Climate Induced Hatchery Upgrades

Mad River Hatchery

Alternatives Analysis Submittal

Final Report
Revision No. 3

February 2025

This page intentionally left blank.

Table of Contents

List of Tables

List of Figures

Distribution

To: Daniel Niederberger, PE
CDFW

Kenneth Kundargi, Hatchery Program Manager
CDFW

From: Jon Burgi, PE
McMillen, Inc.

Prepared By: Jon Burgi, PE
Evan Jones
Laura Bailey
Brian Rogers
Mark Drobish
McMillen, Inc.

Reviewed By: Derek Nelson, PE
Jeff Heindel
Marcelo Cerucci
Sarah Harris
McMillen, Inc.

Revision Log

Revision No.	Date	Revision Description
0	3/15/2024	65% Draft Submittal
1	08/23/2024	Draft Final Submittal
2	10/31/2024	Final Submittal
3	2/14/2025	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 Estimate
- 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).

Mad River Hatchery has an aging infrastructure and deficiencies that need to be addressed in the near future in order to meet fish production goals. Inoperable wells, aging biofiltration system, lack of UV treatment redundancy, unusable raceways, electrical issues, limited rearing space, and the heating of water in the current reuse system are all items that have been noted to hinder current production. The effects of which will magnify with climate change. Biosecurity concerns include a lack of a physical barrier between spawning fish and the incubation space and the lack of foot bath disinfection stations at the hatchery.

The preferred alternative for hatchery upgrades includes installing new deeper wells to provide improved water quality, replacing piping and valving throughout the hatchery, updating electrical systems throughout the hatchery, constructing a new building to house incubation and early rearing separate from spawning, moving smolt rearing to new circular tanks with PRAS, and constructing an additional percolation pond.

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 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	Photovoltaic for ZNE
$22,164,000	$7,134,000

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 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 on achieving 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 Site Location Description

Mad River Hatchery is located in Northern California approximately 9 miles inland and 5 miles east of Arcata, CA (Figure 1-1).

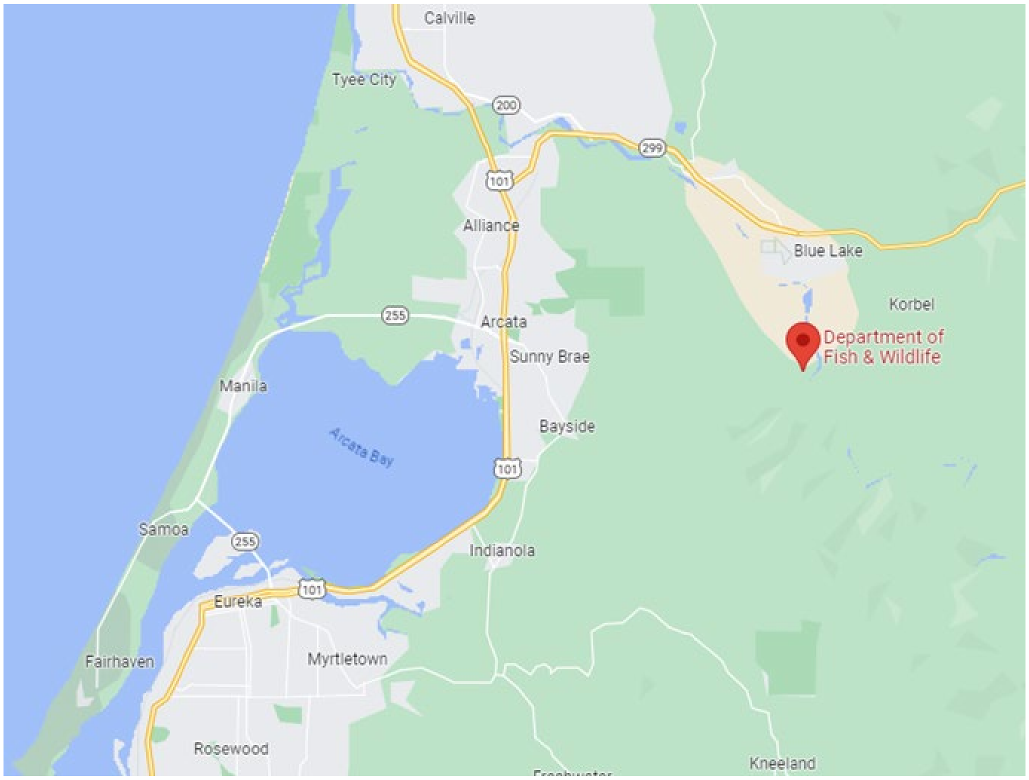

Figure 1-1. Mad River Hatchery Location Map.

The Mad River Hatchery collects broodstock and raises 150,000 Mad River steelhead trout (*Oncorhynchus mykiss*), weighing approximately 17,000 pounds total biomass to a smolt size annually. In addition to the steelhead program, the hatchery receives Rainbow Trout (*O. mykiss*) from other CDFW hatcheries, holds them for 2-4 weeks, and then transports them to their designated release site. The hatchery relies on pumped well water for single-pass use for the egg incubation and early rearing components. The raceways are operated on an 80-90% recirculation system utilizing oyster shell beds to meet biofiltration needs relative to ammonia. The general hatchery facilities are shown in Figure 1-2. See the Site Visit Report (Appendix A) for additional details regarding the existing hatchery descriptions.

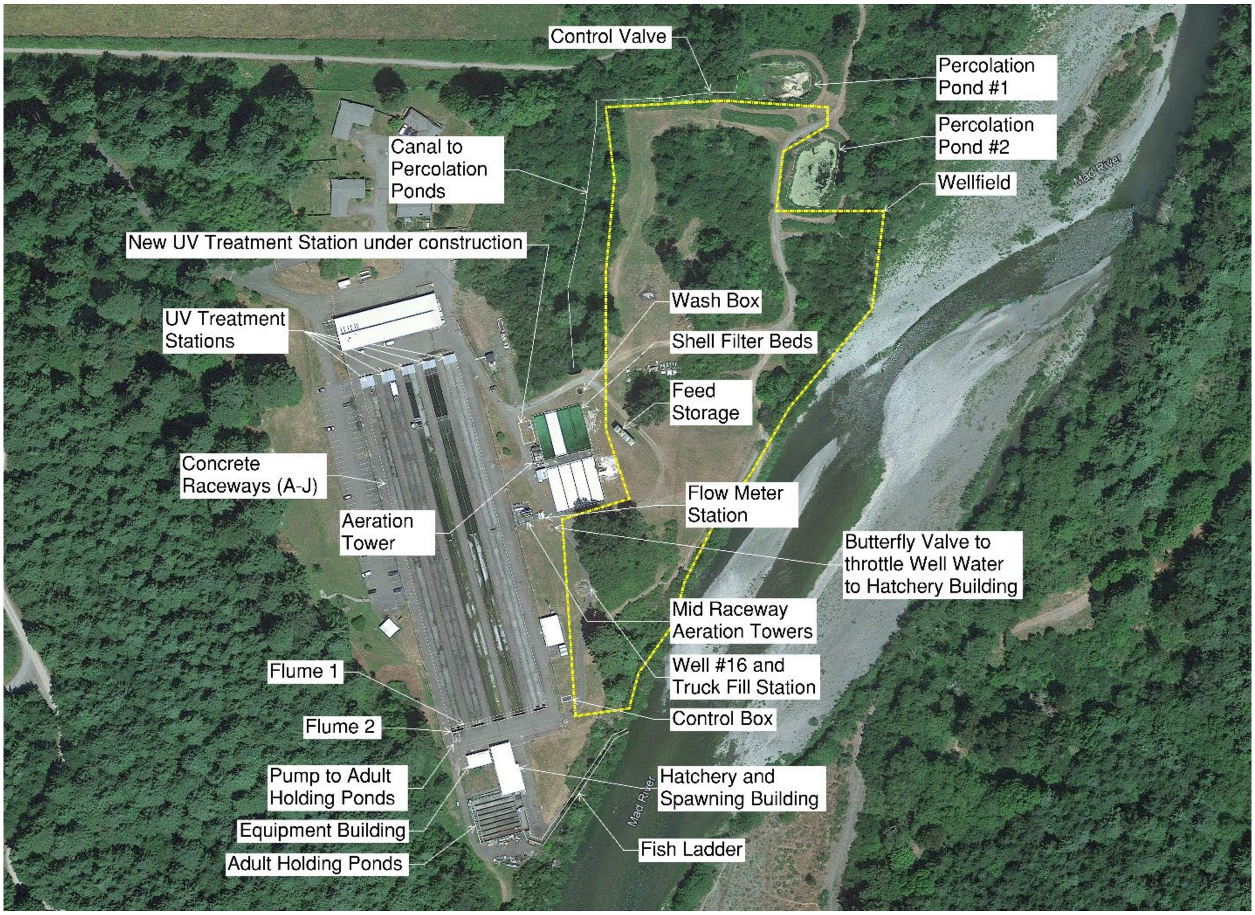

Figure 1-2. Mad River Facility Layout. Google Earth image date: 07/17/2022.

2.0 Bioprogram

2.1 Production Goals and Existing Capacity

The Mad River Hatchery was originally established by CDFW to increase Chinook Salmon (*O. tshawytscha*) for commercial fisheries. Construction of the Mad River Hatchery began in 1969 and was completed in 1971. Current operations include trapping, spawning and rearing Mad River steelhead. The hatchery's mission is not associated directly with habitat loss for wild populations and therefore, a mitigator is not associated with the facility. As a result, funding has been extremely limited to capitalize on the full production potential of this facility. The Mad River Hatchery spawns and produces Mad River steelhead for release directly into the Mad River to augment the population due to a lack of natural reproduction. In addition to steelhead production, the hatchery serves as a holding/transfer facility for the CDFW Inland Fisheries Program. The hatchery temporarily holds Rainbow Trout for short periods (e.g., 2-4 weeks typically) before they are transported to their final stocking location(s). The current production goal for the Mad River Hatchery is shown in Table 2-1.

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 (Piper, 1982) 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 annual production goal at the Mad River Hatchery is 150,000 steelhead smolts at 9 fish per pound (fpp; 6.8 inches) weighing approximately 17,000 pounds as provided by CDFW in the initial questionnaire. The hatchery also serves as a Rainbow Trout transfer facility, holding sub-catchable and/or catchable size trout temporarily until they can be transported and stocked. The fish rearing capacity determined by the Capacity Bioprogram is shown in Table 2-1.

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

Rearing Unit (max. fish size)	Total Capacity (Fish)[a]	Limiting Factor
California Troughs (700 fpp/1.6 inches)	26,826	Rearing Volume
Deep Tanks (700 fpp/1.6 inches)	99,614	Rearing Volume
Total Hatchery Building (700 fpp/1.6 inches)	126,440	Rearing Volume
Raceways (9 fpp/6.50 inches) [b]	877,443	Water Flow
Raceways (9 fpp/6.50 inches) [c]	1,096,804	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.
[b] Based on the use of a portion of 8 raceways totaling 66,000 cubic feet.
[c] Based on the use of all 10 raceways utilizing all 600 ft for a total of 180,000 cubic feet.

