January 2026
Study of Physical Data Gaps to Inform the Implementation of Nur Rematriation Upstream of Shasta Dam
(AB 211 Drought Grant Agreement Number – Q2396040)

Appendix H
Hydrology Study in the Winnemem Waywaket and Cow Creek

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Hydrology Study in the Winnemem Waywaket and Cow Creek

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TABLE OF CONTENTS

TABLES

FIGURES

ABBREVIATIONS

Background Compendium	*Background Compendium and Design Criteria Report for the Feasibility of Volitional Fish Passage above Keswick and Shasta Dams*
CDEC	California Data Exchange Center
CDFW	California Department of Fish and Wildlife
cfs	cubic feet per second
Consultant Team	team of engineering and fisheries science consultants consisting of Anchor QEA; HDR Engineering, Inc.; U.S. Geological Survey; and QEDA Consulting, LLC
EMA	Expected Moments Algorithm
GCM	Global Circulation Model
NMFS	National Marine Fisheries Service
Nomtipom Waywaket	Winnemem Wintu words for Sacramento River
Nur	Winnemem Wintu word for Chinook Salmon
Project	studies to gather data, compile information, and identify data gaps related to physical and biological conditions in the Study Area
RCP	Representative Concentration Pathway
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
Winnemem Waywaket	Winnemem Wintu words for McCloud River

1 Introduction

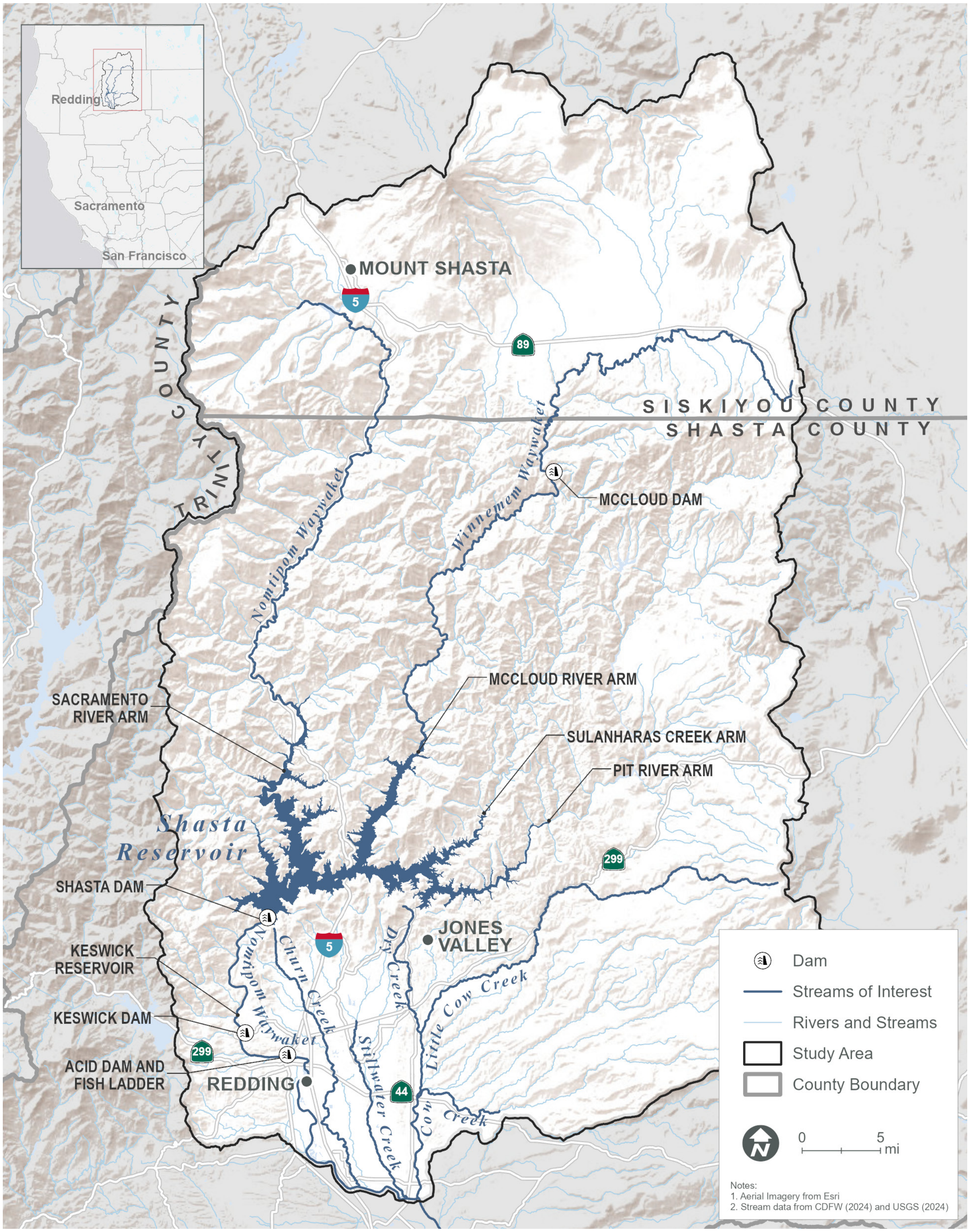
A team of engineering and fisheries science consultants consisting of Anchor QEA; HDR Engineering, Inc.; U.S. Geological Survey (USGS); and QEDA Consulting, LLC, has received funding from the California Department of Fish and Wildlife (CDFW) to implement studies to gather data, compile information, and identify data gaps related to physical and biological conditions in the Study Area. These studies are referred to as the "Project." The results of the Project will support an investigation of the feasibility of providing volitional passage for fish, particularly Chinook Salmon (*Oncorhynchus tshawytscha*), above Keswick and Shasta dams on the Nomtipom Waywaket (also known as the Sacramento River) in northern California. In this document, Chinook Salmon is used to generally describe the species because once connectivity is re-established through reintroduction, fish will adapt to the new environments and could display run timing consistent with multiple runs. It is inclusive of Nur, which the Winnemem Wintu Tribe uses for Chinook Salmon that have been raised by the Tribe. The formal, evolutionarily significant unit-specific name (e.g., Sacramento River Winter-run Chinook Salmon) is used when discussing federal Endangered Species Act-listed Chinook Salmon or steelhead. This document is an appendix to the overarching report documenting the results of the Project, which is called the *Background Compendium and Design Criteria Report for the Feasibility of Volitional Fish Passage above Keswick and Shasta Dams* (Background Compendium). This larger report contains additional background information for the Project and this document should be considered within this context.

