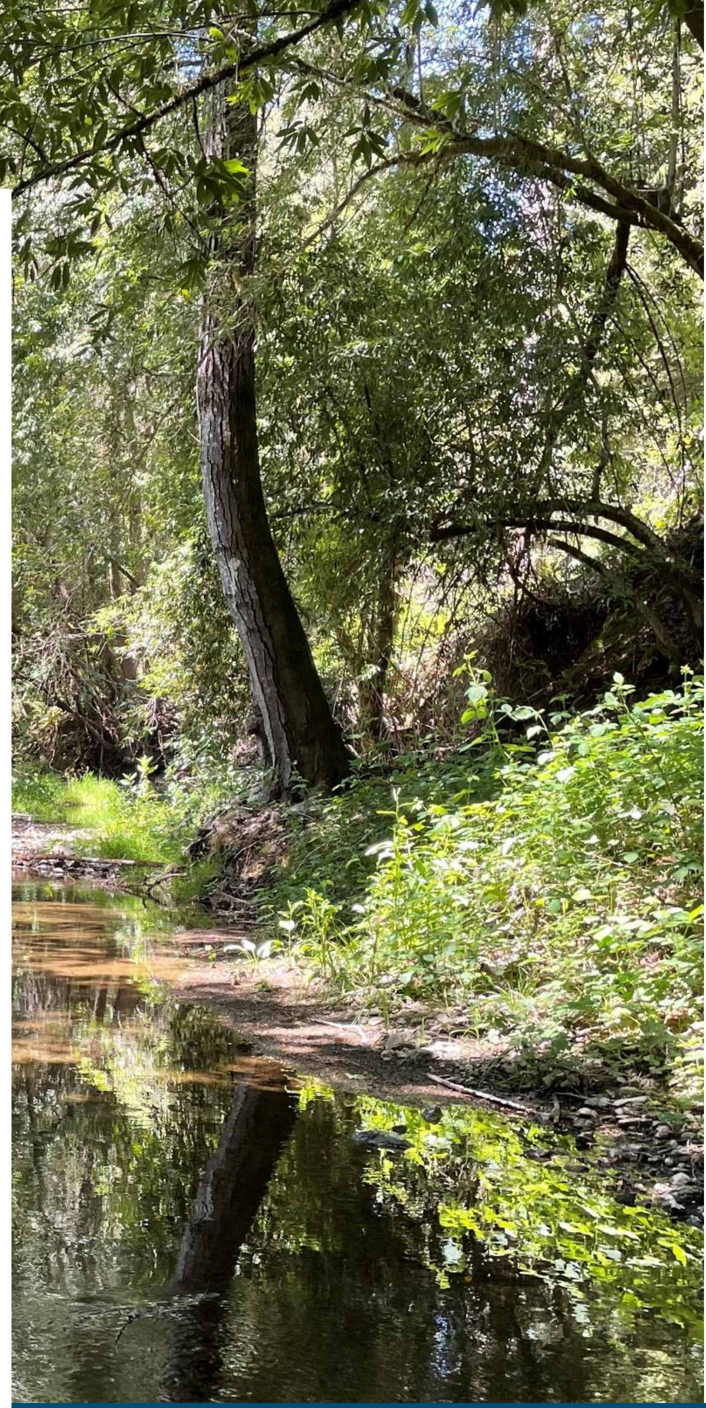
Mill Creek

Annual Environmental Monitoring Report WY2021



MARCH 30, 2022

Prepared for the Wildlife Conservation Board
By: Trout Unlimited and California Sea Grant

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1. Introduction

The Russian River Coho Water Resources Partnership (Coho Partnership) identified insufficient summer streamflow as a primary limiting factor in the Mill Creek system and developed a Streamflow Improvement Plan outlining strategies and project types to enhance streamflow conditions in the watershed (RRCWRP 2015). In April 2020, Trout Unlimited (TU), California Sea Grant's Russian River Salmon and Steelhead Monitoring Program (CSG) and Sonoma Resource Conservation District (SRCD) (members of the Coho Partnership) were awarded a Wildlife Conservation Board (WCB) grant to enhance streamflow in the Mill Creek watershed (Russian River, Sonoma County). This project aims to increase summer streamflow in the watershed by developing a series of storage and forbearance projects that will decrease dry-season demand on instream flows.

One aspect of this WCB project is to operate monitoring programs that will provide baseline data on streamflow, water quality and wetted habitat conditions in critical coho salmon and steelhead rearing reaches in order to document potential impacts of low flow on juvenile salmonids and to demonstrate how stream conditions change with the implementation of streamflow enhancement projects. The project overview map (Figure 1) shows the streamflow gage locations in the Mill Creek watershed. This report is the first of three annual reports prepared by TU and CSG to describe the results of our annual streamflow and environmental monitoring activities.

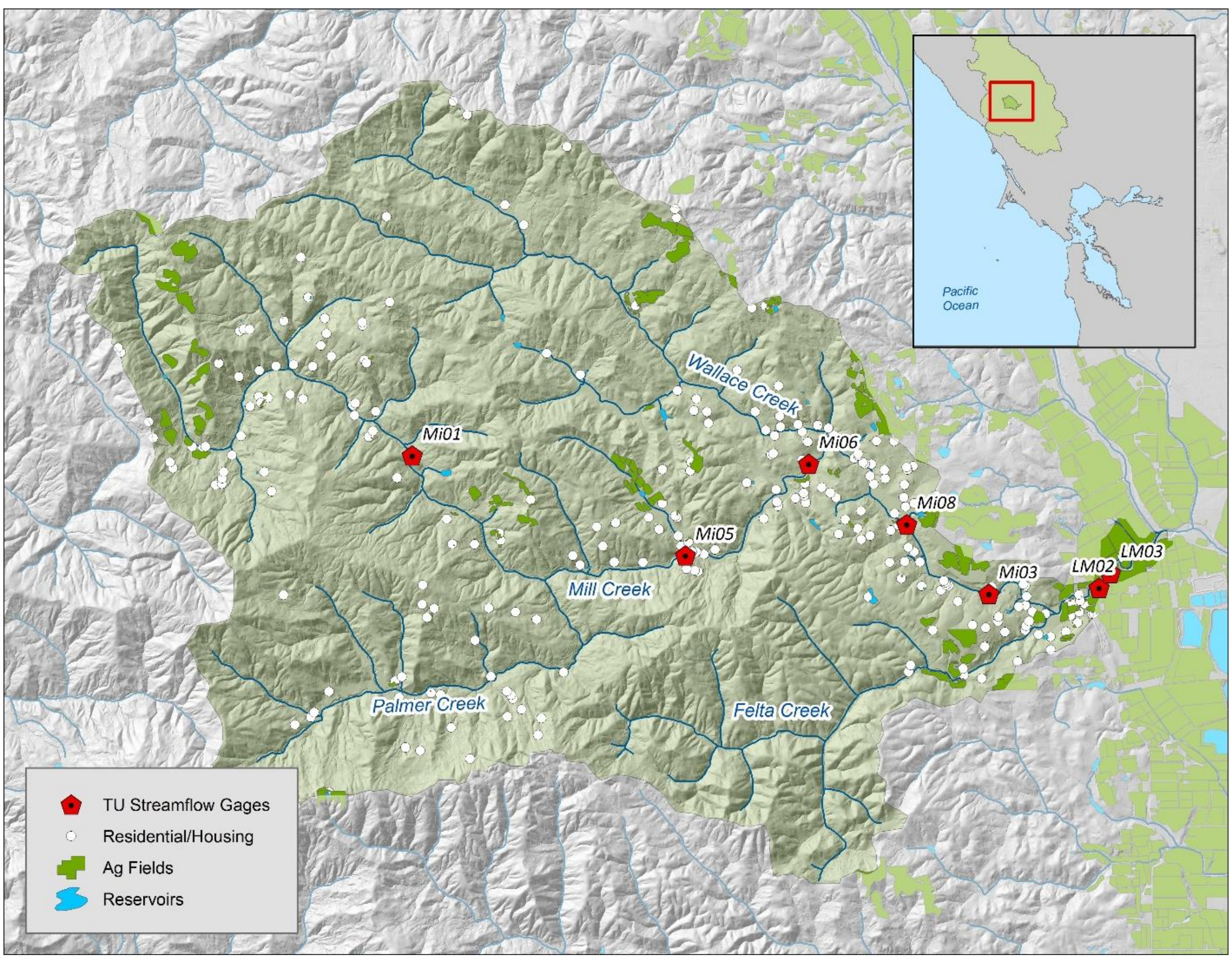

Figure 1. Project overview map, including TU's streamflow gage network and land use – showing potential water use in the watershed.