2.2 Bioprogram Summary

The Capacity Bioprogram in the Site Visit Report (Appendix A) demonstrates the total capacity of each rearing area at the Mad River 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. The total capacity for the Mad River Hatchery aligns with their production goal shown in Table 2-1. 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 Mad River 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 are made and included in Table 2-3. Additional assumptions include the following:

- Broodstock are available to meet full egg production targets for the hatchery program.
- There will be optimal conditions for egg development and fish growth given the existing water temperatures at the facility.
- Spawning occurs weekly from January through March for a total of 12 groups of Mad River steelhead.
- Equal numbers of fish are reared from each spawning event.
- The total rearing volume and flow rates for the troughs and deep tanks were combined to model the capacity of the hatchery building for the Production Bioprogram.
- The use of existing spawning timing and survival rates provided were used to develop the bioprogram for the Mad River Hatchery.

Klontz (1991) provided optimal growth rates, which are variable, for Rainbow Trout at designated water temperatures, and survival rates were provided in the questionnaire completed by Mad River Hatchery staff.

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

Criteria	Value
Density Index (DI)	0.30
Flow Index (FI)	1.32
Water Temperature	Early Rearing: 54-57°F Raceway Rearing: 44-68°F

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

Life Stage	Value
Egg-to-fry	98%
Fry-to-juvenile (700 fpp)	91%
Juvenile-to-outplant (9 fpp)	77%

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 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 is modeled based on weekly spawning events starting in January and ending in March and utilize the timing and growth for the progeny originating from the first spawning event in January for display (Table 2-4,Table 2-5). Hatchery staff adjust growth rates based on the number of months between spawning events, the target release date, and the highly variable water temperatures for the facility. During the summer months, due to the 80-90% recirculation system for the raceways, the water temperatures rise into the upper 60°F range. It is routine practice at the hatchery to slow fish growth by reducing feed when water temperatures rise to ensure the target size is achieved but not exceeded.

2.2.2.1 Mad River Steelhead Early Rearing

The Mad River Hatchery spawn steelhead weekly from January through March resulting in a total of 12 spawning events. Therefore, egg and fish development and growth are staggered by approximately 7 days between each spawning event. For incubation and early rearing, water temperatures from the wells vary from 54-57°F, therefore 56°F was used for a constant water temperature per CDFW staff. Incubation occurs in the Heath trays. It takes approximately 42 days from fertilization (i.e., green eggs) to first feeding which would begin in mid-February when fish are approximately 1,800 fpp (1.2 inches). The progeny from each spawning event move through the various life stages and rearing areas like an assembly line since spawning events occur at approximately 7-day intervals.

After incubation in the Heath trays, the fry are transferred into troughs (8) and deep tanks (6) where they are briefly reared until they reach approximately 700 fpp since early rearing space is limited. Since spawning is spread out over a period of approximately 3 months, only a portion of the steelhead occupy incubation and the early rearing tanks at any one time. Table 2-4 provides a snapshot of the maximum number of fish at a given time during early rearing ranging from February into June. Table 2-4 also provides a snapshot of the month of April when biomass in the early rearing tanks is peaking.

Table 2-4. End of Month Production Information during early rearing for the Mad River Steelhead 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
Feb-June	Troughs and Deep Tanks	14	1,275	1.3	195,000	152.9	0.6	0.28	0.42
April	Troughs and Deep Tanks	14	700.0	1.6	126,000[a]	180.0	0.6	0.27	0.40

[a] Total fish numbers are low as some of the fish from the earlier spawning events have been transferred into the raceways once they have achieved the target transfer size of 700 fpp.

2.2.2.2 Mad River Steelhead Raceway Rearing

The progeny from the first spawning event are transferred into the raceways starting in March and this continues weekly into June as the progeny from each spawning event reach a size of approximately 700 fpp (1.6 inches). Initially, the fish are transferred into the upper 100-200 feet of Raceways A and B as they outgrow the early rearing tanks and over time these fish are all reared in the upper 300 feet of Raceways E-J (6 raceways) where they remain until their release the following spring at a target size of 9 fpp (Table 2-5). Relatively high water temperatures provide growth potential exceeding the needs for the fish to achieve their target size the following March. Hatchery staff adjust feed rates to regulate growth for the progeny from each spawning event to achieve but not exceed the final target size of 9 fpp by the release date(s). In this exercise, it is assumed approximately 220,000 eggs are collected for all steelhead spawning events and approximately 214,000 fry are hatched from those eggs resulting in approximately 195,000 juveniles being transferred into the raceways yielding approximately 150,000 smolts for release into the Mad River.

Table 2-5. End of Month Production Information during raceway rearing for the Mad River Steelhead 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
March-May	Raceways	1	161.0	2.6	90,000[a]	559.0	1.0	0.04	0.48
June	Raceways	2	106.0	3.0	197,000[b]	1,858.5	4.0	0.05	0.34
Jul	Raceways	2	72.0	3.4	191,778	2,663.6	5.0	0.07	0.35
Aug	Raceways	4	48.0	3.9	186,556	3,886.6	12.0	0.04	0.18
Sep	Raceways	4	32.0	4.4	181,334	5,666.7	16.0	0.04	0.18

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Oct	Raceways	6	27.0	4.7	176,112	6,522.7	18.0	0.03	0.17
Nov	Raceways	6	21.0	5.1	170,890	8,137.6	18.0	0.03	0.20
Dec	Raceways	6	17.0	5.5	165,668	9,745.2	18.0	0.03	0.22
Jan	Raceways	6	14.0	5.9	160,446	11,460.4	18.0	0.04	0.24
Feb	Raceways	6	11.4	6.3	115,224	10,107.4	18.0	0.03	0.20
Mar	Raceways	6	9.0	6.7	150,000	16,666.7	18.0	0.05	0.31

[a] Steelhead are still being transitioned from the early rearing tanks into the raceways at this time resulting in an increase in total fish numbers.

[b] All spawn groups have been transferred to the raceways by the end of June.

2.2.2.3 Rainbow Trout Transfer Program

On a seasonal basis, the hatchery temporarily holds Rainbow Trout transfers that have been reared to a catchable or sub-catchable size at another CDFW hatchery and transported to the Mad River Hatchery (Table 2-6). The Mad River Hatchery holds the transfers in two raceways before the fish are transported to the stocking destination. On occasion, the Mad River Hatchery may hold these transfers for 4-6 weeks depending upon water temperatures at the stocking location(s).

Table 2-6. End of Month Production Information for the Rainbow Trout Transfers 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
May/Jun/Jul	Raceways	2	10.0	6.3	230,000	23,000.0	6.0	0.20	1.36
May/Jun/Jul	Raceways	2	2.0	10.8	80,000	40,000.0	6.0	0.21	1.38

2.2.2.4 Summary

It should be noted that the FIs and DIs at the end of each month for both early rearing and raceway rearing are within the criteria specified in Table 2-2. The DI reaches 0.28 during early rearing which approaches the maximum 0.30 identified for the facility and then remains below 0.10 in the raceways throughout the remainder of the rearing cycle (Table 2-5). The FI remains well below the maximum 1.55 identified for the facility in both early rearing and in the raceways (Table 2-5). Maintaining the FI well below the 1.55 value is key as the hatchery operates on 80-90% recirculation as water temperatures increase above recommended rearing temperatures for steelhead. The hatchery has not experienced problems when the warmer water temperatures occur, but both the rearing densities and flows are extremely conservative for the raceways which is likely key to the success at the hatchery.

Water demand will be the highest from October through March as production biomass is the highest until the smolts are released. The water flow specified in Figure 2-1 is intended to show the flow requirement assuming all rearing areas are supplied with the maximum water flow of which is 80-90% recirculated. Specified flow data from the water budget in the questionnaire along with Mad River Hatchery staff input relative to spawning and rearing timing were included in the development of Figure 2-1. Note that the different colored blocks in the following figure correspond to the months for when each species is in the troughs or deep tanks or in the raceways, along with noting when eggs are received and incubated.

The Mad River production cycle is repeated year after year and provides downtime for some hatchery components for cleaning and maintenance. The total annual production meets the mitigation goals for the Mad River Hatchery producing 150,000 smolts weighing approximately 17,000 pounds. In addition to this mitigation production, the hatchery has a limited ability to hold Rainbow Trout transfers for distribution to final stocking locations. There is potential at the Mad River Hatchery to increase production for other species such as Rainbow Trout; however, the facility has several deficiencies preventing this. The hatchery currently operates on four “trusted” wells out of a total of 18 developed wells, the existing raceways have aged/settled and are not all usable, the mid-pond aeration system is currently out of service due to failure and the lack of alarm systems which renders the lower 300 feet of all 10 raceways unusable. Additionally, the existing recirculation system ties all water for the raceways into a single system and bringing in additional outside production including the temporary holding of Rainbow Trout transfers increases the biosecurity risk. UV systems are in place to prevent the spread of disease between raceways under recirculating conditions. These deficiencies will be discussed in greater detail in Section 4.0.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MAD RIVER STEELHEAD																								
Eggs Received																								
Egg Incubation																								
Early Rearing in Troughs/Deep Tanks																								
Production Rearing in Raceways																								
RAINBOW TROUT TRANSFERS																								
Production Rearing in Raceways																								
Max Flow in CFS	6.0	6.3	6.3	0.3	4.3	5.3	5.5	3.0	4.0	6.0	6.0	6.0	6.0	6.3	6.3	0.3	4.3	5.3	5.5	3.0	4.0	6.0	6.0	6.0

Figure 2-1. Production Rearing Schedule Over 2 Years with Peak Water Demand Occurring Annually in October through March (as highlighted in the Max Flow in CFS 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

The primary water source for the hatchery are four operable wells, which are located next to the Mad River. Only two of these four wells are being used consistently.

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 Variable Infiltration Capacity (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.

