staff time compared to automated feeding systems as it is labor intensive but allows staff to observe fish feeding and overall behavior and health. Hand-feeding allows the staff to feed the fish to satiation and minimizes overfeeding, reducing wasted feed and maximizing water quality.

Automated systems require an initial cost for the purchase and installation of the system. The automated feeding systems intermittently provide feed throughout the day to maximize growth. This system reduces staff labor (but also reduces the staff's observations during feeding); however, it requires adjustments for delivering the correct amount of feed and requires preventative and corrective maintenance, which is a continued cost associated with these maintenance requirements. It should be noted that hand and automatic feeding systems are not mutually exclusive. Even with automatic feeding systems, culture operations should still involve regular monitoring of fish and their feeding response throughout the day.

5.6 Biosecurity

The goal of biosecurity measures is to minimize the risk of pathogens entering the facility and spreading between rearing areas at the facility. Crystal Lake Fish Hatchery reported several pathogens of concern at the facility. This included Gyros (*Gyrodactylus* spp.), bacterial gill disease (causative agent *Flavobacterium* spp.), bacterial coldwater disease (causative agent *Flavobacterium psychrophilum*), and *Ceratonova shasta*. The most likely pathways for pathogens to enter the Crystal Lake Fish Hatchery and spread through the facility is through the incoming water supply or environmental exposure within the hatchery. *C. shasta* is present in the Crystal Lake watershed.

5.6.1 Incoming Water Supply

Crystal Lake Fish Hatchery currently has limited measures to prevent pathogens from entering the facility. However, the recommended alternatives improve biosecurity by managing and treating the incoming water supply (i.e., Rock Creek) before entering the facility and abandoning the Crystal Lake water supply which contains *C. shasta*. Upgrading the Rock Creek intake, increasing the pipe diameter, and adding filtration and UV disinfection will provide reliability in flow, protect the hatchery from pathogens, and provide specific protection for the potential spread of *C. shasta* from the Crystal Lake water source to the Rock Creek source. Replacing outdated valves and piping will improve the hatchery's ability to control the flow to operate the new systems correctly and to maximize the protection of the hatchery from pathogens.

5.6.2 Environmental Exposure/Bio Vectors

The existing facility has several areas that are potential pathways for pathogens due to environmental exposure. The existing concrete raceways are enclosed by perimeter fencing with bird wires overtop, but these structures are minimally effective in excluding otters, raccoons, and avian predators from accessing the raceways. All water used for the upper raceways passes through the lower raceways, potentially exposing fish reared in the lower raceways to pathogens from the fish raised in the upper raceways. The recommended alternatives reduce the risk of pathogens entering the rearing areas by reducing environmental exposure and providing isolation between groups of fish by rearing them in multiple biosecure PRAS modules. Implementing PRAS in covered structures will limit potential pathogen vectors from the incoming water supply and other organisms (such as birds, otters, etc.) from entering the rearing vessels. Predators can be a significant source of stress, and they can transmit pathogens into the facility. Additionally, installing PRAS will ensure high-quality, treated water for all rearing vessels.

5.7 Water Quality Impacts

The recommended alternatives will improve the water quality within the existing rearing vessels as well as the effluent leaving the facility. Replacing the existing concrete raceways with dual-drain circular tanks can improve the water quality of the rearing environment. Dual-drain circular tanks provide a completely mixed environment as opposed to a raceway that has a gradient of high to low dissolved oxygen (DO) along its length. This characteristic of circular tanks makes the entire tank volume available to the fish, instead of fish crowding at a raceway’s head end, thereby not using the entire raceway volume. The dual-drain system in circular tanks aids waste removal, allowing for more effective removal of solid waste and uneaten feed. This can contribute to better overall water quality.

The other PRAS equipment will also improve the water quality within the system. The microscreen drum filters will remove the solids in the water. The LHOs will ensure the dissolved oxygen levels enter the tanks at saturation or higher. The carbon dioxide strippers will remove dissolved carbon dioxide as well as other undesirable gases, and the UV unit will reduce the pathogen load of the water that returns to the tanks. Additionally, installing a rigid roof structure with bird netting will reduce heat gain during the summer months and algae growth in the rearing tanks.

Each PRAS module will concentrate the fish waste into smaller flows from the center drain and drum filter backwash. The recommended alternatives include treating this effluent waste with a drum filter and settling pond. This will reduce the solids and improve the water quality of the effluent being discharged.