2. Fire

In summer 2020 the Walbridge fire, part of the LNU Lightning Complex fires, burned the upper portions of the Mill Creek watershed. Between August 17 and October 2, 2020, the fire burned more than 55,000 acres and destroyed more than 150 homes in the rugged hills of northwestern Sonoma County. Sixty-three percent of all accessible salmonid habitat within the Mill Creek watershed was within the Walbridge Fire footprint (https://caseagrant.ucsd.edu/blogs/the-walbridge-fire-and-salmon-habitat). The upper extent of Mill Creek, Felta, Wallace and Palmer creeks experienced extensive burning of the upslope forests as well as the riparian corridor (Figure 2). The burn intensity was greatest in the furthest upstream reaches of Mill Creek, leaving this area exposed to far greater solar radiation and erosion potential than the rest of the watershed. The impact of the fire on streamflow and habitat conditions is largely unknown, and this report describes some of the first empirical data collected and evaluated post fire.

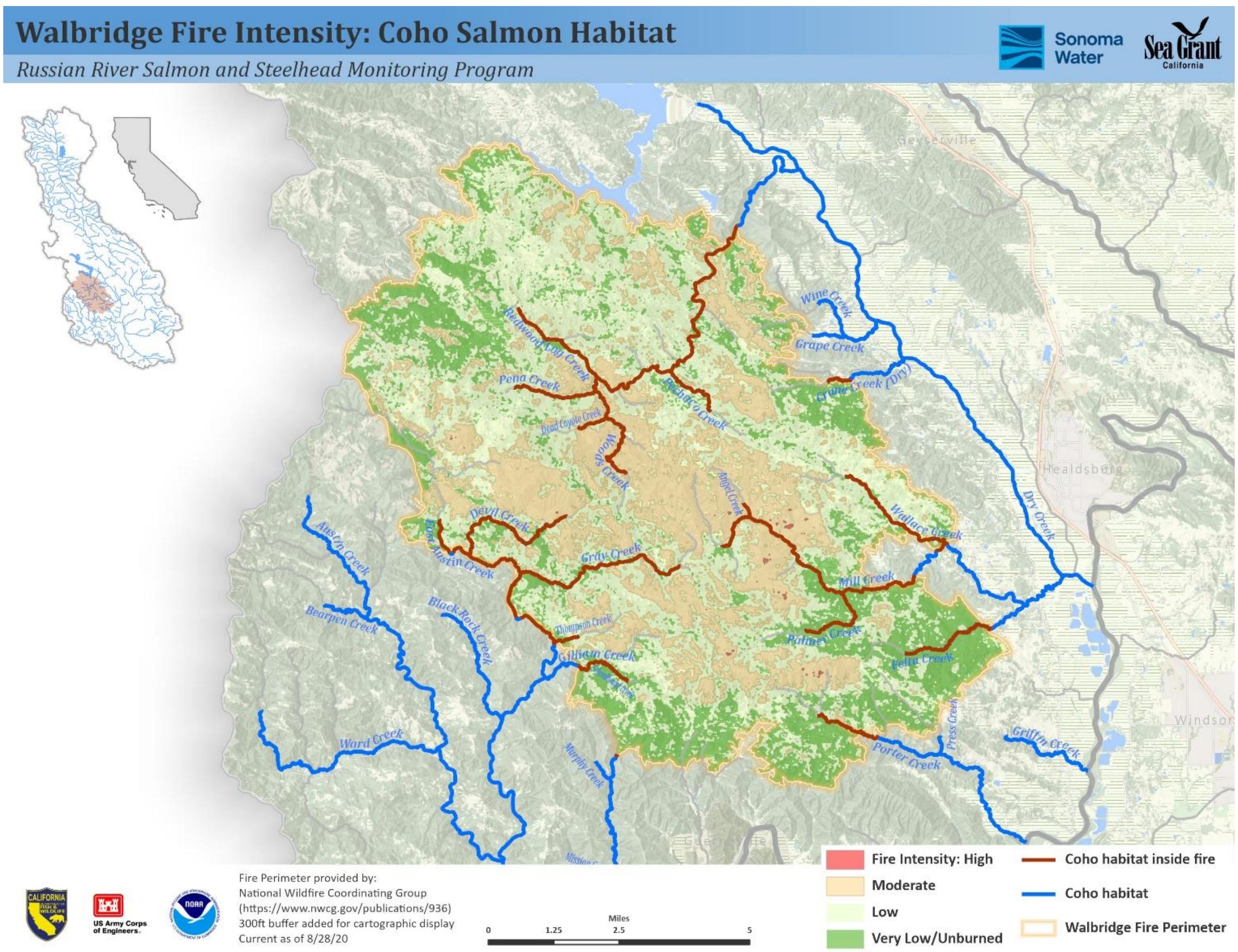

Figure 2. The Walbridge Fire footprint and fire intensity in relation to coho salmon habitat in the lower Russian River basin, including the Mill Creek watershed.

3. Rainfall

The Mill Creek watershed has a climate like many watersheds in coastal California and is considered characteristically Mediterranean — with warm, dry summers and cool, wet winters. Precipitation occurs almost exclusively as rainfall, mostly during the wet winter months (November through April).

Rainfall data were recorded over an 80-year period in nearby Healdsburg, CA at National Climatic Data Center (NCDC) Station # 3875 (Healdsburg station, hereafter), along with the median annual rainfall of 37.6 inches (Figure 3). These long-term records indicate that rainfall can be variable from one year to the next. Notably, 2021 was the driest year on record. Over the 80-year period of 1941 to 2021, annual rainfall has varied from as low as 15.8 inches (2021) to as much as 83.3 inches (1983), with extended periods of low and of high rainfall throughout the historical record. The drought of 2018–2021 represents one of three periods of below-average rainfall for four or more consecutive years: the others were 1989-1992 and 2012-2015.

Figure 3 shows the average monthly rainfall throughout the year at the Healdsburg station. These data show that 90 percent of the average annual rainfall occurs November through April; less than 2 percent of the average annual rainfall occurs from June through September (Figure 4). While the total amount of rainfall may be variable from one year to the next, the seasonality of precipitation is consistent among all years.

The timing and amount of precipitation can have an effect on summer streamflows. Figure 4 shows the monthly rainfall recorded during each month of the 2021 study period. Rainfall can be variable from month to month, as was the case during the years of the study period, but still follows the general pattern of wet winter months and dry summer months. Studies have shown that rainfall that occurs later in the wet season (March-June) can have the effect of prolonging summer flows. Figure 4 shows that in WY2021, rainfall was below average in all months.

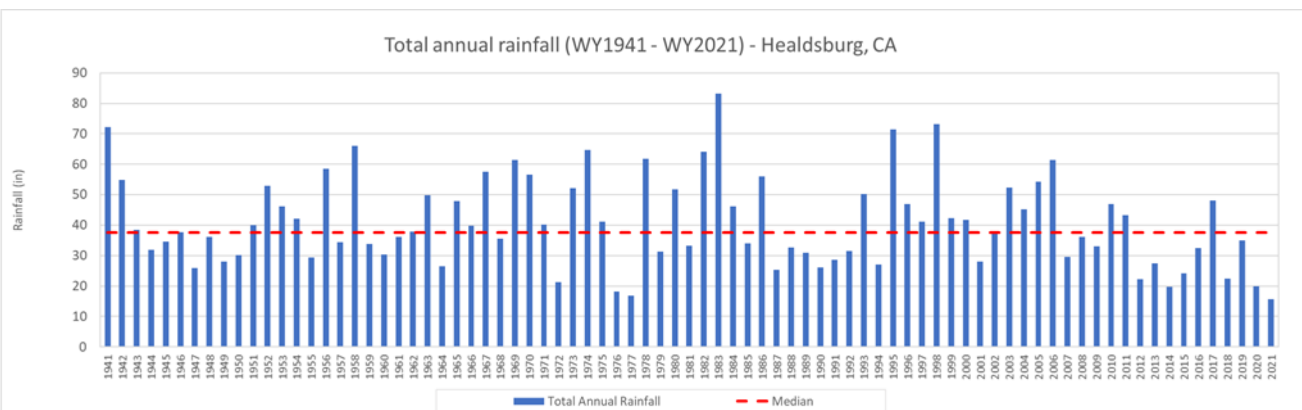

Figure 3. Total and median annual precipitation recorded in Healdsburg, CA (1941-2021) from NCDC station 3875.