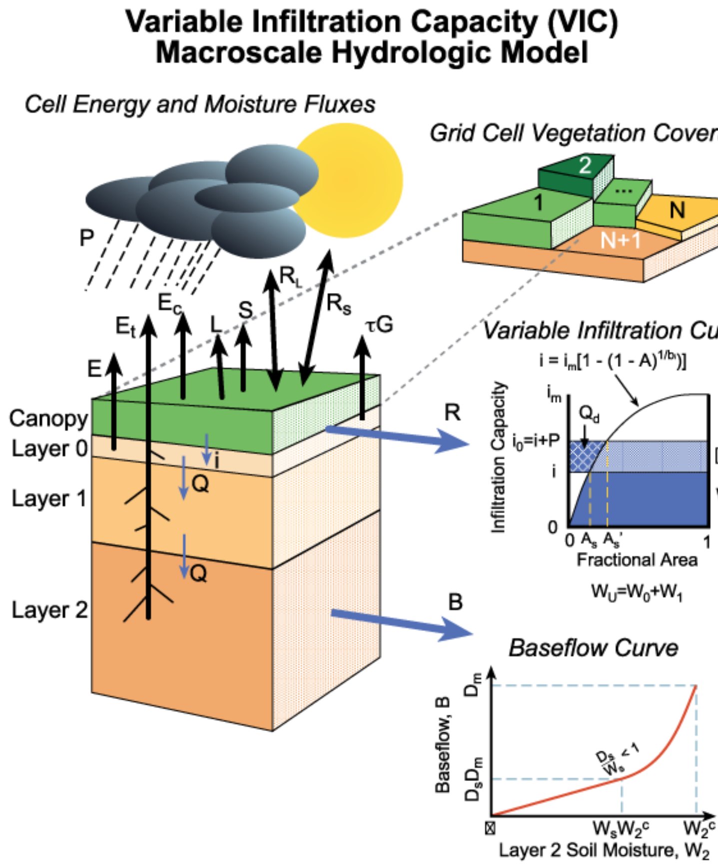

Figure 3-1. The VIC Hydrologic Model. Figure Source: University of Washington, (2021).

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 and precipitation) 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 daily and seasonal snow accumulation over the Mad River watershed, and stream flows nearby the hatchery,** were obtained by aggregating over the watershed the grid cell-based snowpack and streamflow projections made available by the same research consortium as in item (1) above (Vano et al., 2020). These publicly available projections were obtained by driving the VIC hydrologic model with the CMIP5 daily climate projections.
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 affecting groundwater recharge.

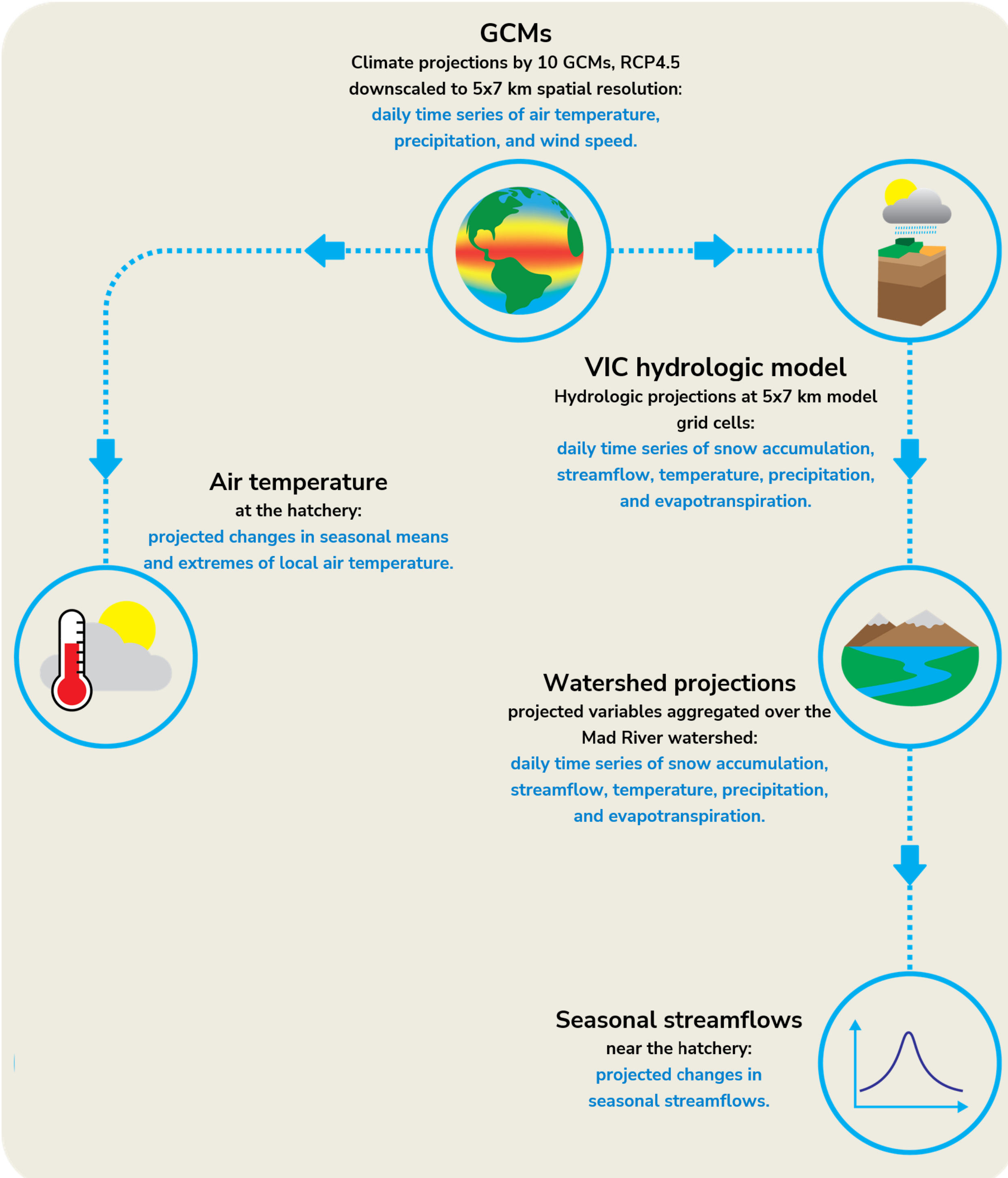

Figure 3-2. Methodology for Obtaining Projections.

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, streamflow 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 site. 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 gives in parentheses the temperature change relative to the reference period. All time horizons, including the reference period, are simulated by the ensemble of 10 GCMs. The highest and lowest change among the 10 different GCMs in each season are also 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 (T_{max}) for two future time periods, relative to the reference period. Again, all time horizons in Table 3-4 and Table 3-5, 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 1.9°F in the near-future period compared to the reference period (1984-2003), and by an additional 1.1°F in the mid-century period. The season with the most warming is the summer (Figure 3-3, 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 2.1°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, 2.4°F, reaching 76.3°F.

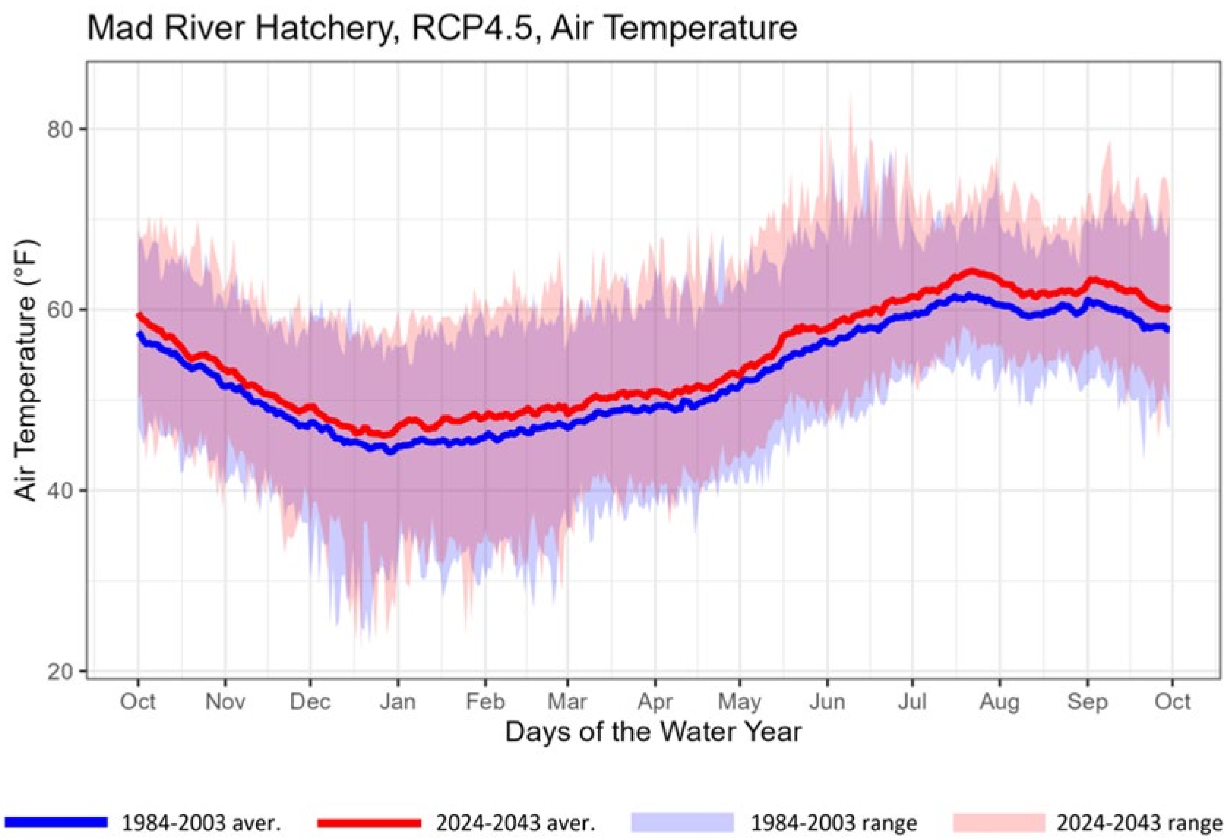

Figure 3-3. Mean Daily Air Temperature and Range for Each Day of the Year.

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	54.7°F (+1.9°F)	48.1°F (+2.0°F)	53.1°F (+1.7°F)	61.9°F (+2.1°F)	55.8°F (+1.9°F)
Lowest	54.4°F (+1.6°F)	47.3°F (+1.2°F)	52.4°F (+1.0°F)	60.8°F (+1.0°F)	55.0°F (+1.1°F)
Highest	55.5°F (+2.7°F)	48.8°F (+2.7°F)	54.2°F (+2.8°F)	63.1°F (+3.3°F)	56.5°F (+2.6°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	55.8°F (+3.0°F)	49.2°F (+3.1°F)	54.1°F (+2.7°F)	63.0°F (+3.2°F)	56.9°F (+3.0°F)
Lowest	55.2°F (+2.4°F)	48.3°F (+2.2°F)	53.1°F (+1.7°F)	61.7°F (+1.9°F)	55.8°F (+1.9°F)
Highest	56.6°F (+3.8°F)	49.8°F (+3.7°F)	64.4°F (+3.6°F)	64.6°F (+4.6°F)	58.3°F (+4.4°F)

Table 3-4. Projected GCM 2024-2043 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	49.9°F (+1.9°F)	57.0°F (+1.8°F)	63.0°F (+1.7°F)	69.9°F (+2.1°F)	76.3°F (+2.4°F)
Lowest	48.8°F (+0.8°F)	56.4°F (+1.2°F)	62.5°F (+1.2°F)	69.5°F (+1.7°F)	75.3°F (+1.4°F)
Highest	51.5°F (+3.5°F)	57.6°F (+2.4°F)	63.5°F (+2.2°F)	71.2°F (+3.4°F)	77.7°F (+3.8°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	51.2°F (+3.2°F)	58.0°F (+2.8°F)	64.1°F (+2.8°F)	70.9°F (+3.1°F)	77.6°F (+3.7°F)
Lowest	50.3°F (+2.3°F)	57.5°F (+2.3°F)	63.2°F (+1.9°F)	69.9°F (+2.1°F)	76.0°F (+2.1°F)
Highest	52.1°F (+4.1°F)	58.4°F (+°3.2F)	64.9°F (+3.6°F)	72.5°F (+4.7°F)	79.1°F (+5.2°F)

3.5.2 Water Temperature

Assuming the groundwater that supplies the hatchery is shallow groundwater, it can be expected that its temperature will rise over time by a similar amount as the mean annual temperature rise. As seen above, the projected mean annual temperature rise for the next 20 years (2024-2043) compared to the reference period (1984-2003) is just under 2°F.