The recommended alternatives also include improving the incoming water quality. The improved intake structures, filtration, and UV disinfection will reduce the debris entering the facility and provide protection from pathogens. This will improve the water quality in the hatchery building, production areas, and broodstock rearing.

6.0 Alternative Cost Evaluation

6.1 Introduction

McMillen has utilized historical costs as a self-performing general contractor in the performance of similarly-technical projects as the basis of the Preliminary Concept Planning – Opinion of Probable Construction Cost (OPCC) estimate for this Project. Additionally, McMillen has solicited pricing or utilized recently received material quotes for similar materials and equipment or components. The appropriate overhead and profit markups have been included in the project pricing. The detailed cost estimates, including assumptions and inflation information are presented in Appendix F.

6.2 Estimate Classification

This OPCC estimate is consistent with a Class 5 estimate as defined by the Association for Advancement of Cost Engineering (AACE) classification system, as shown in Table 6-1 below. As stated in the estimate description below, "Class 5 estimates are generally prepared based on very limited information, and subsequently have wide accuracy ranges." For purposes of this project, McMillen has utilized an accuracy range of -30% to +50% in the estimates presented in Table 6-2.

Table 6-1. AACE Class 5 Estimate Description (Source: Association for Advancement of Cost Engineering).

Criteria	Details
Description	Class 5 estimates are generally prepared based on very limited information, and subsequently have wide accuracy ranges. As such, some companies and organizations have elected to determine that due to the inherent inaccuracies, such estimates cannot be classified in a conventional and systemic manner. Class 5 estimates, due to the requirements of end use, may be prepared within a very limited amount of time and with little effort expended—sometimes requiring less than an hour to prepare. Often, little more than proposed plant type, location, and capacity are known at the time of estimate preparation.
Level of Project Definition Required	0% to 2% of full project definition.

Criteria	Details
End Usage	Class 5 estimates are prepared for any number of strategic business planning purposes, such as but not limited to market studies, assessment of initial viability, evaluation of alternate schemes, project screening, project location studies, evaluation of resource needs and budgeting, long-range capital planning, etc.
Estimating Methods Used	Class 5 estimates virtually always use stochastic estimating methods such as cost/capacity curves and factors, scale of operations factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, and other parametric and modeling techniques.
Expected Accuracy Range	Typical accuracy ranges for Class 5 estimates are -20% to -50% on the low side, and +30% to +100% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.
Effort to Prepare (for US$20MM project)	As little as 1 hour or less to perhaps more than 200 hours, depending on the project and the estimating methodology used.
ANSI Standard Reference Z94.2-1989 Name	Order of magnitude estimate (typically -30% to +50%).
Alternate Estimate Names, Expressions, Synonyms:	Ratio, ballpark, blue sky, seat-of-pants, ROM, idea study, prospect estimate, concession license estimate, guesstimate, rule-of-thumb.

6.3 Cost Evaluation Assumptions

The following assumptions were made while developing the Class 5 cost estimates for this alternatives analysis:

- All unit costs assume total cost for installation including any applicable taxes.
- The cost estimate is at a Class 5 level with an accuracy range of -30% to +50% and includes 25% contingency. This range accounts for current inflation variability within aquaculture projects, unforeseen conditions, and anticipated cost escalation leading up to the projected construction year.
- Prevailing wages are provided as a general increase based on past construction pricing.
- All Division costs are rounded up to the nearest $1,000.

- Length and area dimensions for the estimate were derived from scaled AutoCAD drawings of the facility and the property. A survey was not utilized for this initial estimate.
- Geotech investigation cost assumes seven bore holes (20 feet deep), material testing, piezometer installation, and a written report.
- Topographic survey cost assumption is based on $1,000/acre.
- Building joist/eve height will be 18 feet.
- Additional division specific cost evaluation assumption may be found in Appendix F.

6.4 LEED/Zero Net Energy Assessment

RIM Architects (RIM) and STŌK have reviewed and assessed the facility's location along with reviewing the combination of state law and Leadership in Energy and Environmental Building (LEED) eligibility requirements. From this review, it is determined that this location is not eligible or required under state law to pursue LEED due to the lack of human occupancy in the proposed structures and/or square footage requirements. There is insufficient scope to pursue LEED certification. Refer to Appendix H for more information.

RIM and STŌK also prepared a zero net energy (ZNE) assessment of the facility. This assessment summarizes the power anticipated to be needed at the facility and estimated the size of photovoltaic (PV) system that would be required to offset the power use. Refer to Appendix H for more information.

6.5 Alternative Cost Estimate

The following tables illustrate the estimated costs for each of the alternatives evaluated and depicted within the worksheets in Appendix F.