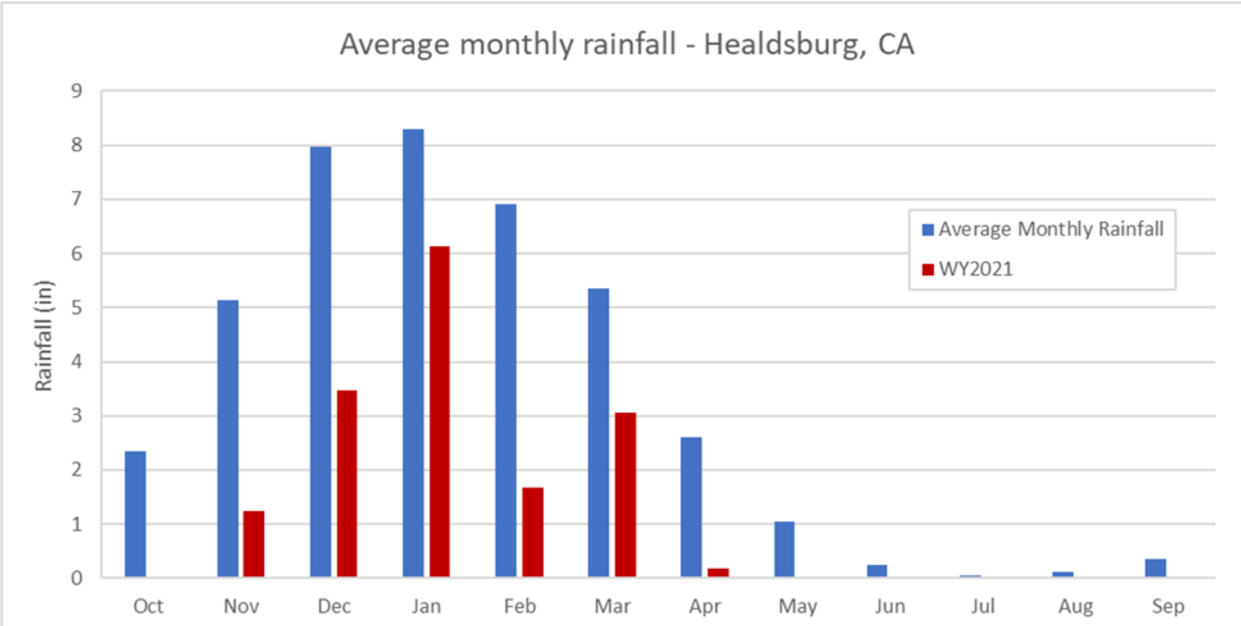

Figure 4. Total monthly precipitation in WY2021 vs monthly average rainfall recorded in Healdsburg, CA from NCDC station #3875.

4. Streamflow

Mill Creek at Bear Flat

Figure 5 and Figure 6 show stage and streamflow throughout the dry season for site Mi01 (Mill Creek at Bear Flat). Streamflow data were collected from late March through late September. Stage slowly decreased from late March to mid-April (Figure 5). A small storm in April (~0.19 in) caused stage to rise, then level out through mid-June, with small fluctuations observed. Stage receded from mid-June through mid-August, before leveling out in September.

Figure 6 shows streamflow in late March was approximately 1.6 ft^3/sec, and dropped quickly to 0.4 ft^3/sec in mid-April. Flow spiked due to the small storm on April 25, then leveled out through mid-June, aside from small fluctuations. Flow then dropped more steeply, and reached a low baseflow. Flows were between about 0.02 and 0.4 ft^3/sec from mid-June to mid-August, and averaged about 0.05 ft^3/sec from mid-August through late September.

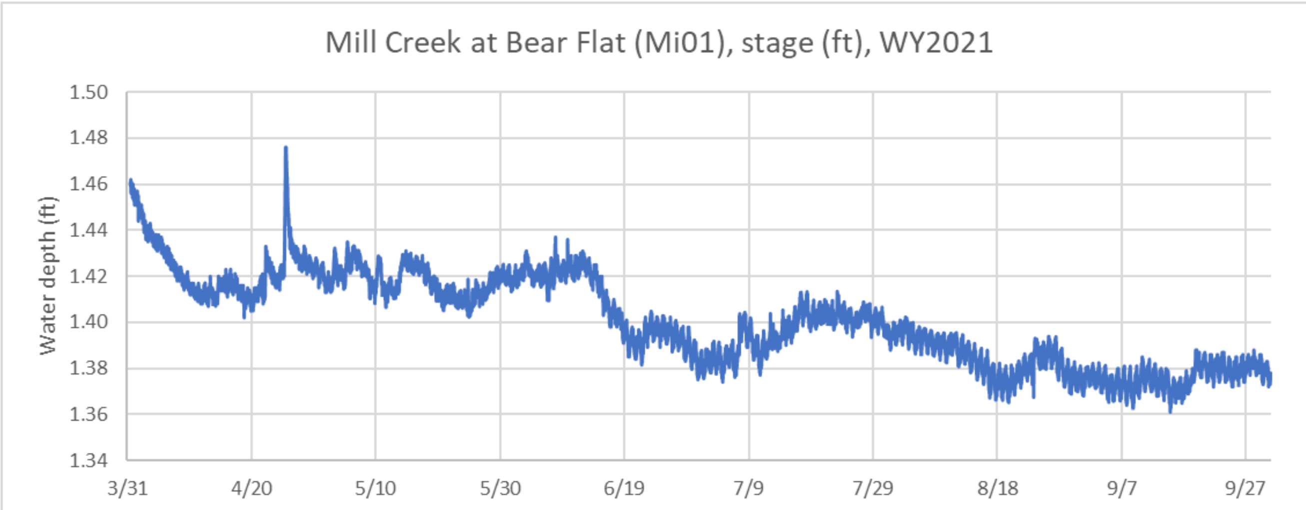

Figure 5. Stage at Mill Creek at Bear Flat, WY2021.

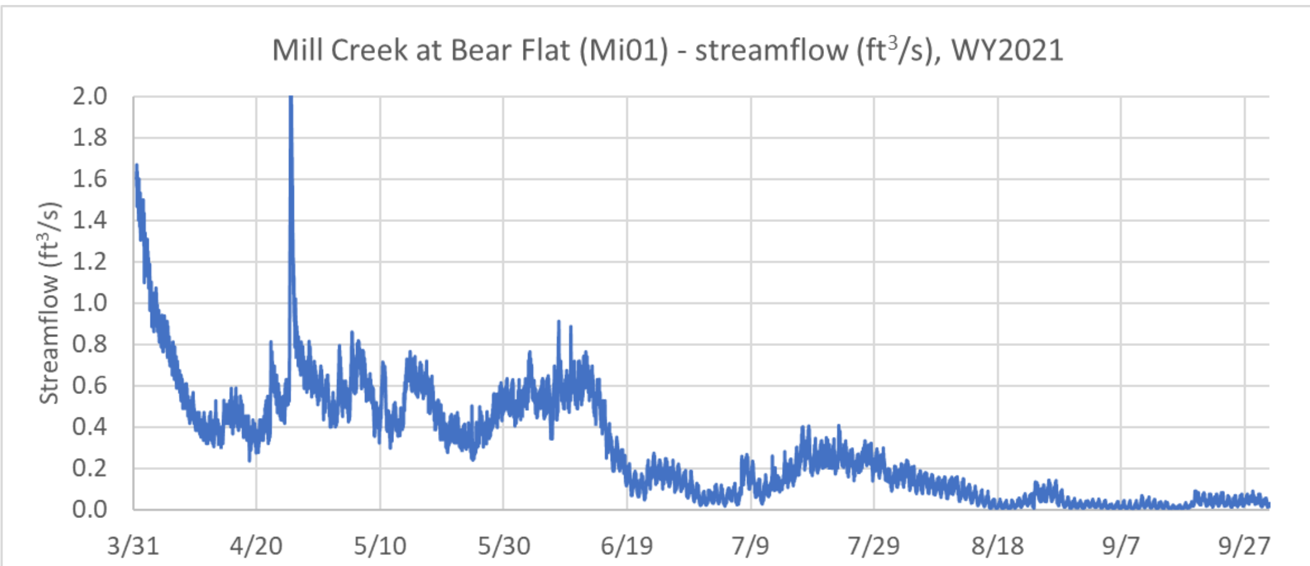

Figure 6. Streamflow at Mill Creek at Bear Flat, WY2021.

Mill Creek below Puccioni Road

Figure 7 and Figure 8 show stage and streamflow throughout the dry season for site Mi05 (Mill Creek below Puccioni Rd). Streamflow data were collected from late March through late September. Figure 9 shows stage slowly decreasing from late March through mid-August, before levelling out for the remainder of the dry season. The April storm is visible as a small rise in stage. From May 28 through July 8, the gage pool became very shallow; the gage was moved to a deeper pool on July 8. Daily fluctuations and possible human water use signatures can be seen throughout the record, and especially in the later portion of the season.

Figure 8 shows streamflow in late March 2021 was around 3.4 ft^3/sec. Flow decreased steadily until April 25, when it rose to about 2.5 ft^3/sec. From late April through mid-August, flow steadily declined before reaching a low summer baseflow of between 0.1 and 0.01 ft^3/sec. As seen in the stage record, dips in flow that may be human water use signatures can be seen throughout the record. Figure 9 shows multiple surface water diversions detected at the Mill Creek below Puccioni Rd gage site, during the diversion periods flows dropped between 0.05 – 0.2 ft^3/sec.