The Project Study Area extends from the confluence of Cow Creek and the Nomtipom Waywaket to the Winnemem Waywaket (also known as the McCloud River; in this document, Winnemem Waywaket is used except when referring to USGS stream gages that include McCloud River in their titles) from Shasta Reservoir to the McCloud Dam (Figure 1). It includes portions of the Winnemem Waywaket; Nomtipom Waywaket, including Keswick and Shasta dams and reservoirs; Cow Creek; Little Cow Creek; and Dry Creek. These water bodies vary in hydrology, geomorphology, and water quality, with seasonal fluctuations in temperature and flow; these parameters are being measured in this Project to evaluate habitat suitability and passage for salmonids. Understanding these physical conditions is essential to evaluating the feasibility of restoring fish passage to historical spawning and rearing areas upstream of the dams.

The purpose of this document is to summarize available data on hydrologic conditions in the Winnemem Waywaket and Cow Creek. Information provided in this document and other documents created as part of this study will be used to support a volitional passage feasibility study that will be reviewed by the salmon co-managers (Winnemem Wintu Tribe, CDFW, and National Marine Fisheries Service [NMFS]) and used to inform fish passage decisions.

Readers should understand that on December 12, 2025, the team of engineering and fisheries science consultants consisting of Anchor QEA; HDR Engineering, Inc.; U.S. Geological Survey; and QEDA Consulting, LLC, (Consultant Team) received an email stating that the Winnemem Wintu Tribe does not endorse these reports (referring to the Background Compendium and appendices and *Alternatives Formulation and Evaluation Report* [Anchor QEA and HDR 2026]).

Figure 1
Study Area



2 Hydrologic Data Analysis

Hydrologic calculations were performed to estimate current (regulated) flow exceedance conditions, current peak-flow conditions, unregulated conditions, and potential future conditions with climate change on the Winnemem Waywaket and Cow Creek using the available streamflow data described below.