3.5.3 Snowpack and Streamflow in the Mad River Watershed

Information received from the hatchery indicates the risk of flooding from the Mad River is remote because the hatchery is located some height above the river, and the riverbed widens at that location. Nevertheless, per the hatchery questionnaire responses, well water becomes cloudy during high flow events on the river. For this reason, in this sub-section projected peak flows are presented.

Projected air temperature rise will lead to important changes in the hydrologic regime of the Mad River watershed. Figure 3-4 displays the projected mean daily snowpack (solid lines) and range from minimum to maximum (shaded areas) for each day of the year at Mad River near the hatchery, for the near future (red) and the reference time period (blue). Figure 3-5 displays the projected streamflow in a similar manner to Figure 3-4. Data in both figures are simulated by the ensemble of 10 GCMs for each time period, including the reference period. The Mad River watershed upstream of the hatchery site has an estimated 395 square miles, according to StreamStats (USGS, 2019).

The shift from snowfall to rainfall in the cold months will result in diminished snowpack and earlier snowmelt (Figure 3-4), and increased risk of high streamflow peaks in the cold season (Figure 3-5). Reflecting the increase in winter rain-to-snow ratio, the projected 2024-2043 snow accumulation is on average smaller and, given the higher spring and summer temperatures, projected snowmelt occurs earlier (Figure 3-5). Significant increases in fall and winter streamflow are projected for the near-future period (+9% and +16%, respectively), and in winter streamflow for the mid-century period (+37%), relative to the reference period.

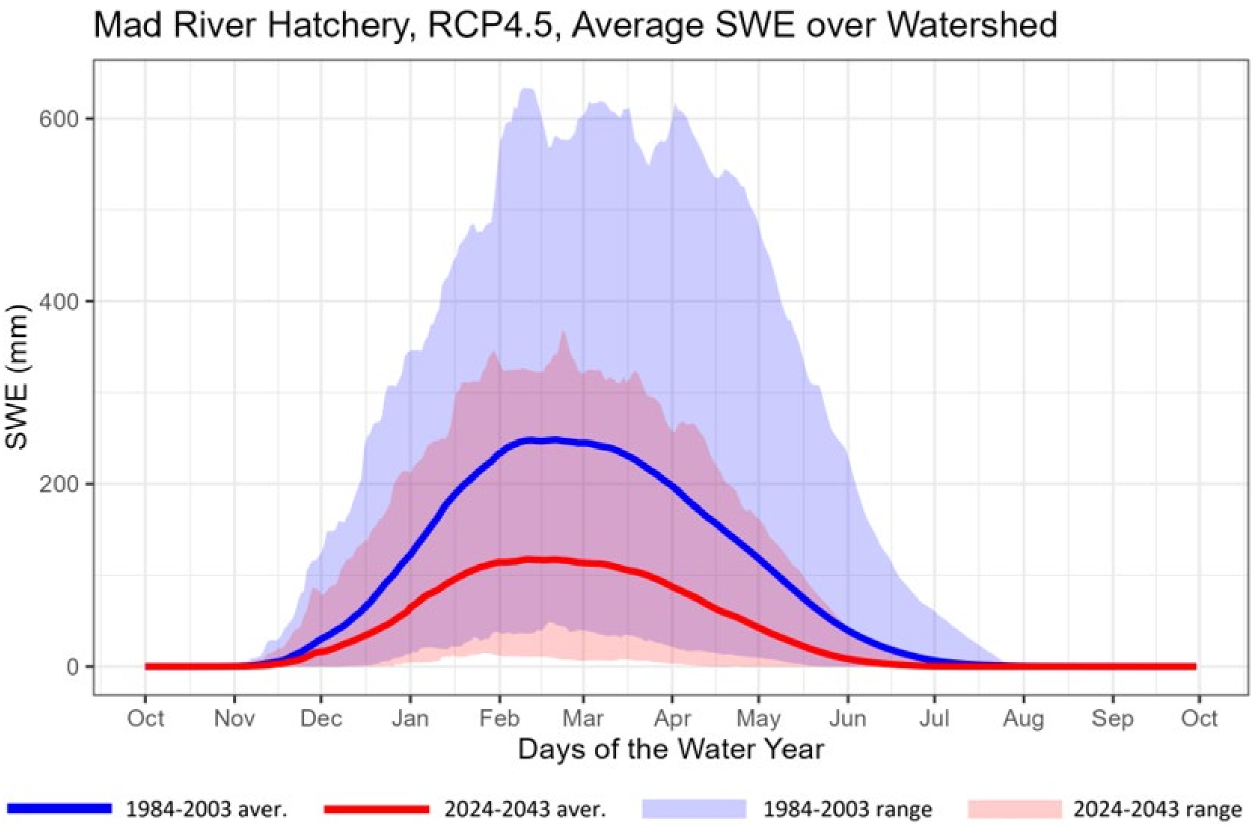

Figure 3-4 Mean Daily Snow Water Equivalent and Range for each day of the year.

The mean daily streamflows (solid lines) displayed in Figure 3-5 show increases in the colder months (November through March) and declines in summer (June-August). Seasonal streamflow changes are summarized in Table 3-6, with large increases in mean winter streamflow and percentually large declines in the already dry summer. There is also a projected increase in total winter precipitation for 2024-2043 compared to 1984-2003, but it is small (+1.5%), contributing little to the higher winter peak flows. Projected summer low flows start about one month earlier (Figure 3-5).

Note that precipitation is subject to intense natural variability (from year to year and decade to decade), especially in California. The GCM simulations also behave in this way. Therefore, there is a strong stochastic component in all precipitation projections, which implies that the percentages in Table 3-6 reflect random variations as well as a possible climate change signal. There is therefore great uncertainty associated with the values in the table. The stochastic element also explains the sign reversal in fall season projections seen in the table, which are positive (increase in P-E) in the near future period, but negative (decline in P-E) in the end-century period.

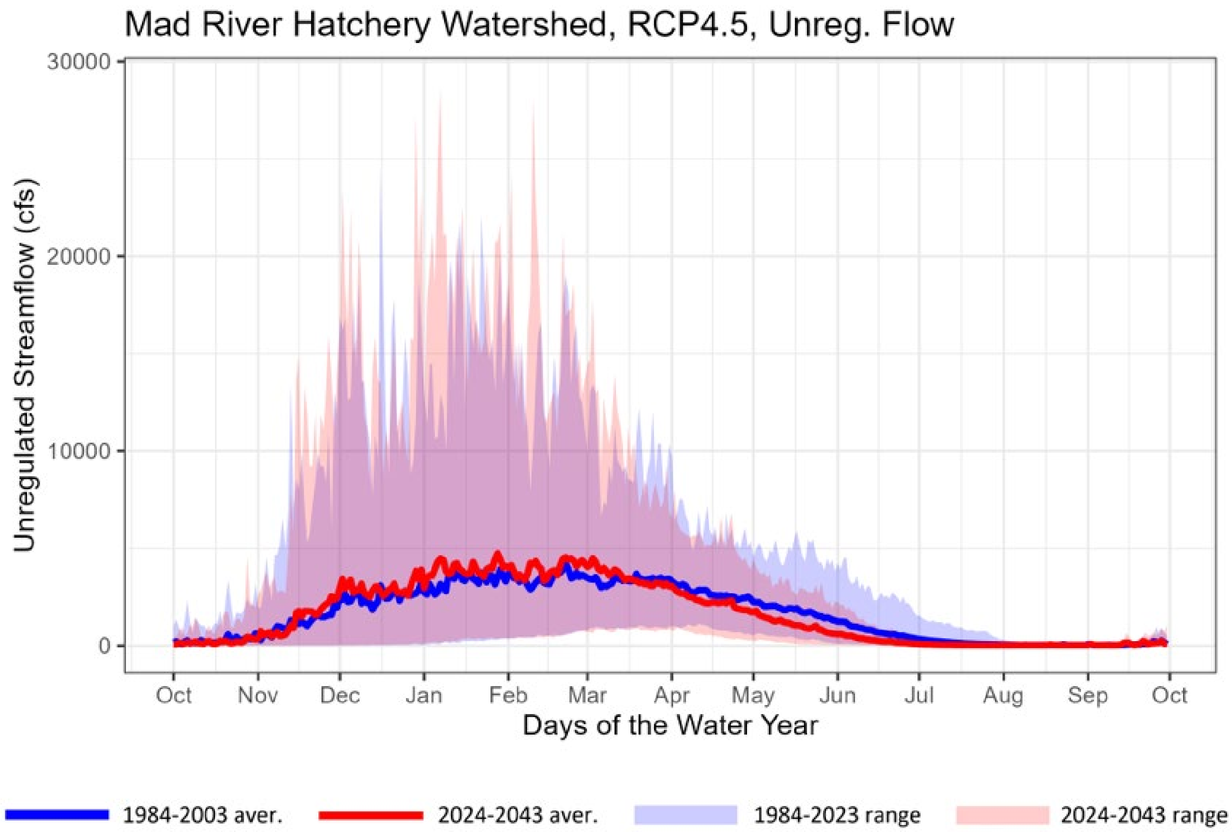

Figure 3-5 Mean Daily Streamflow and Range for each day of the year.

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	≈0%	+16%	-12%	-62%	+9%

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	+5%	+37%	-22%	-72%	-7%

The daily streamflow values which in the reference period (1984-2003) had a probability of being exceeded in any given year equal to 1-in-5, 1-in-10 and 1-in-20, i.e., being surpassed once every 5 years, 10 years and 20 years, were determined by frequency analysis of the hydrologic model simulations for the 10 GCMs. The new return period for these peak flows projected for the current period and each future period is given in Table 3-8 and Table 3-7. These streamflow peaks, which occur mostly in winter (December-February) correspond to heavy rainfall events or rain-on-snow events. The return period of a fixed peak flow declines over time.

Table 3-8 Projected Change in Peak Streamflow Frequency for the Mad River.