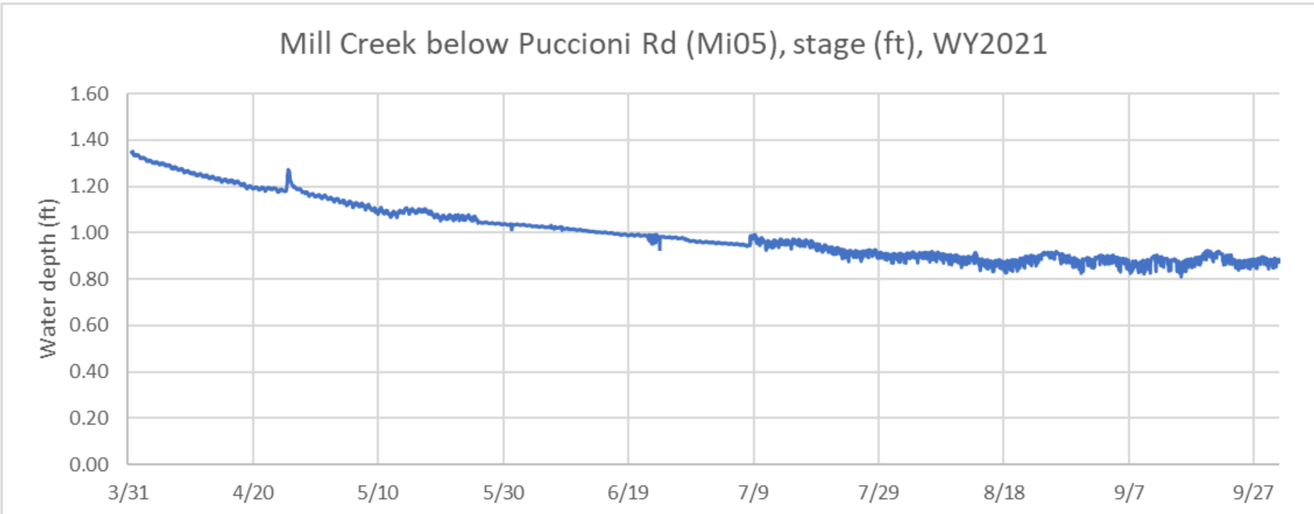

Figure 7.Stage at Mill Creek below Puccioni Road, WY2021.

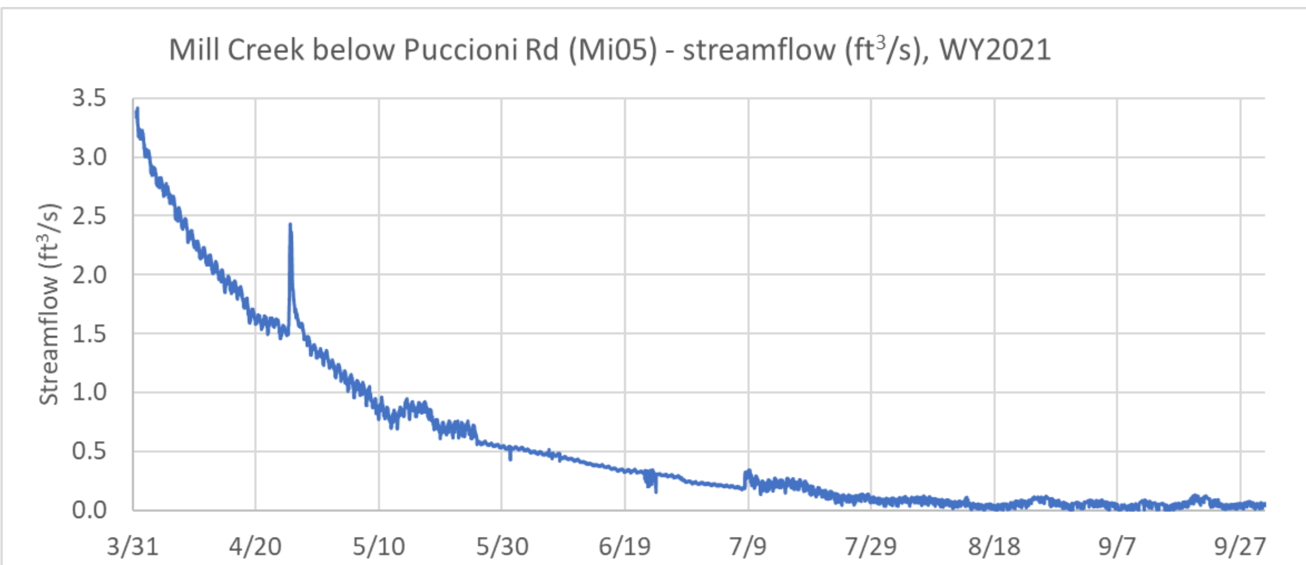

Figure 8. Streamflow at Mill Creek below Puccioni Road, WY2021.

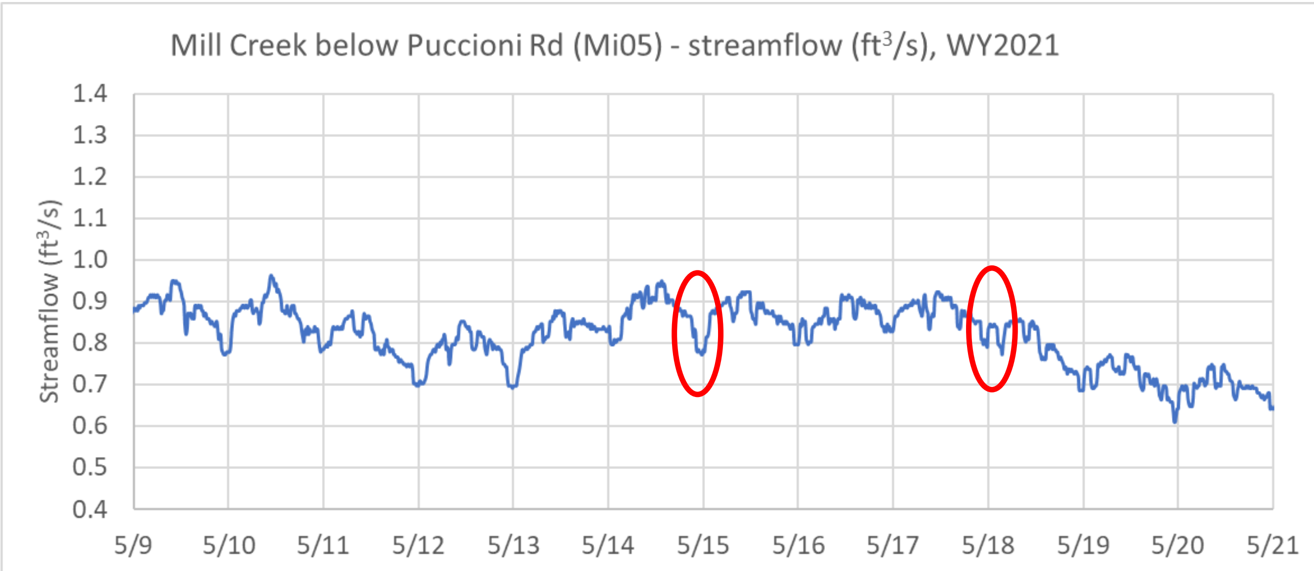

Figure 9. Surface water diversion signals detected at the Mill Creek below Puccioni Rd gage (red circles show two examples of the diversion signals detected).

Mill Creek above Wallace Creek

Figure 10 and Figure 11 show stage and streamflow throughout the dry season for site Mi06 (Mill Creek above Wallace Creek). Streamflow data were collected from late March through late September. Figure 10 shows stage slowly decreasing from late March through late July, with a rise in response to the April 25 storm. In late July though late September, stage dropped quickly as streamflow became intermittent, and stage rose and fell as the water depth in the gage pool fluctuated.

Figure 11 shows streamflow from late March through late September. In late March streamflow was approximately 2.8 ft^3/sec, then dropped sharply until rising due to the April 25 rainstorm. Following this storm, flow continued to steadily decline until becoming intermittent in mid-July 2021. Figure 12 shows daily surface water diversions signals detected at the gage site. The gage data show the signature of multiple diversions ranging between 0.076 – 0.2 ft^3/sec.