These data are being calculated because the NMFS's Fish Passage Guidelines (NMFS 2023a) require a fishway design and/or facility to allow for the safe, timely, and efficient passage of fish within a specific range of streamflow. The design streamflow range is bracketed by the designated fish passage design low flow and high flow. The design low flow for fishways is the average daily streamflow that exceeds 95% of the time during periods when migrating fish are normally present at a site. The design high flow for fishways is the average daily streamflow that exceeds 5% of the time during periods when migrating fish are normally present at the site. The fish passage design high flow is the highest streamflow, and the design low flow is the lowest streamflow for which migrants are expected to be present, migrating, and dependent on the proposed fishway for safe passage. Note that NMFS also released pre-design guidelines for projects in California that suggest project proponents consider using 1% daily exceedance values during the period from November 1 to May 15, conduct appropriate migration opportunity studies and discuss the results with NMFS and develop fish passage design flows on a case-by-case basis (NMFS 2023b). Therefore, in future fish passage design efforts it may be helpful to calculate the 1% flow exceedance probabilities (and possibly other probabilities) for comparison of the different values and use of future design flow considerations.

A list of gages with streamflow data available in the Winnemem Waywaket and Cow Creek watersheds is provided in Table 1, and the locations of the stations are shown in Figure 2. Data are available from California Data Exchange Center (CDEC) and USGS.

Table 1
Streamflow Data Available in Project Area

Station	Name	Type of Flow Data Available	Period of Record	Data Source
MSS	McCloud River above Shasta Lake	Daily	01/01/1993 to present	https://cdec.water.ca.gov/dynamicapp/staMeta?station_id=MSS
MSS	McCloud River above Shasta Lake	Full natural flow	06/01/2022 to present	https://cdec.water.ca.gov/dynamicapp/staMeta?station_id=MSS
MSS	McCloud River above Shasta Lake	Hourly	08/01/1991 to present	https://cdec.water.ca.gov/dynamicapp/staMeta?station_id=MSS
MCA	McCloud River at Ah-Di-Na	Hourly	06/30/2010 to present	https://cdec.water.ca.gov/dynamicapp/staMeta?station_id=MCA

Station	Name	Type of Flow Data Available	Period of Record	Data Source
MCD	McCloud River near McCloud, California	Hourly	5/28/1999 to 11/17/2005	https://cdec.water.ca.gov/dynamicapp/staMeta?station_id=MCD
MC7	McCloud River Below McCloud Dam	Event flow	04/12/2011	https://cdec.water.ca.gov/dynamicapp/staMeta?station_id=MC7
No. 11368000	McCloud River above Shasta Lake	Daily	10/01/1945 to 09/30/2023	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=11368000
No. 11367800	McCloud River at Ah-Di-Na	Daily	10/01/1964 to 09/30/2023	https://waterdata.usgs.gov/nwis/inventory/?site_no=11367800&agency_cd=USGS
No. 11367760	McCloud River below McCloud Dam near McCloud, California	Daily	05/01/1966 to 09/30/2023	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=11367760
No. 11367500	McCloud River near McCloud, California	Daily	04/01/1931 to 09/30/2023	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=11367500
ICT	McCloud-Iron Canyon Diversion	Daily flow, daily reservoir storage	8/23/2016, 01/01/2020 to present	https://cdec.water.ca.gov/dynamicapp/staMeta?station_id=ICT
MCT	McCloud Tunnel	Monthly storage, canal diversions	10/01/1985 to present	https://cdec.water.ca.gov/dynamicapp/staMeta?station_id=MCT
No. 11374000	Cow Creek near Millville, California	Daily	10/01/1998 to 09/30/2023	https://waterdata.usgs.gov/nwis/inventory/?site_no=11374000

Figure 2
Streamflow Gage Station Locations

LEGEND:

▲ Stream Gage

NOTES:

11367500 – McCloud River near McCloud USGS gage
11367760 – McCloud River below McCloud Dam near McCloud USGS gage
11367800 – McCloud River at Ah-Di-Na USGS gage
11368000 – McCloud River above Shasta Lake USGS gage
11374000 – Cow Creek near Millville USGS gage
ICT – McCloud-Iron Canyon Diversion CDEC gage
MC7 – McCloud River below McCloud Dam CDEC gage
MCA – McCloud River at Ah-Di-Na CDEC gage
MCD – McCloud River near McCloud CDEC gage
MCT – McCloud Tunnel CDEC gage
MSS – McCloud River above Shasta Lake CDEC gage

0 8
Miles

2.1 Flow Exceedance Calculations for Current Conditions

Flow exceedance calculations were performed for the Winnemem Waywaket and Cow Creek gages using data compiled from CDEC and USGS websites listed in Table 1. The calculations were performed using the last 26 years of record (1997 to 2023), which represents current hydrologic conditions, including climate change effects to date.

2.1.1 McCloud River Above Shasta Lake (MSS)

The 5% and 95% exceedances for mean daily flow are provided by month in Table 2.

Table 2
Mean Daily Flow Exceedance – McCloud River Above Shasta Lake (MSS)

Month	95% Exceedance (cfs)	5% Exceedance (cfs)
1	263	4,060
2	373	5,853
3	367	4,131
4	365	3,588
5	292	2,266
6	254	1,022
7	237	574
8	223	470
9	230	472
10	230	869
11	269	868
12	269	2,492

Notes:
Period of Record Analyzed: 10/01/1997 to 09/30/2023
Missing Data: 11/22/1998 to 12/10/1998; 9/2/2010 to 1/23/2011

2.1.2 McCloud River Above Shasta Lake (USGS 11368000)

This USGS gage appears to be in a slightly different location than MSS. The 5% and 95% exceedances for mean daily flow are provided by month in Table 3. The results are very close to that shown in Table 2 for MSS. A reason for variation might be the amount of missing data from the USGS station. For example, water year 2008 data are missing.

Table 3
Mean Daily Flow Exceedance – McCloud River Above Shasta Lake (USGS 11368000)

Month	95% Exceedance (cfs)	5% Exceedance (cfs)
1	270	4,010
2	280	5,801
3	357	4,018
4	327	3,521
5	288	2,078
6	260	1,020
7	239	506
8	227	396
9	241	368
10	258	832
11	280	884
12	221	2,720

Notes:
Period of Record Analyzed: 10/01/1997 to 09/30/2023
Missing Data: 10/01/2007 to 9/30/2008

2.1.3 McCloud River at Ah-Di-Na (USGS 11367800)

The 5% and 95% exceedances for mean daily flow for the USGS gage at Ah-Di-Na are provided by month in Table 4.

Table 4
Mean Daily Flow Exceedance – McCloud River at Ah-Di-Na (USGS 11367800)

Month	95% Exceedance (cfs)	5% Exceedance (cfs)
1	179	681
2	187	1,561
3	193	1,053
4	188	1,631
5	179	1,220
6	175	560
7	180	269
8	181	263
9	203	271
10	203	469

Month	95% Exceedance (cfs)	5% Exceedance (cfs)
11	200	338
12	185	520

Notes:
Period of Record Analyzed: 10/01/1997 to 09/30/2023
Missing Data: 10/01/2021 to 11/08/2021

2.1.4 Cow Creek near Millville (USGS 11374000)

The 5% and 95% exceedances for mean daily flow for the USGS gage on Cow Creek are provided by month in Table 5.

Table 5
Mean Daily Flow Exceedance – Cow Creek near Millville (USGS 11374000)

Month	95% Exceedance (cfs)	5% Exceedance (cfs)
1	105	6,088
2	159	5,708
3	161	4,680
4	141	2,362
5	44	1,525
6	11	730
7	4	200
8	2	95
9	5	82
10	18	202
11	59	1,022
12	82	5,353

Note:
Period of Record Analyzed: 10/01/1997 to 09/30/2023

2.2 Peak Flow Calculations for Existing Conditions

Estimates of instantaneous peak flows at different recurrence intervals were prepared using the entire period of record available for each gage. The period of record for each gage varies, and gages with short periods-of-record have a wide spread between expected peaks and upper and lower confidence limits. The PeakFQ software package from USGS (available at: https://www.usgs.gov/tools/peakfq) was used in the analysis, with a regional skew coefficient recommended for this geographic area. The Expected

Moments Algorithm (EMA) is a generalized method of moments procedure used in the analysis in accordance with USGS Bulletin 17C guidelines (England et. al. 2018).