Table 6-2. Alternative Cost Estimate.

Item	Estimate
Division 01 - General Requirements	$ 8,014,000
Division 02 – Existing Conditions	$ 738,000
Division 03 - Concrete	$ 4,190,000
Division 05 - Metals	$ 300,000
Division 07 – Thermal and Moisture Protection	$ 20,000
Division 08 - Openings	$ 240,000
Division 13 – Special Construction (Buildings and Tanks)	$ 24,890,000

Item	Estimate
Division 23 - Mechanical & HVAC	$ 330,000
Division 26 - Electrical	$ 3,825,000
Division 31 - Earthwork	$ 1,507,000
Division 32 – Exterior Improvements	$ 329,000
Division 33 - Utilities	$ 1,007,000
Division 40 – Process Water System	$ 2,693,000
DIRECT CONSTRUCTION COST	**$ 48,083,000**
Construction Contingency	$ 12,021,000
Overhead	$ 2,885,000
Profit	$ 3,847,000
Bond Rate	$ 481,000
TOTAL CONSTRUCTION PRICE	**$ 67,317,000**
Design, Permitting and Construction Support	$ 10,223,000
TOTAL COST ESTIMATE	**$ 77,540,000**
Accuracy Range +50%	$ 116,310,000
Accuracy Range -30%	$ 54,278,000
Photovoltaic	$ 13,225,000

7.0 Crystal Lake Fish Hatchery Environmental Permitting

7.1 Anticipated Permits and Supporting Documentation

The proposed Project would involve the modification to the existing hatchery or construction of a new hatchery facility and associated infrastructure. It would potentially involve the development of new water supply/intake/pumpstation, which would require instream construction, for the hatchery operations. A list of anticipated permits, agency review time, submittal requirements, and supporting documentation for the proposed project regardless of which alternative is selected are summarized in Table 7-1, Table 7-2, and Table 7-3. The review timeframes are estimated and are based on the recommendations presented in permit guidance documentation and experience with other permitting projects in California.

We reviewed the location through online mapping tools (USFWS IPAC and California BIOS) to determine if species listed under the Endangered Species Act (ESA) and the California Endangered Species Act (CESA) potentially occur at the site. The results indicated that the site has the potential for species to be present that are identified as endangered or threatened. The site does not contain critical habitat. The results of these mapping tools indicate that a Biological Assessment of the area would need to be prepared prior to consultation with the USFWS, NOAA, and other state agencies.

The list is developed at a high level and additional permits may need to be assessed as the project is advanced.

Table 7-1. Anticipated Federal Permits and Approvals for Selected Location.

Agency and Permit/Approval	Submittal / Document Type	Supporting Documentation	Anticipated Time Frame	Notes
USFWS National Environmental Policy Act (NEPA) Compliance	Environmental Assessment	Analysis of potential impacts on various natural resources, Design Package	12 – 18 months	Evaluation of the selected alternative to identify if there would be a significant impact.

Agency and Permit/Approval	Submittal / Document Type	Supporting Documentation	Anticipated Time Frame	Notes
U.S. Army Corps of Engineers (USACE) Clean Water Act (CWA) Section 404 - Nationwide Permit Authorization	Pre-Construction Notification Application	Wetland and Stream Delineation, Design Package	3 months	Required if jurisdictional waters of the U.S. or wetlands are affected by the Project area.
USFWS ESA Section 7 Consultation	Biological Assessment	Field surveys of affected area, Design Package	4 months	The site has potential for species listed under the ESA to occur.
National Oceanic and Atmospheric Administration (NOAA) Section 10(a)(1)(A) of the ESA	Application	Supplemental information to include description of proposed project, analysis of potential take and potential impact to species, proposed minimization and mitigation measures, and funding source	4 months	Authorization for scientific purposes or to enhance the propagation or survival of an endangered or threatened species.

Table 7-2. Anticipated State Permits and Approvals for Selected Location.

Agency and Permit/Approval	Submittal / Document Type	Supporting Documentation	Anticipated Time Frame	Notes
Lead Agency TBD California Environmental Quality Act (CEQA)	Environmental Impact Report	Analysis of potential impacts on various natural resources, Design Package	12 – 18 months	Required for issuing state permits. Potential to be coordinated with the NEPA compliance for efficiency.