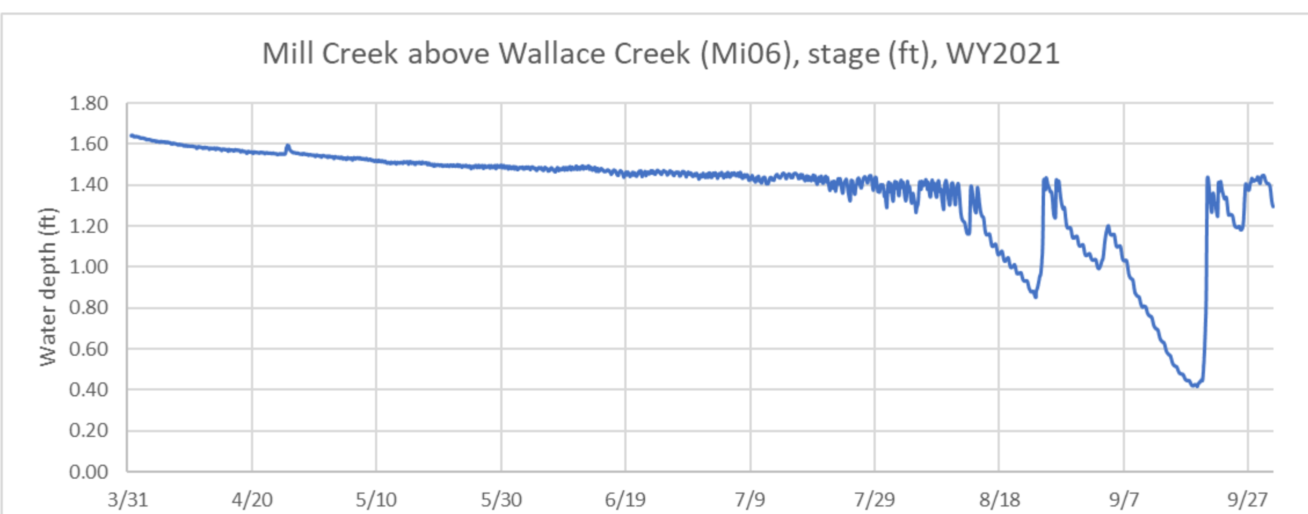

Figure 10. Stage at Mill Creek above Wallace Creek, WY2021.

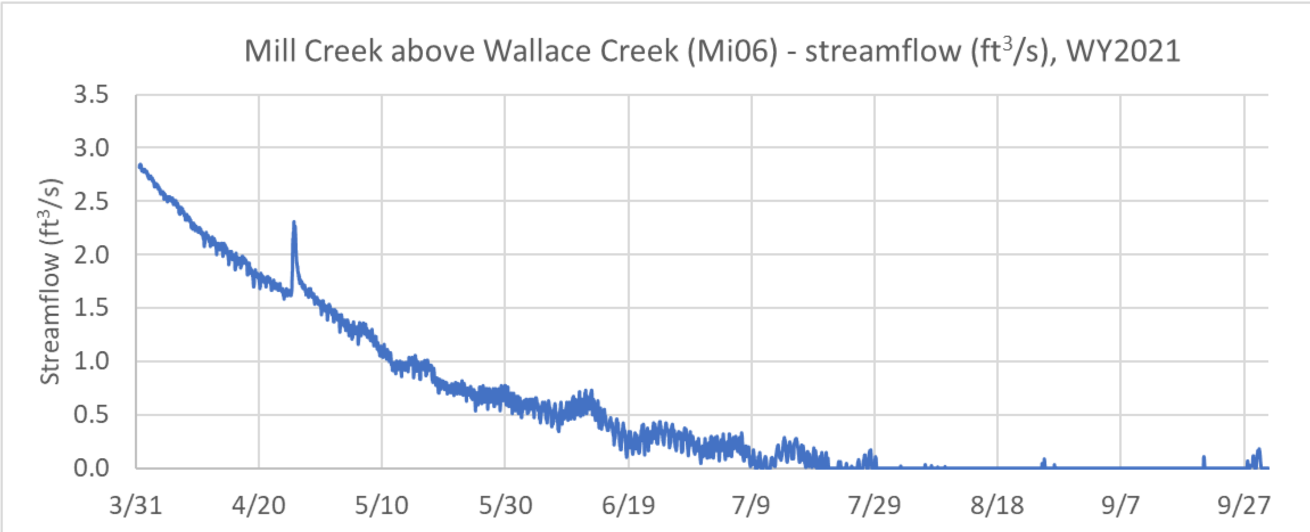

Figure 11. Streamflow at Mill Creek above Wallace Creek, WY2021.

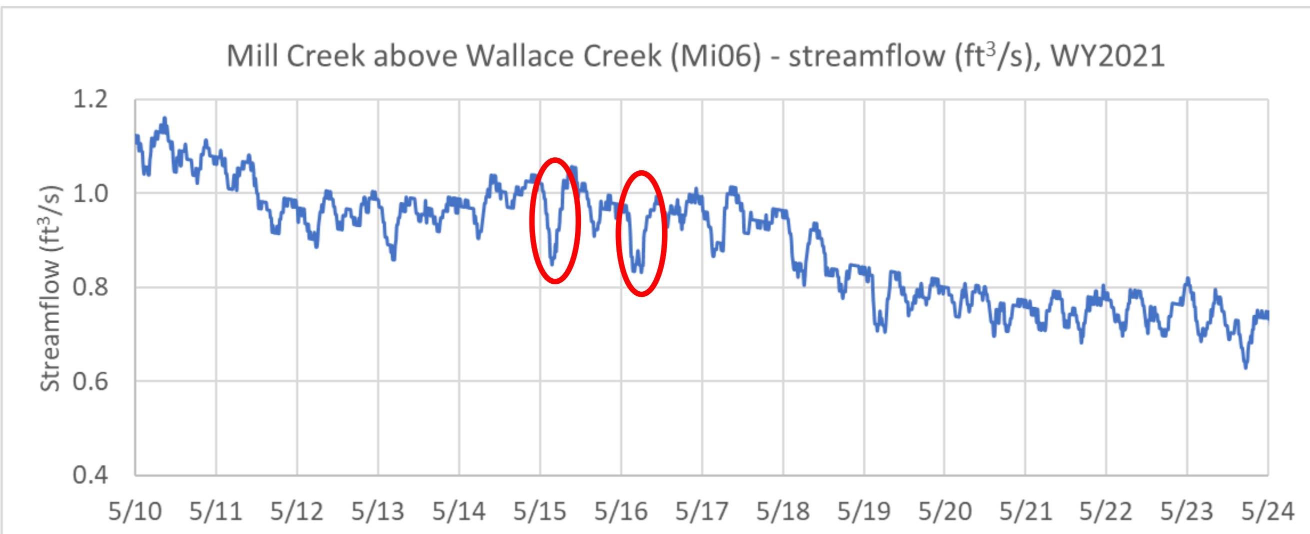

Figure 12. Surface water diversion signals detected at TU's Mill Creek above Wallace gage site (red circles show two examples of the diversion signals detected).

Mill Creek at Mill Creek Lane

Figure 13 and Figure 14 show stage and streamflow throughout the dry season for site Mi08 (Mill Creek at Mill Creek Lane). Streamflow data were collected from late March through late September. Figure 13 shows stage decreasing steadily from late March. The April 25 storm caused a small rise in stage, then stage continued to slowly fall through early July. In mid-July, stage dropped sharply as the gage pool dried.

Figure 14 shows streamflow from late March through late September. In late March streamflow was approximately 4.5 ft^3/sec, then dropped sharply until rising due to the April 25 rainstorm. Following this storm, flow continued to steadily decline until drying out in mid July 2021. Figure 15 shows surface water diversions detected at the gage site. During the periods of pumping, streamflow dropped by approximately 0.2 ft^3/sec.

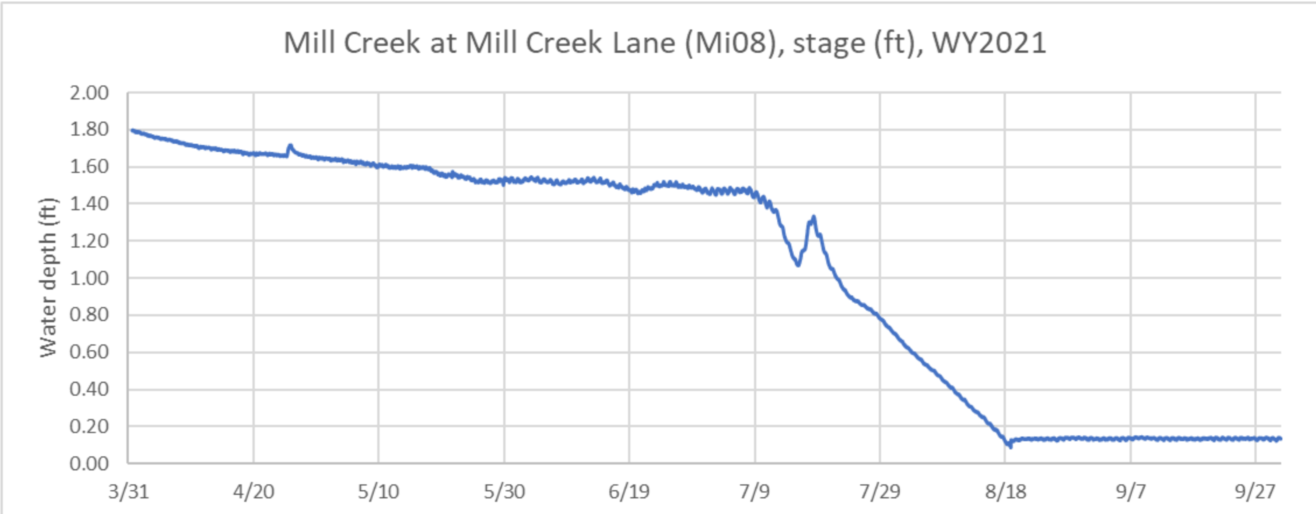

Figure 13. Stage at Mill Creek at Mill Creek Lane, WY2021.