2.2.1 McCloud River Above Shasta Lake (MSS)

Table 6 provides estimates of instantaneous peak flows along with upper and lower confidence limits. This gage has a relatively short period of record (31 years) compared to the USGS gage located nearby; therefore, there are differences in expected peaks and upper and lower confidence limits.

Table 6
PeakFQ Analysis – Water Years 1992 to 2023 for MSS

Recurrence Interval (years)	Annual Exceedance Probability	EMA Estimate (cfs)		Confidence Limits (with Regional Skew Estimate; cfs)	
		With Regional Skew	Without Regional Skew	5% Lower	95% Upper
1.005	0.995	922	794	381	1,517
1.01	0.99	1,160	1,033	537	1,816
1.05	0.95	2,152	2,063	1,277	3,035
1.11	0.9	2,975	2,933	1,946	4,039
1.25	0.8	4,381	4,425	3,118	5,765
1.5	0.6667	6,258	6,403	4,679	8,110
2	0.5	9,049	9,292	6,949	11,720
2.33	0.4292	10,530	10,790	8,124	13,690
5	0.2	18,320	18,420	14,060	25,090
10	0.1	26,280	25,760	19,720	38,590
25	0.04	38,370	36,220	27,620	62,880
50	0.02	48,850	44,750	33,870	87,520
100	0.01	60,570	53,800	40,300	119,000
200	0.005	73,610	63,380	46,880	159,000
500	0.002	93,010	76,830	55,760	228,100

2.2.2 McCloud River Above Shasta Lake (USGS 11368000)

Table 7 provides estimates of instantaneous peak flows along with upper and lower confidence limits. This gage has a longer period of record (77 years) compared to the MSS gage located nearby. Anchor QEA recommends these peak flows be used in analyses and design of fish facilities.

Table 7
PeakFQ Analysis – Water Years 1946 to 2023 for USGS 11368000

Recurrence Interval (years)	Annual Exceedance Probability	EMA Estimate (cfs)		Confidence Limits (with Regional Skew Estimate; cfs)	
		With Regional Skew	Without Regional Skew	5% Lower	95% Upper
1.005	0.995	1,240	1,024	322	2,135
1.01	0.99	1,542	1,316	467	2,471
1.05	0.95	2,756	2,531	1,207	3,753
1.11	0.9	3,724	3,526	1,937	4,745
1.25	0.8	5,320	5,185	3,344	6,386
1.5	0.6667	7,363	7,320	5,414	8,566
2	0.5	10,270	10,340	8,482	11,860
2.33	0.4292	11,760	11,880	9,962	13,620
5	0.2	19,220	19,430	16,500	22,980
10	0.1	26,350	26,380	22,160	32,850
25	0.04	36,550	35,940	29,770	48,480
50	0.02	44,930	43,480	35,620	62,570
100	0.01	53,920	51,300	41,520	78,990
200	0.005	63,540	59,380	47,450	98,120
500	0.002	77,260	70,460	55,310	128,400

2.2.3 McCloud River at Ah-Di-Na (USGS 11367800)

Table 8 provides estimates of instantaneous peak flows along with upper and lower confidence limits. This gage has a 58-year period of record and includes the historic peak that occurred in 1956.

Table 8
PeakFQ Analysis – Water Years 1965 to 2023 for USGS 11367800

Recurrence Interval (years)	Annual Exceedance Probability	EMA Estimate (cfs)		Confidence Limits (with Regional Skew Estimate; cfs)	
		With Regional Skew	Without Regional Skew	5% Lower	95% Upper
1.005	0.995	144	155	67	236
1.01	0.99	189	199	96	292
1.05	0.95	394	403	251	547
1.11	0.9	587	592	407	786

Recurrence Interval (years)	Annual Exceedance Probability	EMA Estimate (cfs)		Confidence Limits (with Regional Skew Estimate; cfs)	
		With Regional Skew	Without Regional Skew	5% Lower	95% Upper
1.25	0.8	954	951	706	1,243
1.5	0.6667	1,509	1,494	1,154	1,941
2	0.5	2,450	2,420	1,902	3,153
2.33	0.4292	3,000	2,963	2,331	3,874
5	0.2	6,405	6,371	4,901	8,640
10	0.1	10,660	10,710	7,913	15,370
25	0.04	18,450	18,850	12,980	29,900
50	0.02	26,370	27,310	17,670	47,270
100	0.01	36,440	38,270	23,150	72,710
200	0.005	49,060	52,280	29,450	109,500
500	0.002	70,520	76,630	39,100	183,200

2.2.4 Cow Creek near Millville (USGS 11374000)

Table 9 provides estimates of instantaneous peak flows along with upper and lower confidence limits. This gage has a 73-year record.