Time Horizon	Return period (yr)	Return period (yr)	Return period (yr)
1984-2003	5	10	20
2004-2023	4	9	17
2024-2043	4	8	15
2044-2063	3	5	10

3.5.4 Wildfire Risk

Historical wildfires have been documented within the watershed perimeter, as mapped in Figure 3-6. The historical 2020 August Complex Fire (more than one million acres) burned the upper portion of the watershed, but the lower basin has not burned in the past century (or has not been documented). The watershed is primarily forested and mapped as redwood, with some grassland and shrubland in the immediate vicinity of the hatchery. For the broader watershed, which consists of mostly conifer forests, the fuel recovery rate is typically more than 10 years but varies with burn severity and tree type, while shrubland and grassland can recover in less than five years.

Expressing wildfire risk as a percent chance of occurring at least once in a decade, the projected wildfire risk averaged across the watershed is 25% through mid-century (Figure 3-6). At the hatchery site, the risk is much lower at 10 to 15% through mid-century.

Fire-related risks to the hatchery consist of surface water impacts from wildfire burn scars as well as infrastructure impacts. Increased runoff along burn scars can increase flooding and turbidity with the first five years of a post-fire landscape. Given the history of large fires in the watershed and surrounding basins, future concerns to the hatchery include burn scar-induced flooding, turbidity, debris (soil erosion), and relatively higher water temperatures while riparian shade trees recover. Given the lack of documented fires in the lower basin, there is also an increasing risk of fire occurring in the mature forests closer to the hatchery.

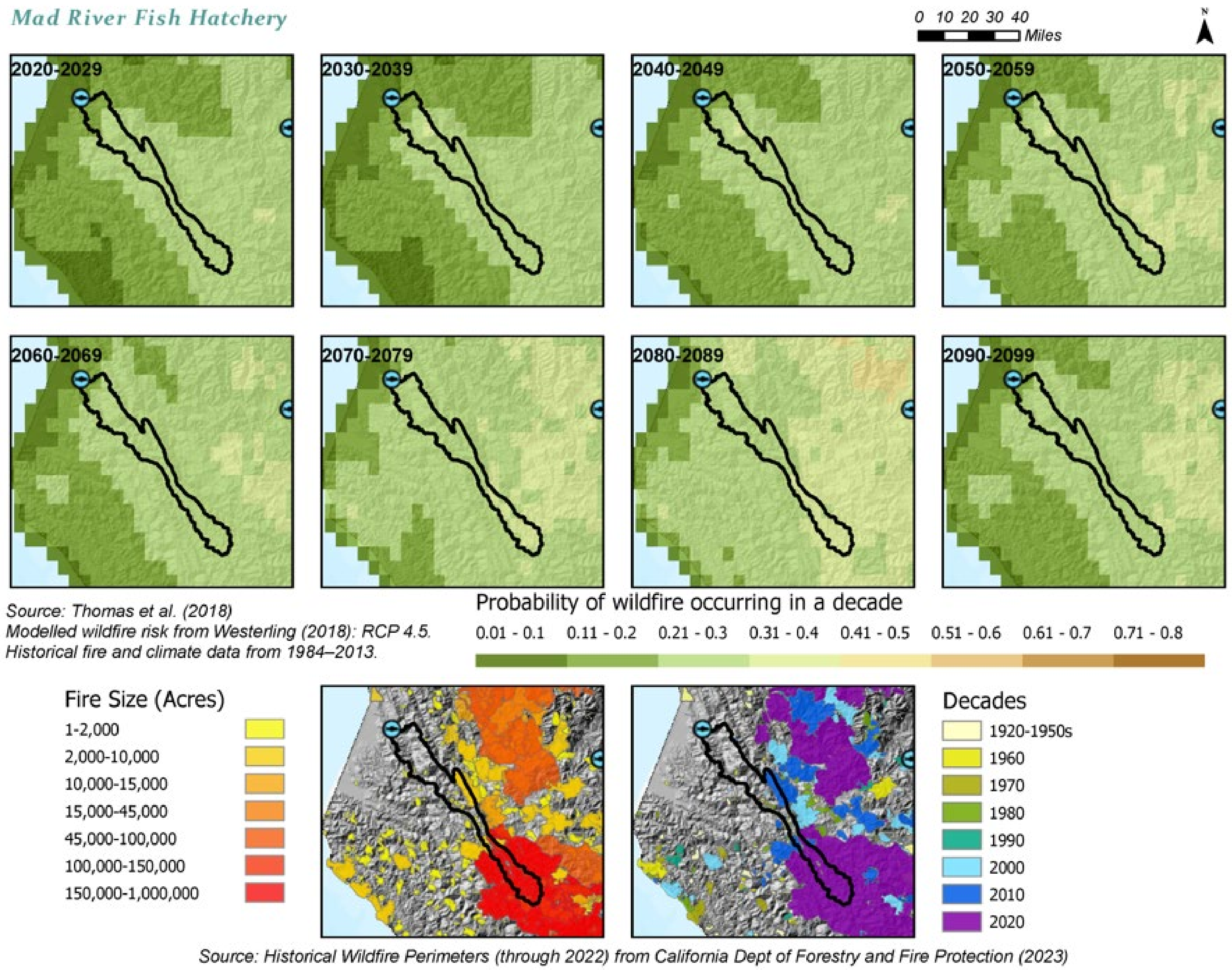

Figure 3-6. Wildfire Risk as Probability of Future Occurrence and Known Historical Fires.

3.6 Conclusions

Significant increases in air temperature are expected for the Mad River Hatchery location. Mean annual air temperature is projected to rise by 1.9°F in the next 20 years (2024-2043) and by an additional 1.1°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 2.1°F and 2.4°F, respectively, in the next 20 years, relative to the reference period.

According to the observations-based gridded air temperature dataset used in this study (Livneh et al., 2013), the 75th and 97th percentiles of peak daytime temperature (i.e., the temperature at the hottest time of day) at the hatchery site in the reference period (1984-2003) were 67.8°F and 73.9°F. For the near future period (2024-2043), these percentiles are projected by the GCM ensemble to rise to 69.9°F and 76.3°F, respectively.

Assuming the groundwater that supplies the hatchery is shallow groundwater, it can be expected that its temperature will rise over time by a similar amount as the mean annual temperature rise. As seen above, the projected mean annual temperature rise for the next 20 years (2024-2043) compared to the reference period (1984-2003) is just under 2°F.

The projected air temperature rise will lead to important hydrologic changes in the Mad River watershed, with a shift from snowfall to rainfall in the cold months. As a result, a diminished snowpack and an earlier snowmelt timing by about one month are projected. Increased risk of high streamflow peaks in the cold season are also projected, reflecting the increase in winter rain-to-snow ratio. For example, the peak flow which in the reference period had a return period of 20 years (i.e., had a probability of 1-in-20 of being surpassed in any given year), has a projected return period of 15 years in the near-future period and of 10 years in the mid-century period.

The hatchery is at significant risk of wildfires. There is a history of large fires in the watershed and, given the absence of fire in the lower basin, there is an increasing risk of fire in the near term. The projected chance of at least one wildfire occurring in a 10-year period at the hatchery site is estimated as 15% through mid-century. Across the watershed, this risk is estimated as one-in-four (25%). 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

Multiple hatchery deficiencies were identified during the site visit and 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 maintain current production goals. The primary areas of concern for the Hatchery are the inoperable wells, aging biofiltration system, lack of UV treatment redundancy, lack of an alarm on the mid-raceway aeration system, electrical issues, limited early rearing space, and the warming of water in the PRAS system. Biosecurity deficiencies and potential solutions for addressing them were identified in Sections 3.0 and 3.2 of the Site Visit Report, respectively. The primary biosecurity concerns for the hatchery are the lack of a physical barrier between the spawning and incubation space and the lack of foot cleaning stations at the hatchery entrances. The details of these deficiencies are further expanded upon in Sections 4.1 and 4.2.

4.1 Water Process Infrastructure

4.1.1 Inoperable Wells

The Mad River Hatchery has 18 wells on site, of which only four are "trusted" by the hatchery staff. The remaining 14 wells are inoperable due to providing poor quality water or to mechanical failure. All 18 wells are located in a well field adjacent to Mad River. The wells range between 38 to 75 feet deep, which likely means there is groundwater-to-surface water interaction. The water quality of the Mad River could be affecting the water quality of the wells. Additionally, the limited number of wells reduces the resiliency of the incoming water supply. If one of the remaining wells breaks, it could severely limit the hatchery's production capabilities.

4.1.2 Aging Biofilter System

The reuse water is treated for ammonia using eight filter beds consisting of four feet of coarse rock and two feet of oyster shells. The oyster beds were installed when the hatchery was built in 1968 and show signs of aging. The hatchery staff has been diligent in its system maintenance, but it is likely reaching the end of its lifespan. The condition of the concrete is starting to deteriorate. The oyster shells are supplied by a local supplier and replaced yearly, but the coarse rocks have not been replaced since construction. The efficiency of ammonia removal by the oyster bed biofilter has not been measured by hatchery staff, but they did not note any water quality concerns related to ammonia.

Additionally, the reuse system at Mad River Fish Hatchery does not have any solids filtration before the filter beds, and as a result, solids settle out on the oyster shells. This can increase the biochemical oxygen demand (BOD) of the water. The filter beds are also not biosecure and are exposed to the environment.

The biofilter infrastructure needs rehabilitation, and the deteriorated intake manifold currently limits the system and requires replacement. Piping and valves are in poor condition, with several valves being inoperable. Each filter bed has one backwash system that uses compressed air. The backwash system and blowers are from the original installation. The hatchery staff have been able to maintain this system, but it is likely reaching the end of its lifespan.

4.1.3 No UV Treatment Redundancy

In 2023, the Mad River Hatchery installed a new UV treatment system downstream of the aeration chamber, providing UV treatment to all water going to the raceways. The existing UV treatment stations at the heads of each raceway will be removed. However, the hatchery only had finalized plans to install one unit to treat the entire flow. The installation of only one unit does not create any redundancies and puts the hatchery at risk of failure. If the UV unit is taken offline or fails, the reuse flow is not disinfected, and pathogens could spread throughout the system. Furthermore, UV Units require the bulbs to be replaced, the quartz sleeves to be cleaned annually, and general maintenance.

4.1.4 No Alarm on Mid-Raceway Aeration System

The hatchery can treat the water at the 300-foot point in the raceways using an aeration tower. The mid-raceway aeration system was renovated in 2014, and new pumps with variable frequency drives were installed. However, the mid-raceway aeration has been offline for several years following an incident where the variable frequency drive (VFD) pump controls shut down, resulting in the loss of steelhead. The incident occurred in the middle of the night, and the staff were not alerted to the pump failure. The lower 300 feet of the raceway did not receive water, resulting in a significant fish loss. The aeration tower has not been used since the incident. This limits the use of the lower 300 feet of the raceways because of low oxygen levels.