Agency and Permit/Approval	Submittal / Document Type	Supporting Documentation	Anticipated Time Frame	Notes
California Department of Fish and Wildlife (CDFW) California Fish and Wildlife Code Section 2081 Incidental Take	Application	Supplemental information to include description of proposed project, analysis of potential take and potential impact to species, proposed minimization and mitigation measures, and funding source	4 months	Required for the authorization to take any species listed under the California Endangered Species Act.
California Department of Fish and Wildlife (CDFW) California Fish and Wildlife Code Section 1600 Lake and Streambed Permits	Application/ Notification	N/A	1-3 months	Required for hatchery intake diversions.
Central Valley Regional Water Quality Control Board (RWQCB) 401 Water Quality Certification	Application	Wetland and Stream Delineation USACE Review NEPA/CEQA Compliance	3 months	Required if jurisdictional waters of the U.S. or wetlands are affected by the Project area.
California Office of Historic Preservation Section 106 Review	Concurrence Request Letter	Cultural Resources Survey, Design Package	3 months	Required as part of the NEPA/CEQA process.
California Division of Water Rights Water Rights	Application or Transfer	N/A	4 months	N/A

Agency and Permit/Approval	Submittal / Document Type	Supporting Documentation	Anticipated Time Frame	Notes
California State Water Resources Control Board (SWRCB) National Pollutant Discharge Elimination System (NPDES)	Facility renovation/construction may trigger "New Source" permit for NPDES	N/A	6 months	Required if hatchery effluent is discharged to a jurisdictional waterway.
SWRCB Construction General Permit	Application	Stormwater Pollution Prevention Plan (SWPPP)	2 months	Required if construction activities disturb greater than one acre.

Table 7-3. Anticipated Shasta County Permits and Approvals for Selected Location.

Agency and Permit/Approval	Submittal / Document Type	Supporting Documentation	Anticipated Time Frame	Notes
Shasta County Building Division	Grading, Building, Electrical, Mechanical, Pumping Applications	Project Summary and Design Package	2 months	N/A

7.2 National Pollutant Discharge Elimination System (NPDES) Permitting

The Crystal Lake Fish Hatchery is classified as a cold water Concentrated Aquatic Animal Production (CAAP) facility and is eligible to operate under General Order R5-2019-0079-009 issued by the Regional Water Quality Control Board, Central Valley (Region 5) and NPDES Permit No. CAG135001. This general order supersedes the previous NOA issued April 11, 2016.

Wastewater is discharged through Outfall 001 (Latitude: 40° 56' 00.03" N; and Longitude: 121° 32' 38.99" W) and Outfall 002 (Latitude: 40° 56' 02.07" N; and Longitude: 121° 32' 51.89" W).

The permit identifies formaldehyde and chlorine as potential pollutants from the hatchery. The following limitations for formaldehyde and chlorine effluent are specified:

- Formaldehyde: 0.65 mg/L (monthly average), 1.3 mg/L (daily maximum)

- Chlorine: 0.018 mg/L (daily maximum)

7.3 Water Rights

Water rights documentation can be obtained from the client if requested by an agency.

8.0 Conclusions and Recommendations

This report provides a summary of the state of the Crystal Lake Hatchery, identifies and quantifies the impacts that the Hatchery could experience as a result of climate change, and provides proposed facility design modifications to increase the resiliency of the hatchery in conjunction with the associated costs and the potential impacts of the proposed modifications.

The in-depth analysis of the available hydrologic and climatologic data performed by NHC provides projections to forecast changes that may be experienced at the hatchery. In general, significant increases in air and water temperature are expected at Crystal Lake. Additionally, there will be an increasing risk of wildfire as the climate changes.

To meet CDFW's goal of continuing to provide recreational fishing opportunities for the public and for the conservation of endangered or threatened species as the climate changes, the resiliency of existing hatcheries will need to be increased. Increasing resiliency will also require updating existing infrastructure that is nearing the end of its effective lifespan.

Some recommendations that would help to achieve this goal include the following:

- Improving the treatment of the incoming water will provide improved flow control and protection against pathogens.
- Replacing pipes and valves that are near the end of their effective lifespan or are currently inoperable due to age.
- Replacing flow-through style raceways with circular dual-drain tanks utilizing partial recirculating aquaculture systems (PRASs) to reduce the amount of water that is required to raise fish and to provide for improved effluent handling and treatment.
- Covering all rearing vessels with solid roofs will reduce the impacts of increased heat for both the fish and the employees.

The proposed upgrades to the Crystal Lake Fish Hatchery would have negligible impacts on the natural resources in the surrounding area. All improvements would occur within currently developed areas, which lessen the permit requirements. The total cost estimate of the proposed design modifications is $77,540,000.

9.0 References

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