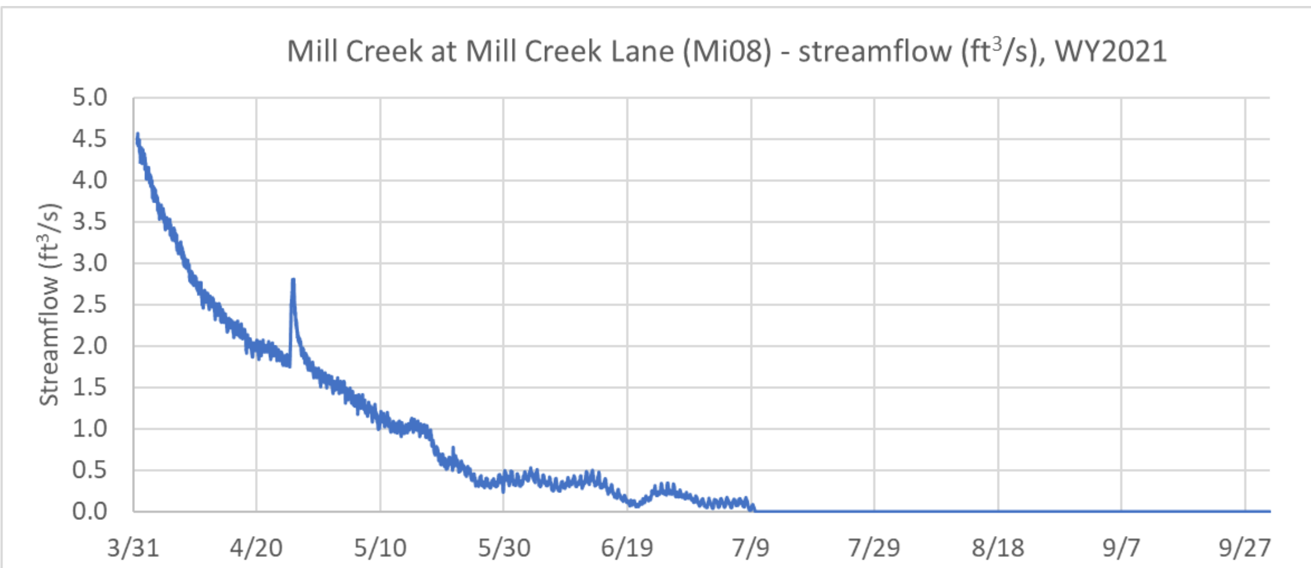

Figure 14. Streamflow at Mill Creek at Mill Creek Lane, WY2021.

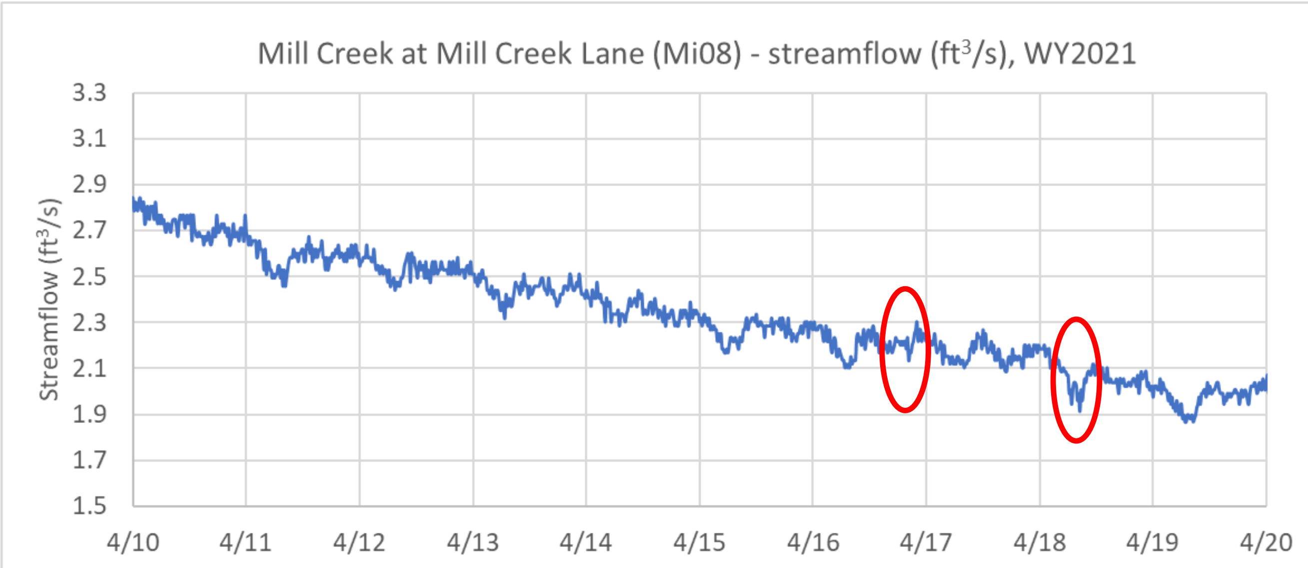

Figure 15. Surface or shallow groundwater diversion signals detected at TU's gage site Mill Creek at Mill Creek Lane (red circles show two examples of the diversion signals detected).

Mill Creek above the Falls

Figure 16 and Figure 17 show stage and streamflow throughout the dry season for site Mi03 (Mill Creek above the Falls). Streamflow data were collected from late March through late September. Figure 16 shows stage decreasing steadily from late March. The April 25 storm caused a small rise in stage, then stage continued to slowly fall through early July. In mid-July, stage dropped sharply until the gage pool dried.

Figure 17 shows streamflow from late March through late September. In late March streamflow was just above 4 ft^3/sec, then dropped sharply until rising due to the April 25 rainstorm. Following this storm, flow continued to steadily decline until drying out in mid July 2021.

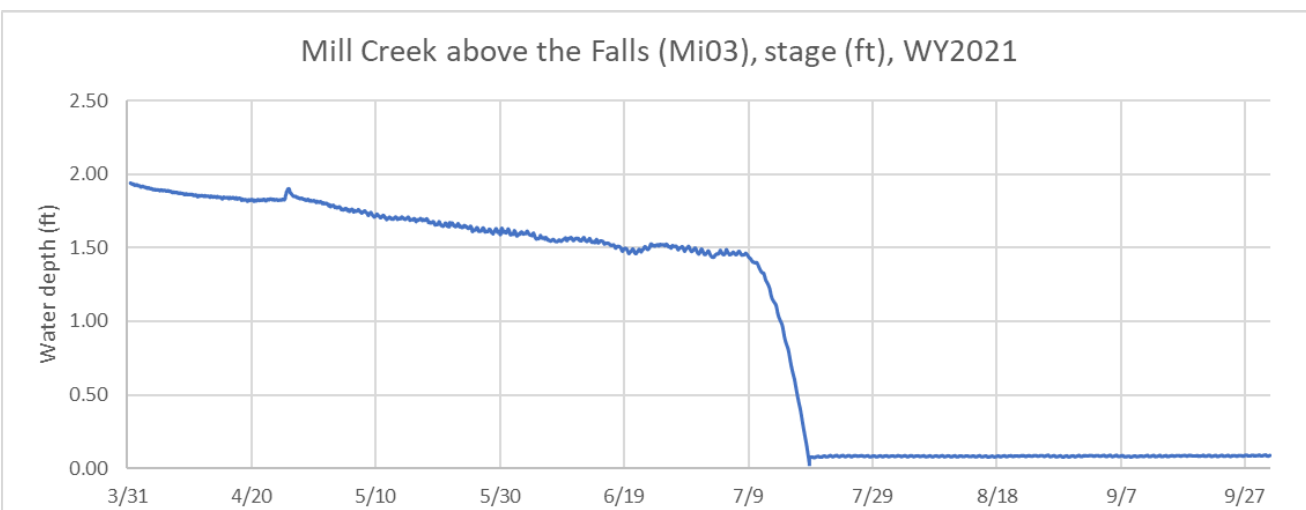

Figure 16. Stage at Mill Creek above the Falls, WY2021.