4.2 Rearing Infrastructure

4.2.1 Hatchery-wide Electrical Issues

The electrical systems at the Mad River Hatchery are antiquated, have failed, and have shown evidence of arcing issues when the systems were energized. The outdated electrical system is a high priority to the hatchery manager because it poses a risk to staff at the facility.

Replacement of the electrical systems across the facility is needed to ensure the safety of CDFW staff. Additionally, the hatchery relies on pumps to move the water to the rearing areas. An electrical failure that prevented water from entering the raceways could result in a catastrophic fish loss.

4.2.2 Limited Early Rearing Space

The hatchery currently has only six deep tanks and eight troughs for early rearing. As identified in Section 2.1, early rearing space is limited, requiring young fish to be moved into the raceways smaller than desired. Moving smaller fish to the raceways can create several challenges related to fish rearing. The steelhead fry are fed a feed type known as “crumble” until they reach approximately 2.6 inches in length. The crumble feed is highly susceptible to even light wind, making it more difficult to feed the fish outdoors. The crumble feed is also more likely to clump or “ball up,” which prevents the fry from eating the feed.

Additionally, young fish are more susceptible to predation even by opportunistic predators, including smaller birds, which may not typically predate on older fish. Mammals and avian predators may infect the raceways with disease as they move back and forth from other water sources, increasing the risk of exposure to pathogens. The smaller fish are also more susceptible at Mad River Hatchery because of the reuse system. Pathogens shed by older fish in the system can be spread to the smaller fish through the reuse water. The immune systems of the young steelhead develop with age and size, making them most vulnerable to pathogens at the earlier life stages.

4.2.3 Warm Temperatures in Production Raceways

The existing wells provide cold water ranging from 44-55°F, which typically keeps water temperatures low. However, Mad River Hatchery reuses 80-90% of its total flow. During summer, the water frequently warms up to 68 F, as it recirculates. The concrete raceways and the biofiltration beds are exposed to direct sunlight, which can result in significant heat gain. Water with warmer temperatures holds less dissolved oxygen (DO), so when the production water warms up, it can cause stress and health issues in the fish.

4.2.4 No Separation Between Incubation and Early Rearing Areas in Spawning Building

The current hatchery building consists of one large room that houses the spawning area, incubation, and early rearing. Having these activities in the same general area creates a biosecurity risk for the fish reared at the hatchery. The adult fish that are spawned on site are returning fish from the Mad River. They are either collected from the fish ladder or wild-caught and brought on site. These adult fish are more likely to have pathogens because of their exposure to the natural environment. The immune systems of the young steelhead develop with age and size, making the early-rearing fish the most vulnerable to pathogens. The potential spread of pathogens from the spawning process to the eggs or fry in the rearing tanks increases due to the proximity and the lack of a physical barrier. Equipment, gear, and personnel are typical vectors to transfer disease present in fish mucus and/or various fluids (e.g., ovarian fluid, milt). Pathogens can even spread by water vapor or splashing in areas with limited space. The primary pathway into the building also passes directly through the incubation and early-rearing area.

4.2.5 Unusable and Aging Raceways

The Mad River Hatchery has ten concrete raceways labeled A through J. However, only six are still fully operable. Ground subsidence has damaged Raceways A, B, C, and D. The upper ends of Raceways A and B are still usable, but only in the first 200 feet due to ground subsidence in the lower sections. The concrete on the raceways is starting to show signs of deterioration. The concrete in the unused raceways had significant spalling and cracking. The raceways still in operation were in better condition but still showing signs of aging.

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. Appendix E- Alternatives Development TM 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. The conceptual layout of the alternative described below is shown in Appendix C – Figure 1.

5.1 Alternative Description

5.1.1 New Wells

As noted in Section 4.1.1, many of the existing wells are not operable due to mechanical or water quality issues. The current wells pull water from depths below the ground surface ranging from 38 feet to 75 feet. It is the preferred alternative to complete a well and aquifer assessment to identify the potential benefit of installing new wells to avoid the effect of the Mad River on the well water. If opportunities to install new and deeper wells are present, this would potentially improve water quality and quantity available to the hatchery.

The hatchery has operated on an 80-90% reuse system for final rearing of steelhead smolts. Table 5-1 provides a water budget comparison between the water requirements for the existing facility relative to the proposed preferred alternatives including expanding early rearing capacities and PRAS for final rearing of steelhead. Water requirements for incubation will remain the same utilizing 16 Heath incubation stacks with 16 trays per stack. A range of 5-10 gpm per stack aligns with current hatchery operations. Water requirements for early rearing will increase for the proposed facility components (24 tanks) as it addresses the limitations associated with early rearing relative to the existing facility troughs (8) and deep tanks (6). Final rearing components for the existing facility and the proposed facility components operate on RAS (existing) and PRAS (proposed), both of which maximize production and minimize water use. The Rainbow Trout transfers in the raceway(s) occurs May through June when water required for fish production is minimal and the ladder and adult holding are not in operation. A single raceway is used for the Rainbow Trout transfers with a flow rate of 1,344 gpm per raceway. This number was also used for the proposed facility components as two raceways will be maintained for use for the Rainbow Trout transfers; however, LHOs at the head and mid-point of the raceways can be utilized to maintain oxygen saturation throughout the length of the raceway(s). 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, an increase of approximately 470 gpm will result with the increased water use for early rearing of 330 gpm and 140 gpm for final rearing in the PRAS circular tanks.

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

Characteristics	Existing Facility Components	Proposed Facility Components
Ladder Operations	1400	1400
Adult Holding (1 pond)	900	900
Incubation	80-160	80-160
Early Rearing	270	600
Final Rearing	300	440
Rainbow Trout Transfers[a]	1,344	1,344
Miscellaneous Water Use	300	300
Total GPM	**3,330**	**3,800**

[a] The 1,344 gpm for the Rainbow Trout transfers was not included in the total since it is during non-peak water use for the facility.

5.1.2 Replace Valves and Piping throughout the Hatchery

The original construction of Mad River Hatchery was completed in 1971, and some infrastructure has not been replaced since then. It is the preferred alternative to inspect valves and pipes throughout the hatchery and to replace them as needed. New pipes and valves could lead to improved water quality. Additionally, some old valves cannot be operated in their aged state, so new valves would allow for improved flow control throughout the hatchery.

5.1.3 Update Existing Electrical System throughout the Hatchery

The existing electrical system is original to the hatchery dating back to the 1960s and is in need of major upgrade. The components of the electrical system are outdated relative to current technologies resulting in concern for staff safety. Along with renovations throughout the hatchery, updating the entire electrical system would provide a safer working environment for the hatchery staff and would also provide protection from potential electrical failures and fires.

The hatchery currently has a 400 KW generator which is utilized to provide emergency power to pumps and UV system. A second (older) generator provides emergency power to the main sump pumps.

5.1.4 Construct New Hatchery Building for Incubation and Early Rearing

The facility is limited in early rearing volume; therefore, the hatchery currently rears the young steelhead to approximately 700 fpp (1.6 inches) before transferring them into the upper ends of two raceways. The preferred alternative will provide a new hatchery building isolated from the spawning building where both egg incubation and early rearing will occur. The incoming water will be treated using an aeration tower providing oxygenation and head pressure to gravity supply water to the Heath stacks and early rearing tanks. Egg incubation will continue to use Heath stacks, and these units can be moved from the spawning building into the new hatchery building depending on their current condition. The water requirement for the Heath stacks is 5 gpm per stack for a total water requirement of 80-160 gpm with a flow rate of 5-10 gpm/stack (16 stacks). The new hatchery building will house twenty-four nursery tanks with a length of 16 feet, width of 3 feet and an operating depth of 1.8 feet per tank. This allows hatchery staff to use two nursery tanks for progeny resulting from each of the twelve spawning events. The nursery tanks will operate on single-pass water with each tank receiving 25 gpm for a total water requirement of 600 gpm. Hatchery staff can adjust water flows throughout the early rearing cycle as smaller fish will require less water than larger fish. Assuming 9,000 juvenile steelhead are reared in each of the new nursery tanks to a size of 150 fpp, the DI and FI values will be below the criteria established for the hatchery at 0.26 and 0.90, respectively.

If adjustments are made to the existing raceways as suggested in Sections 5.1.5 or 5.3, the new hatchery building could be placed in the footprint of the lower section of the concrete raceways. If no adjustments to the raceways are made, the new hatchery building could potentially be placed directly east of the existing hatchery building. The construction of a new hatchery building would provide additional space such that the incubation and early rearing stages could be moved from their current location adjacent to the spawning area reducing biosecurity concerns. Additionally, the proposed new hatchery building could be built large enough to address the early rearing limitations allowing the hatchery staff to raise the young steelhead to a larger size before transferring them into the raceways or into new smolt rearing circular tanks on PRAS. To accommodate the deep tanks and incubation stacks, the proposed hatchery building would be approximately 81 feet by 54 feet.

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

5.1.5 Replace Raceways with New Circular Tanks on PRAS

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.

It is the preferred alternative to demolish the existing raceway infrastructure (including the UV treatment stations at the head of each existing raceway) and install circular tanks with PRAS. The hatchery uses the first 300 feet of Raceways E, F, G, H, I and J for steelhead rearing. Each raceway is 10-feet wide and has a water depth of 3-feet. Therefore, the hatchery currently uses 54,000 ft^3 to rear fish. The hatchery has a production goal of 150,000 fish to a size of 9 fpp. Based on a density index of 0.30, Mad River would require a minimum of 8,170 ft^3.

The incoming well water will be supplied directly from the wells into the PRAS sumps and therefore will pass through the aeration tower allowing the water to be oxygenated prior to entering the PRAS tanks. A standard size of larger dual-drain circulars is a 20-foot diameter tank with a 4-foot operating depth. Each 20-foot tank provides 1,257 ft^3 of rearing volume. A total of 8 tanks would be required to meet the production goal. There will be a total of two PRAS modules, each with four tanks. This will provide 10,053 ft^3 of rearing volume and result in a maximum density index of 0.24. 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. However, a density of less than 0.30 is used to provide the hatchery with some flexibility and resiliency. Table 2-1 outlines the production goal and current capacity of the raceways.

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

Characteristics	Existing Raceway	Circulars
Max Number of Fish	150,000	150,000
Fish Size at Max	9 FPP at 6.8 inches	9 FPP at 6.8 inches
Density Index	0.045	0.24
Dimensions (ft)	300 ft long; 10 ft wide	20-ft diameter
Operating Depth (ft)	3	4
Volume Per Rearing Vessel (ft^3)	9,000	1,257
Number of Rearing Vessels	6	8
Total Volume Required (ft^3)	**54,000**	**10,053**

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 220 gpm then the resulting HRT would be 43 minutes. The entire flow for a four tank PRAS module would be 880 gpm. If the system is operated at 75% reuse rate the total make-up flow per module would be 220 gpm. The PRAS modules would require a combined total of 440 gpm of make-up water. Each PRAS module would have a new microscreen drum filter (40 micron), CO_2 removal, LHO, and UV disinfection (126 mJ/cm^2). Appendix F (Alternatives Development TM) provides detailed information for the equipment components required for each PRAS module. This would eliminate the need for a biofilter altogether allowing for the removal of the aging reuse equipment at Mad River, which is reaching the end of its expected lifespan. Removing the biofilter would eliminate the need for the existing blower and backwash system which is reaching the end of its life. 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, and 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 self-cleaning of fish waste, concentration of fish waste in a small center drain flow that can be treated continuously, and capacity for providing exercise velocities. Covering the tanks with a rigid roof structure will also reduce heat gain and improve biosecurity.