Table 9
PeakFQ Analysis – Water Years 1950 to 2023 for USGS 11374000

Recurrence Interval (years)	Annual Exceedance Probability	EMA Estimate (cfs)		Confidence Limits (with Regional Skew Estimate; cfs)	
		With Regional Skew	Without Regional Skew	5% Lower	95% Upper
1.005	0.995	6,146	4,798	2,520	8,578
1.01	0.99	7,044	5,736	3,182	9,419
1.05	0.95	10,060	9,010	5,745	12,190
1.11	0.9	12,050	11,220	7,682	14,010
1.25	0.8	14,860	14,370	10,720	16,640
1.5	0.6667	17,930	17,770	14,390	19,610
2	0.5	21,640	21,800	19,010	23,460
2.33	0.4292	23,330	23,590	20,990	25,310
5	0.2	30,480	30,830	28,010	33,660
10	0.1	35,990	36,010	32,730	40,820

Recurrence Interval (years)	Annual Exceedance Probability	EMA Estimate (cfs)		Confidence Limits (with Regional Skew Estimate; cfs)	
		With Regional Skew	Without Regional Skew	5% Lower	95% Upper
25	0.04	42,570	41,710	38,040	50,190
50	0.02	47,210	45,430	41,570	57,250
100	0.01	51,640	48,750	44,770	64,330
200	0.005	55,910	51,740	47,700	71,490
500	0.002	61,340	55,280	51,200	81,180

2.3 Unregulated Flow Conditions for Existing Conditions

Unregulated flow conditions for the Winnemem Waywaket were estimated using water storage data from McCloud Reservoir, discharge data from the tunnel that transfers water from McCloud Reservoir to Iron Canyon, and flow data from Winnemem Waywaket gages. The steps performed included the following:

- Calculating the natural flow below McCloud Reservoir using the McCloud Reservoir and tunnel data
- Calculating the natural flow between McCloud Reservoir and the McCloud River above Shasta Lake by subtracting concurrent flows from gages
- Adding the two calculated natural flows together

The calculations were performed using mean daily flows. The result is an estimate of natural mean daily flow at the location of the McCloud River above Shasta Lake (USGS 11368000) gage.

Exceedance values for unregulated flows are provided in Table 10.

Table 10
Mean Daily Flow Exceedance for Unregulated Flows – McCloud River Above Shasta Lake (USGS 11368000)

Month	95% Exceedance (cfs)	5% Exceedance (cfs)
1	866	5,423
2	983	7,334
3	1,000	5,686
4	970	4,670
5	872	3,231
6	806	2,379

Month	95% Exceedance (cfs)	5% Exceedance (cfs)
7	762	1,665
8	720	1,372
9	734	1,257
10	697	1,245
11	746	1,698
12	806	3,995

Notes:
Period of Record Analyzed: 10/01/1997 to 09/30/2023
Missing Data: 10/01/2007 to 9/30/2008

Table 11 provides estimates of mean daily peak flows along with upper and lower confidence limits. Instantaneous peak flows may be 10% to 40% higher, based upon a comparison of historical instantaneous peak flows to mean daily flow for the same day performed for the McCloud River near McCloud gage (USGS 11367500).