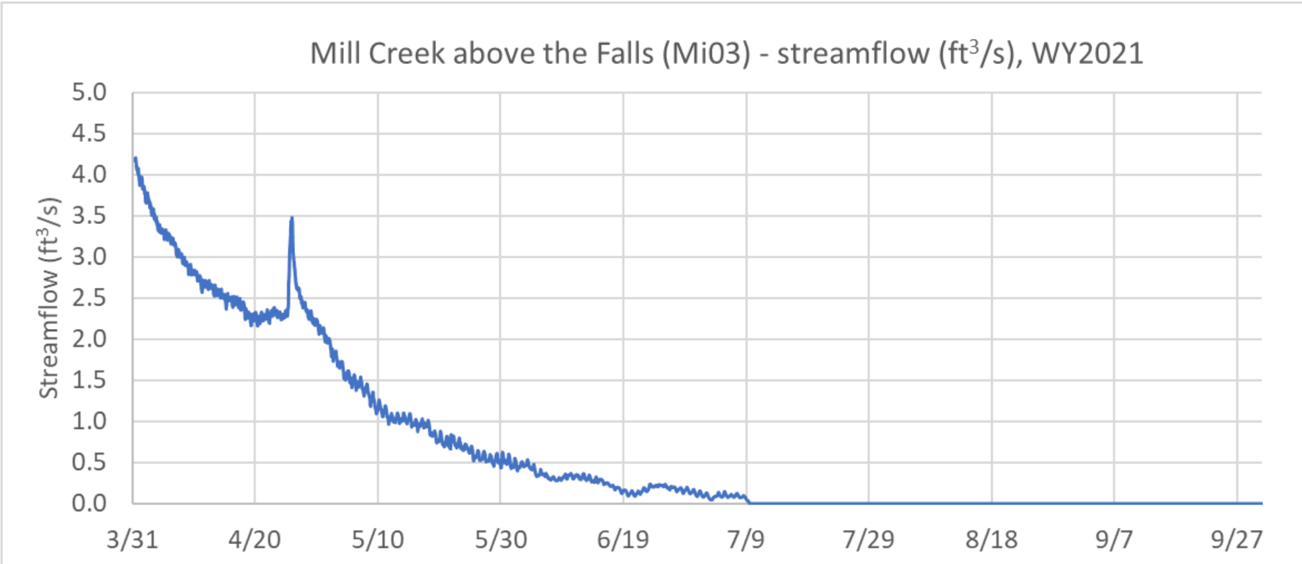

Figure 17. Streamflow at Mill Creek above the Falls, WY2021.

Mill Creek all gage sites

Figure 18 shows streamflow from late March through late September, WY2021, at all sites in the Mill Creek watershed. It shows that in late March, the lowest flows were recorded at the site highest in the watershed, Mi01 (Mill Creek at Bear Flat). At about 1.6 ft^3/sec, this site had flows about 1-3 ft^3/sec lower than sites further downstream. However, by mid-July, the furthest upstream sites (Mi01 and Mi05) had flows higher than sites downstream. Mi06 (Mill creek above Wallace) became intermittent at this time, and Mi03 (Mill above the Falls) and Mi08 (Mill Creek at Mill Creek Lane) dried and stayed dry for the remainder of the summer.

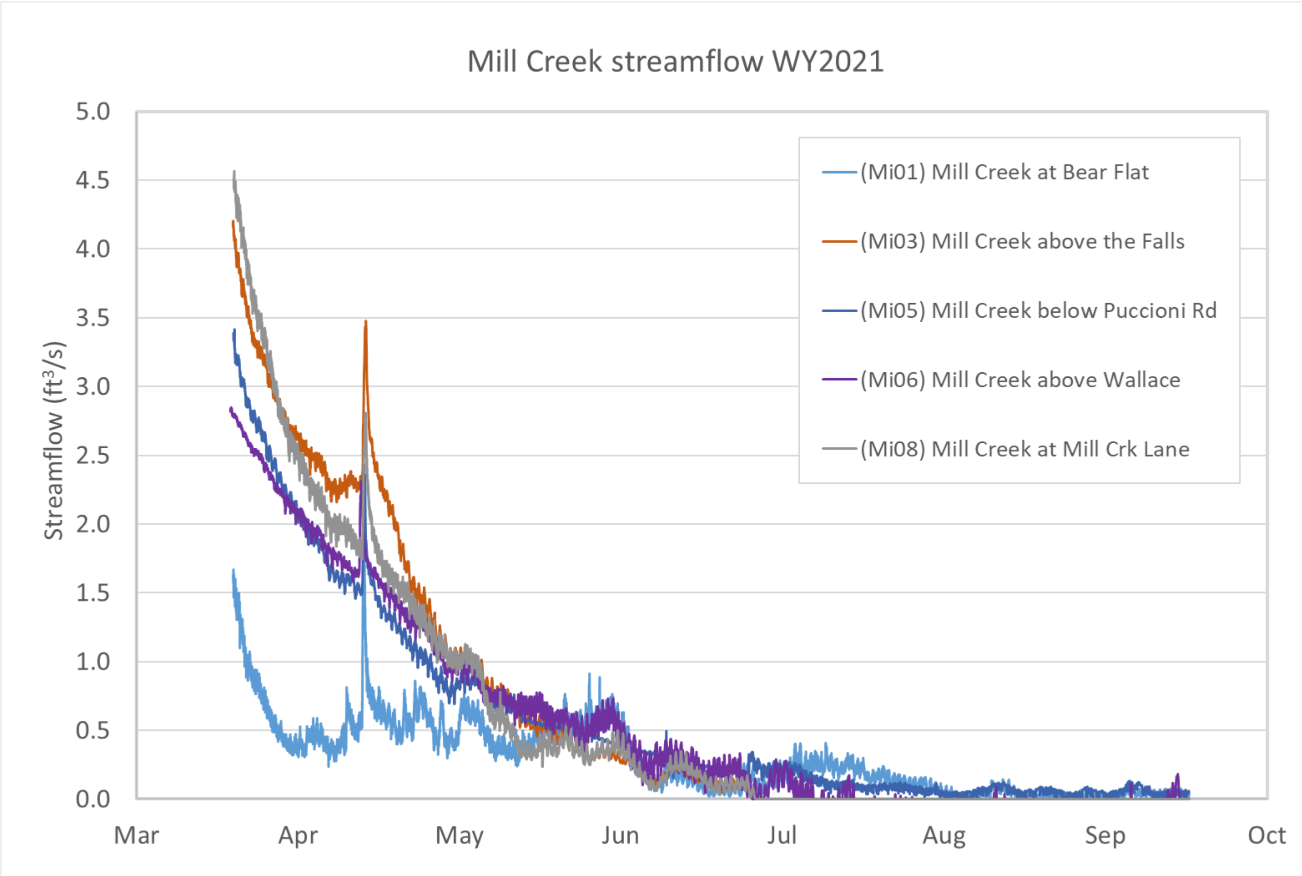

Figure 18. Streamflow at all upper Mill Creek sites, WY2021.

Streamflow and groundwater conditions – Lower Mill Creek

In WY2021 TU monitored two surface water gages (LM02 and LM03) and one continuous groundwater well gage (LM01) in the lower alluvial portion of Mill Creek (Figure 1). The lower portion of Mill Creek flows out of a confined bedrock canyon into a broad alluvial valley before joining Dry Creek, which then flows into the Russian River. The reach is highly incised and disconnected from its floodplain. The surrounding floodplain is primarily used for vineyards and small-scale agriculture. Due to the permeable nature of the underlying alluvial sediments in this reach, surface flows can be absorbed into the channel bed and underlying aquifers, causing the lower reaches of the channel to dry out in the summer months.

Figure 19 shows streamflow from late March through late September at LM02 and LM03 for WY2021. LM02, the further upstream of the lower Mill sites, has a flow of about 4.4 ft^3/sec in late March, and LM03, further downstream, had a flow of about 4.1 ft^3/sec. Flow at both sites dropped steeply in April, then rose slightly due to the late April storm. Flows at both sites were similar to each other thought the spring and early summer, with flow at LM03 generally slightly higher than the upstream LM02 site. LM02 dried to zero flow in late May, and flow at LM03 dried in mid-June.