In addition to the steelhead, the hatchery holds Rainbow Trout in the raceways for four to eight weeks during late spring/early summer. These Rainbow Trout transfers are only on site for a short period and can vary in number. It is recommended that the hatchery keep two raceways to use for these transfers. The hatchery can primarily hold the fish in one raceway but expand to two if needed. The raceways should be operated as flow-through since the existing reuse system will be taken offline with the addition of PRAS. Having two raceways that are still operational will provide flexibility for the hatchery. LHOs would be added to the head end and mid-point in the raceways to ensure oxygen levels are maintained at saturation to hold fish for the Rainbow Trout Transfer Program.

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

5.1.6 Construct Additional Percolation Pond

The hatchery staff currently uses two percolation ponds to treat the effluent water. The two existing percolating ponds are operated such that one pond is receiving hatchery effluent while the other is allowed to drain. The rate at which the percolating ponds drain can be affected by the nearby Mad River. When the Mad River experiences higher flows, the groundwater table rises above the bottom of the percolating ponds, limiting the water that can seep out.

It is the preferred alternative to construct an additional percolating pond that would increase the amount of effluent the hatchery can treat. The size of the additional pond will depend on the effluent flows after any upgrades and the percolation rate. However, the hatchery has ample space to build a pond that is equal to or larger than the existing ponds. The construction of a third percolation pond would allow the hatchery to handle a greater range of effluent flows as needed. Additionally, it would allow the hatchery staff to perform maintenance and regular cleaning of the existing ponds. Having three ponds would allow the hatchery staff to take one offline to clean and repair as needed. This would also improve the overall efficiency of the existing ponds.

5.1.7 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 and cons for Mad River Hatchery's selected alternative.

Table 5-3. Pros/Cons of Selected Alternative - Mad River Hatchery

Description	Pros	Cons
Dig new wells.	• May increase water availability. • May improve water quality. • Replaces aging infrastructure. • Improves water supply resiliency.	• Increases cost due to installation. • May have difficulty obtaining water rights. • Has unknown water quality and temperature. • Has unknown groundwater availability.
Replace valves and pipes throughout the hatchery.	• Provides improved water control. • Replaces prior to failure.	• Increases cost due to installation. • May disrupt hatchery operations during construction.
Update existing electrical system throughout the hatchery.	• Improves staff safety. • Improves fire protection. • Increases equipment reliability.	• Increases cost due to installation.

Description	Pros	Cons
Construct new hatchery building that includes PRAS.	• Provides early rearing capacity. • Allows juvenile steelhead to be reared to an appropriate size before moving to the raceways or PRAS. • Increases survival during early rearing phase. • Provides consistent rearing technology with current hatchery operations. • Improves biosecurity by separating the spawning area from incubation/early rearing. • Provides opportunity to expand/modify the incubation area.	• Increases cost due to installation. • May have permitting challenges.
Replace raceways with new circular tanks on PRAS and a solid roof with enclosed sides.	• Replaces aging infrastructure with current technology which will allow for many years of operation. • Improves flow control. • Provides a healthier rearing environment for fish. • Reduces staff labor as the PRAS are self-cleaning. • Protects fish from sunburn and predation and reduces heat gain. • Improves biosecurity. • Concentrates waste for effluent treatment for NPDES permit.	• Increases cost due to installation and operation/maintenance (UV bulb replacement, drum filter panels, etc.). • Requires additional training for staff. • Increases pumping on site. • Requires additional components (e.g., drum screen, UV, LHO, CO_2 removal). • Increases power requirements.
Construct additional percolating pond(s).	• Allows hatchery to handle wider range of effluent flow. • Provides redundancy. • Allows hatchery staff to perform regular cleaning and maintenance.	• Increases cost due to installation. • May have permitting challenges.

Description	Pros	Cons
Install backup power generator(s).	• Provides power to all life support systems in the event of a power outage. • Supports the function of modernized PRAS equipment.	• Increases cost. • Increases complexity. • Increases maintenance.

5.3 Alternatives For Short-Term Improvements

In the event that funding is not available to construct the preferred alternative, the following short-term improvements are recommended for continued hatchery operation. The conceptual layout of the short-term improvements described below is shown in Appendix C – Figure 2.

5.3.1 Replace Existing Recirculation Pumps

The hatchery has three 50-hp pumps that return the water to the raceways after treatment. The hatchery alternates using the three pumps, but they are reaching the end of their lifespan. Although the hatchery had a local contractor perform some required maintenance on these pumps (i.e., rewind of the pump motors) and they are currently operating as needed, these pumps will require replacement to ensure a reliable water supply to the raceways.

5.3.2 Improve the Mid-Pond Aeration System

As noted in Section 4.1.4, the current mid-pond aeration system is not used due to pump reliability issues. The hatchery had the mid-pond aeration system upgraded with new pumps and VFD. However, after installation one of the VFD units failed, which resulted in a large fish loss. The hatchery staff has opted not to use the system since that time.

It is recommended that the hatchery install an alarm system with multiple redundancies, so the hatchery can use the mid-pond aeration and not worry about fish loss. This could include level alarms and/or DO probes. The level alarms and/or DO probes would notify hatchery staff as soon as levels drop below a specified value.

5.3.3 Install Secondary UV Treatment Unit

During the site visit, the hatchery was installing a new UV unit to treat the reuse water. The new UV unit was one larger unit to replace multiple smaller units which are plumbed into the head box of the raceways. However, the hatchery only had finalized plans to install one unit that treated the entire flow. Relying on one unit to treat the entire flow limits the hatchery's ability to perform routine maintenance and puts them at risk if the unit fails. If the UV unit is taken offline or fails, the reuse flow is not disinfected, and pathogens could spread throughout the system. UV units require the bulbs to be replaced and the quartz sleeves to be cleaned annually, as well as other regular maintenance to ensure they continue to operate as designed.

It is recommended the hatchery install a secondary UV unit and remove the existing UV treatment stations at the head of each raceway. This will create redundancies in the system and allow hatchery staff to perform routine maintenance. The hatchery noted that they do have preliminary plans for a second UV unit, but at the time of the site visit, the funding was not available.

5.3.4 Replace Media in Shellbed Filter System

The oyster beds were installed when the hatchery was built in 1968 and are showing signs of aging. The concrete has deteriorated over time, and coarse rock media has never been replaced. The efficiency of ammonia removal by the oyster bed biofilter has not been measured by hatchery staff, but they noted they do not have water quality concerns related to their use. It is recommended that the hatchery replace all the media, including the coarse rock media, as well as replace all aging piping and valves that are at risk of failure. The hatchery should perform surface repairs and apply a coating to extend the life of the units.

5.3.5 Upgrade Aeration Tower

The existing aeration tower is part of the reuse system at Mad River. It is a passive aeration system that uses media to break up the water as it cascades downward, and the mixing adds oxygen back into the system. However, the aeration tower is starting to show signs of aging and may need to be replaced or upgraded in the near future. The last modifications occurred in 1979. The media inside the aeration tower has not been replaced, the screens inside the units are showing signs of deterioration, and the concrete is showing signs of aging. It is recommended that if the hatchery continues to use the existing reuse system, the media should be replaced, the units should be upgraded, and the concrete sump should be coated. This will extend the lifespan of the unit. Additionally, a blower could be added to the unit to increase oxygenation.

5.3.6 Isolate Incubation and Early Rearing

In the hatchery building, the spawning area, incubation and early rearing are all housed in close proximity. This poses increased biosecurity risks for the steelhead program with the greater potential of cross-contamination due to the lack of isolation. Ideally, a physical wall would separate the spawning area from the incubation and early rearing areas, but installing a wall is not feasible given the layout of the building and current operations. Installation of a moveable curtain would provide a physical barrier between these areas along with the development of standard operating procedures (SOP) for staff to minimize the potential for the spread of pathogens. The SOPs may include disinfection procedures when moving between areas such as footbaths/hand sanitizing stations, a designated individual remaining outside the spawning area to disinfect and tray eggs, separate gear, daily staff assignments to eliminate moving between the areas, etc.

5.3.7 Skim Coat Raceways E-J and Abandon Raceways A-D

All existing raceways (A-J) are 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 protect the concrete from further deterioration. In addition to aging concrete, Raceways A-D have experienced settling due to ground subsidence. This settling has caused the entirety of Raceways C-D and the lower 400 feet of raceways A-B to be unusable.

Applying a protective skim coating to Raceways E-J would help to extend the lifespan of the existing concrete. Additionally, since the majority of Raceways A-D are unusable, demolishing them would create space for hatchery expansion in the future. The proposed hatchery building described in Section 5.1.4 could potentially be placed in the lower footprint of Raceways A-D which would be ideal as the location is close to the existing hatchery building.

5.4 Natural Environment Impacts

The proposed upgrades to the Mad River 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 Mad River Fish Hatchery will change the existing infrastructure and the number of rigid structures on site. However, they will not increase or decrease the fire risk. Based on the climate change evaluation, the projected fire risk at the hatchery site is relatively low at 10 to 25% through mid-century.

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 Mad River Fish Hatchery will significantly reduce the fish production footprint relative to the existing infrastructure and decrease the impact of flooding on the facility. The new hatchery building for incubation and early rearing and the fiberglass circular tanks for final smolt rearing would be located in a small portion of the existing footprint of the raceways. Risk of flood impacts to these areas would be less than the current flood risk since the new hatchery building would be located further from the Mad River and the fiberglass circular tanks for smolt final rearing will provide additional flood protection as they will be installed with the tank tops at heights between 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.

5.4.2 Effluent Discharge

The recommended changes to the hatchery do not include an overall increase in production goals at the Mad River Fish Hatchery. This will ensure there will be no change to the NPDES permit requirements. However, the recommended alternatives will likely improve the water quality of the effluent discharge. The hatchery meets current NPDES permit requirements. Installing dual-drain circular tanks and expanding effluent treatment will improve the water quality of the discharge. The addition of a third percolation pond will increase the hatchery's capability for water treatment prior to discharging to the Mad River and allow the hatchery to rotate the operation of the percolation ponds providing cleanout and maintenance windows.