Table 11
PeakFQ Analysis – Water Years 1946 to 2023 for USGS 11368000

Recurrence Interval (years)	Annual Exceedance Probability	EMA Estimate (cfs)		Confidence Limits (with Regional Skew Estimate; cfs)	
		With Regional Skew	Without Regional Skew	5% Lower	95% Upper
1.005	0.995	1,240	1,024	322	2,135
1.01	0.99	1,542	1,316	467	2,471
1.05	0.95	2,756	2,531	1,207	3,753
1.11	0.9	3,724	3,526	1,937	4,745
1.25	0.8	5,320	5,185	3,344	6,386
1.5	0.6667	7,363	7,320	5,414	8,566
2	0.5	10,270	10,340	8,482	11,860
2.33	0.4292	11,760	11,880	9,962	13,620
5	0.2	19,220	19,430	16,500	22,980
10	0.1	26,350	26,380	22,160	32,850
25	0.04	36,550	35,940	29,770	48,480
50	0.02	44,930	43,480	35,620	62,570
100	0.01	53,920	51,300	41,520	78,990
200	0.005	63,540	59,380	47,450	98,120
500	0.002	77,260	70,460	55,310	128,400

2.4 Climate Change Analysis

A review of climate change modeling for the Nomtipom Waywaket, which includes the Winnemem Waywaket, was performed. One source of climate change information is the Climate Toolbox (Hegewisch et. al. 2024; available at: https://climatetoolbox.org/). The Climate Toolbox contains a collection of tools for addressing questions relating to water resources, forecasts, and projections. Data is available from the website for mean changes in seasonal runoff on a grid-cell-by-grid-cell basis (6- to 7-kilometer grid cell) and for daily flow at selected locations. One of the select locations where projections of change in daily flow is available is the Nomtipom Waywaket above Bend Bridge near Red Bluff. Those data are available on a nonregulated basis (i.e., assuming reservoirs are not in place).

Options for hydrologic projections for the climate change analysis include assumptions on carbon emissions scenarios used in Global Circulation Models (GCMs) through selecting Representative Concentration Pathway (RCP) 4.5 or RCP 8.5 loading (4.5 or 8.5 is the assumption of the radiative forcing measured in watts per square meter). RCP 8.5 also assumes no climate policy and business-as-usual emissions. The most used pathway is RCP 8.5 and is recommended by NMFS to be used in fish passage design (NMFS 2023c). Another option is the analysis time frame, either midcentury (2040 to 2069) or late century (2070 to 2099). The selection of the time frame is dependent on the project life span and the tolerance to risk. Mid-century conditions are acceptable for projects with shorter than 10-year life spans with low to moderate risk. Late-century conditions are recommended for projects with longer life spans or if the risk to design or to the fish population is higher (NMFS 2023c). This analysis assumes late-century conditions will be used.

Runoff and streamflow are obtained from hydrologic models using different GCMs for climate input. A number of GCMs have been utilized in hydrologic modeling, and it is recommended that the average of an ensemble of model output be used (NMFS 2023c), typically using about 10 to 12 different GCMs.

The change in mean runoff for the Nomtipom Waywaket above Bend Bridge from historic conditions (1950 to 2005) to future conditions was obtained from the Climate Toolbox. The Climate Toolbox contains links to individual model results at a daily time step and a summary on a monthly basis of a 10-model mean. Table 12 summarizes the estimated changes using RCP 8.5, late-century conditions, and a mean of an ensemble of 10 climate models on a monthly basis.

Table 12
Comparison of Average Monthly Flows from Future Late-Century to Historic Conditions Using 10 Model Ensemble for Unregulated Conditions

Month	10-Model Percentage Change from Historic
October	-9%
November	1%
December	37%
January	59%
February	52%
March	11%
April	-40%
May	-54%
June	-42%
July	-26%
August	-13%
September	6%

The percentage change is based upon the difference between modeled future conditions and the mean of modeled historic conditions for the period of 1950 to 2005. A challenge to using these percentage changes is that flow has changed during that period and some of the increases and decreases have already occurred.

To estimate future changes from current conditions (1998 to 2023), daily flow projections were downloaded for an individual GCM. Output from the hydrologic model using the CanESM2 GCM was downloaded, and flow exceedance analyses like those shown in Tables 2 through 5 were performed. Use of the CanESM2 GCM is considered to result in average results compared to other GCMs (Pierce et. al 2018). The output downloaded included modeled conditions for the period of 1998 to 2023 (which matches the period used for current conditions flow exceedance calculations) and late-century conditions. The percentage change for the 5%, 50%, and 95% exceedances from modeled historic streamflows were computed and are shown in Table 13.

Table 13
Percentage Change in Flows for Future Conditions Using CanESM2 Climate Model, Water Years 2070 to 2099 Versus Water Years 1998 to 2023

Month	Change in 5% Exceedance (High Flow)	Change in 50% Exceedance (Median Flow)	Change in 95% Exceedance (Low Flow)
January	91%	85%	89%

Month	Change in 5% Exceedance (High Flow)	Change in 50% Exceedance (Median Flow)	Change in 95% Exceedance (Low Flow)
February	103%	78%	14%
March	20%	15%	14%
April	-28%	-31%	-38%
May	-5%	-44%	-31%
June	-32%	-18%	29%
July	-1%	-2%	-8%
August	105%	-4%	-29%
September	99%	9%	5%
October	-9%	9%	7%
November	85%	7%	1%
December	28%	32%	19%

Applying these changes to the values shown in Table 10 would be a reasonable approach to estimating climate change impacts to flows in the Winnemem Waywaket for unregulated conditions. Climate change data for Cow Creek were not found; therefore, the percentage change calculated for future unregulated conditions in the Winnemem Waywaket was also applied to Cow Creek.

2.4.1 McCloud River Above Shasta Lake (USGS 11368000)

The estimated 5% and 95% exceedances for mean daily flow for late-century RCP 8.5 conditions are provided by month in Table 14. The estimate is for unregulated flow conditions.

Table 14
Mean Daily Flow Exceedance for Future Unregulated Flow Conditions – McCloud River Above Shasta Lake (USGS 11368000)

Month	95% Exceedance (cfs)	5% Exceedance (cfs)
1	1,654	10,249
2	1,995	8,361
3	1,200	6,482
4	698	2,895
5	828	2,229
6	548	3,069
7	754	1,532
8	1,476	974
9	1,461	1,320

Month	95% Exceedance (cfs)	5% Exceedance (cfs)
10	634	1,332
11	1,380	1,715
12	1,032	4,754

2.4.2 Cow Creek near Millville (USGS 11374000)

The estimated 5% and 95% exceedances for mean daily flow for late-century RCP 8.5 conditions are provided by month in Table 15. These exceedances were calculated using the same percentage change as used for the Winnemem Waywaket.

Table 15
Mean Daily Flow Exceedance Cow Creek near Millville (USGS 11374000)

Month	95% Exceedance (cfs)	5% Exceedance (cfs)
1	201	11,506
2	323	6,507
3	193	5,335
4	102	1,464
5	42	1,052
6	7	942
7	4	184
8	4	67
9	10	86
10	16	216
11	109	1,032
12	105	6,370

2.5 Peak Flow Estimates for Future Conditions

Another source of climate change information is the U.S. Forest Service (USFS). The USFS has a web map (USFS 2024) that summarizes streamflow metrics for hydrologic modeling using downscaled RCP 8.5 climate projections that were used as inputs to the variable infiltration capacity macroscale hydrologic model produced by the University of Washington Climate Impacts Group. The modeling is available at: https://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html#About. The modeling was performed with a daily time step.

The percentage change in peak flows and number of winter floods for the Winnemem Waywaket above Shasta Lake was obtained from the USFS web map (USFS 2024) and is summarized in Table 16. The percentage change reflects late-century RCP 8.5 conditions. Peak flows in winter are predicted to increase substantially for frequently occurring events.

Table 16
Future Flood Metrics for McCloud River Above Shasta Lake

Flow Metric	Percent Change
1.5-Year Flood	66%
10-Year Flood	35%
25-Year Flood	37%
Number of Winter Floods	27%

To estimate 50- and 100-year recurrence interval floods, the same percentage change for a 25-year flood was used. Table 17 provides an estimate of future flood flows in the McCloud River above Shasta Lake.

Table 17
Estimate of Future Peak Flows McCloud River Above Shasta Lake

Recurrence Interval (years)	Annual Exceedance Probability	EMA Estimate for Current Conditions (cfs)	Multiplier (%)	Future Flow Estimate (cfs)
1.5	0.6667	7,363	66	12,223
10	0.1	26,350	35	35,573
25	0.04	36,550	37	50,074
50	0.02	44,930	37	61,554
100	0.01	53,920	37	73,870

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