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

Broodstock collection and spawning operations will continue using the hatchery's standard practices. Egg incubation and early rearing will occur in the new early rearing building. Egg incubation will remain the same utilizing Heath stacks and early rearing will occur in nursery tanks utilizing the same fish culture practices with single-pass flow in the nursery tanks. The 24 nursery tanks provide more rearing volume than the previous troughs and deep tanks allowing the young fish to be grown to a larger size of approximately 150 fpp. As the fish reach their target size, they will be transferred into the final rearing circular PRAS tanks. A small fish pump (e.g., 2.5-inch-diameter hose) would minimize handling and stress on the fish as they are transferred. The distance between the new nursery tanks and the final rearing tanks is a maximum of approximately 200 feet; therefore, pumping distance and hose requirements are minimal making this a feasible method to transfer fish into the final rearing tanks while minimizing handling and stress to the fish. If enumeration of the fish is desired, a fish counter may be utilized in conjunction with the fish pump.

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. All steelhead smolts are released directly into the Mad River via the fish release pipe. The final rearing tanks will be configured and plumbed to allow the smolts to pass through the tank drains into the existing release pipe to minimize handling and maximize survival.

One of the benefits of this proposed design is to provide the means for staff to maintain fish health and welfare. The nursery tanks allow for administering chemical treatments as needed (e.g., coldwater disease, columnaris) during the early life stages and provide a simple system to work from for required marking/tagging activities.

5.5.1 PRAS Circular Tank Operations

The 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. Seine nets, clamshell crowders or other crowder types can be used to concentrate fish for collection and handling.

Transfer of fish between tanks will utilize fish pumps and hosing to minimize handling and stress on the fish and decrease physical labor for staff transferring fish between tanks. 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. If fish enumeration occurs utilizing a dewatering system of any type, water should be routed back to the sump 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. The production of steelhead smolts in the PRAS modules is seasonal, providing maintenance windows and opportunities for cleaning and disinfection. All PRASs 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 nursery 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 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 provide feed intermittently throughout the day including staff non-duty times to maximize growth, reduces staff labor (but reduces the staff's observations during feeding), requires adjustments to deliver the correct amount of feed, requires preventative and corrective maintenance and continued cost associated with these maintenance requirements. Given there are only 8 final rearing tanks to meet the production goal for the facility, hand-feeding is a viable option. 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.

5.5.4 Rainbow Trout Transfers

Rainbow Trout reared at other CDFW facilities are transported and temporarily held at the Mad River Hatchery. Two raceways will be available and operate on single-pass well water. LHOs units will be located at the head end and the mid-point of each raceway to maintain oxygen levels at saturation. The LHOs will allow the raceways to be operated at lower flow rates if desired while maintaining excellent water quality. Procedures for loading fish transport tankers will continue as the hatchery has traditionally operated in the past.

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. The Mad River Fish Hatchery did not identify specific pathogens of concern at the facility. The most likely pathways for pathogens to enter the Mad River Fish Hatchery and spread through the facility is through the incoming water supply or environmental exposure within the hatchery. Typically, well water sources have a lower risk of pathogens relative to surface water sources; however, the Mad River water may be infiltrating the well field increasing the risk of pathogens in the well water supply. The UV units on the recommended PRAS modules will reduce the risk of pathogens entering the systems.

5.6.1 Incoming Water Supply

The Mad River Fish Hatchery currently has measures to prevent pathogens from entering the facility. The well water supply for final rearing operates on an 80-90% reuse system which includes UV disinfection. The recommended alternatives provide consistency in operations for incubation and early rearing and advanced rearing provides water filtration, UV disinfection, LHOs and CO_2 stripping to maximize water quality while eliminating the requirement for biofiltration. Replacing outdated valves and piping will improve the hatchery's ability to control the flow and provide reliability to operate the new systems correctly and 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. 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 accessing 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 in 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 the addition of a third percolation pond, the hatchery will increase its ability for water treatment prior to discharging to the Mad River. 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 by investigating and drilling new reliable wells to provide good quality cold water for consistent fish production into the future.

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. 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.
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.

Criteria	Details
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 $1000.
- Length and area dimensions for the estimate were derived from scaled AutoCAD drawings of the facility and the property. 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/Net Zero 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 summarized the anticipated power 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	2,282,000
Division 02 - Existing Conditions	1,808,000
Division 03 - Concrete	725,000
Division 05 - Metals	100,000
Division 07 - Thermal and Moisture protection	10,000
Division 08 - Openings	101,000
Division 13 - Special Construction	4,694,000
Division 23 - Mechanical & HVAC	177,000
Division 26 - Electrical	1,375,000
Division 31 - Earthwork	671,000
Division 32 - Exterior Improvements	507,000
Division 33 - Utilities	402,000
Division 40 - Process Water Systems	837,000

Item	Estimate ($)
Direct Construction Cost	**13,689,000**
Contingency (Construction Cost)	3,422,000
Overhead	821,000
Profit	1,095,000
Bond Rate (Approximate)	137,000
Total Construction Cost	**19,164,000**
Design, Permitting and Construction Support	3,000,000
Total Cost Estimate	**22,164,000**
Accuracy Range +50%	33,246,000
Accuracy Range -30%	12,515,000
Photovoltaic	7,134,000

7.0 Mad River 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/wells, requiring a review of water rights 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 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.
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.

Agency and Permit/Approval	Submittal / Document Type	Supporting Documentation	Anticipated Time Frame	Notes
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.
North Coast 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 Humboldt County Permits and Approvals for Selected Location.

Agency and Permit/Approval	Submittal / Document Type	Supporting Documentation	Anticipated Time Frame	Notes
Humboldt County Planning and Building	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 Mad River Fish Hatchery is classified as a cold water Concentrated Aquatic Animal Production (CAAP) facility and is eligible to operate under General Order R1-2015-0009 issued by the Regional Water Quality Control Board, North Coast (Region 1) and NPDES Permit No. CAG131015.

The permit identifies suspended solids and settleable solids as potential pollutants from the hatchery. The following effluent limitations are specified:

- Suspended solids: 8 mg/L (monthly average) and 15 mg/L (daily maximum)
- Settleable solids: 0.1 mL/L (monthly average) and 0.2 mL/L (daily maximum)

The permit specifies an effluent minimum pH of 6.5 and an effluent maximum pH of 8.5.

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 Mad River Fish 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, air temperatures are predicted to rise by 3°F by mid-century. Assuming the well water supplies at the hatchery are relatively shallow, water temperatures are expected to rise by a similar magnitude as the air temperatures at the Mad River Hatchery. Additionally, there will be an increasing risk of wildfire as the climate changes but is expected to remain relatively low at 10-15% at the hatchery site.

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 water supply for the hatchery will include exploring and drilling new wells.
- Replacing pipes and valves that are near the end of their effective lifespan or are currently inoperable due to age.
- Upgrading the existing electrical to address life/safety items and align electrical systems with the facility's equipment.
- Constructing a separate hatchery building isolating the spawning area from incubation/early rearing while increasing the early rearing capacity.
- Replacing deteriorated concrete raceways and biofilter with circular dual-drain tanks utilizing partial recirculating aquaculture systems (PRASs) to continue to operate the hatchery on a limited water supply.
- Covering all rearing vessels with solid roofs and predator exclusion sidewalls will reduce the impacts of increased temperatures for both the fish and the employees and provide protection against predation.
- Adding a percolation pond to ensure the facilities effluent needs align with NPDES permit requirements and accommodate maintenance of these ponds.

The proposed upgrades to the Mad River Hatchery would have negligible impacts on the natural resources in the surrounding area. All improvements would occur mostly within currently developed areas, which lessen the permit requirements. The total cost estimate of the proposed design modifications is $22,164,000.

9.0 References

Cal-Adapt. (2023). Wildfire Simulations Derived Products, RCP 4.5, Global Climate Models HadGEM2-ES, CNRM-CM5, CanESM2, MIROC5. Cal-Adapt website developed by University of California at Berkeley's Geospatial Innovation Facility under contract with the California Energy Commission. Retrieved [1 September 2023], from https://cal-adapt.org/data/download/

California Department of Forestry and Fire Protection (2023). California Fire Perimeters (1950+). https://gis.data.cnra.ca.gov/datasets/CALFIRE-Forestry::california-fire-perimeters-1950/explore (data access)

IPCC, Intergovernmental Panel on Climate Change. 2014. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri, and L.A. Meyer (eds.)].* IPCC, Geneva, Switzerland, 151 pp.

Klontz, G. W. 1991. Manual for Rainbow Trout on the Family-Owned Farm. University of Idaho Department of Fish and Wildlife Resources. Moscow, ID.

Krantz, W., Pierce, D., Goldenson, N., and Cayan, D. R. 2021. Memorandum on Evaluating Global Climate Models for Studying Regional Climate Change in California. [online] Available from: https://www.energy.ca.gov/sites/default/files/2022-09/20220907_CDAWG_MemoEvaluating_GCMs_EPC-20-006_Nov2021-ADA.pdf.

Livneh B., E.A. Rosenberg, C. Lin, B. Nijssen, V. Mishra, K.M. Andreadis, E.P. Maurer, and D.P. Lettenmaier. 2013. A Long-Term Hydrologically Based Dataset of Land Surface Fluxes and States for the Conterminous United States: Update and Extensions, Journal of Climate, 26. https://psl.noaa.gov/data/gridded/data.livneh.html (information) and https://downloads.psl.noaa.gov/Datasets/livneh/metvars/ (data access)

Piper, R.G., I.B. McElwain, L.E. Orme, J.P. McCraren, L.G. Fowler, and J.R. Leonard. 1982. Fish Hatchery Management. U.S. Fish and Wildlife Service. Washington, D.C.

Thomas, Nancy, Shruti Mukhtyar, Brian Galey, and Maggi Kelly (University of California Berkeley). 2018. Cal-Adapt: Linking Climate Science with Energy Sector Resilience and Practitioner Need. California's Fourth Climate Change Assessment, California Energy Commission. Publication Number: CCCA4-CEC-2018-015

University of Washington Computational Hydrology Group. 2021. VIC Model Overview. https://vic.readthedocs.io/en/master/Overview/ModelOverview/

USGS, U.S. Geological Survey. 2019. The StreamStats program, online at https://streamstats.usgs.gov/ss/, accessed in October 2023.

Vano, J., J. Hamman, E. Gutmann, A. Wood, N. Mizukami, M. Clark, D.W. Pierce, D.R. Cayan, C. Wobus, K. Nowak, and J. Arnold. 2020. Comparing Downscaled LOCA and BCSD CMIP5 Climate and Hydrology Projections – Release of Downscaled LOCA CMIP5 Hydrology. 96 p. https://gdo-dcp-ucllnl.org/downscaled_cmip_projections/dcpInterface.html

Westerling, A.L. 2018. Wildfire Simulations for California's Fourth Climate Change Assessment: Projecting Changes in Extreme Wildfire Events with a Warming Climate. California's Fourth Climate Change Assessment, California Energy Commission. Publication Number: CCCA4-CEC-2018-014. https://www.energy.ca.gov/sites/default/files/2019-11/Projections_CCCA4-CEC-2018-014_ADA.pdf