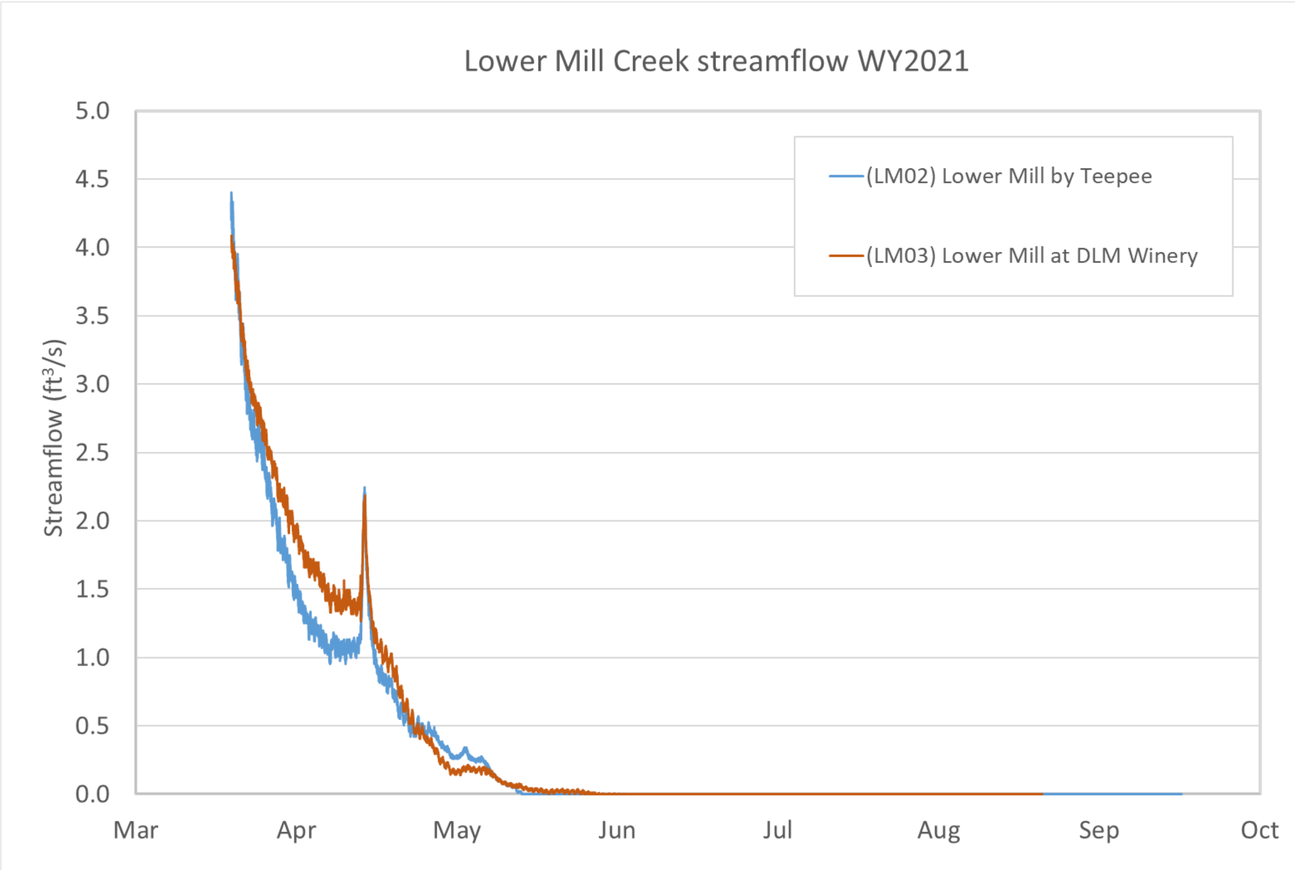

Figure 19. Streamflow at lower Mill Creek sites, WY2021.

Figure 21 shows continuous groundwater elevation in feet above mean sea level (MSL) at well LM01 (Unused Well 1) through WY2021, as well as the elevation of surface water at LM02 and LM03. LM01 is a well is adjacent to the channel slightly downstream of surface water gage LM02. A datalogger in this well reads 15-minute elevation data year-round. For the portions of the year that LM02 and LM03 were wetted, elevation data is shown in comparison to groundwater data. Note that elevations at LM03 are about 7 feet lower than LM01 and LM02 because LM03 is further downstream. While LM03 has continuous stage data through the year, LM02 is removed during high flows and re-installed in the spring to prevent washouts.

Early in WY2021, groundwater levels at LM01 continued to fall following the summer of WY2020, which was also a very dry year. Water levels reached a low point on November 11, 2020, before beginning to rise. In mid-December, water levels rose more steeply has larger rain events occurred, and the LM03 gage regained water and rose at this time as well. By late December, the groundwater reconnected with the surface water, and water levels held steady. Both groundwater and surface water rose and fell in response to winter storms. From mid-March to early June, ground and surface water levels declined slowly. In early June, the gage pool at LM02 dried, corresponding with groundwater levels dropping slightly faster. In mid-July, the downstream LM03 gage pool dried. About a week later, groundwater levels dropped steeply, and continued to drop through the period of record, reaching a low point of 67.4 feet in mid-October.

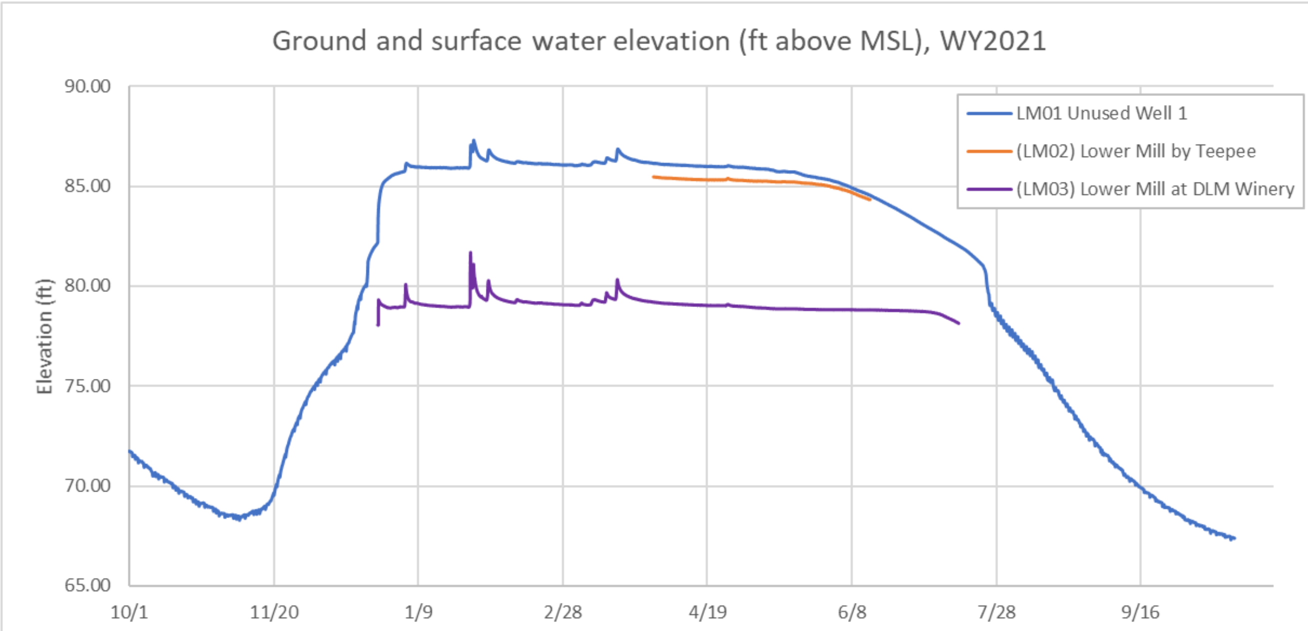

Figure 20. Continuous groundwater and surface water elevation, lower Mill Creek sites, WY2021.

5. Wetted habitat and water quality

CSG mapped stream channel conditions in the Mill Creek watershed during the driest period of 2021 using a protocol they developed to document wetted habitat available to fish at the end of the dry season. Wetted habitat surveys, also referred to as wet/dry mapping, are performed by walking the stream channel and recording wet and dry stream lines on a GPS field device. The lines are later run through a geospatial tool in ArcGIS, where the condition of "intermittent" is assigned to sections of stream with alternating short lengths (<50 feet) of wet and dry lines. Water temperature and dissolved oxygen (DO) concentrations are also measured in wet pools with handheld meters at 5-minute intervals. The full field protocol is available online (California Sea Grant 2021b) and data processing procedures are described in the WCB contract report *Flow and survival studies to support endangered coho recovery in flow-impaired tributaries of the Russian River Basin* (California Sea Grant 2019).

Wetted habitat surveys were completed on all accessible reaches of Wallace Creek on August 18, Mill and Palmer creeks on September 27-29, and Felta Creek on September 27 and October 4, 2021. Data were used to create a map displaying the spatial distribution of wet, dry and intermittent stream habitat (Figure 21). Reaches where we were not able to obtain access are indicated in grey lines. Overall, at the end of the 2021 dry season, 46% of the 12.6 rkm surveyed in Mill Creek was dry, 4% was intermittent and 50% remained wet and connected (Figure 22). Nearly all of the stream channel below the confluence with Wallace Creek was dry and nearly all of the channel surveyed above Wallace Creek was wet.

End-of-season available wetted habitat in the tributary streams varied (Figure 223). Of the 3.6 rkm surveyed in Felta Creek, 54% was dry, 31% was intermittent and 16% was wet; of the 2.5 rkm surveyed in Wallace Creek, 98% was dry, 1% was intermittent and <1% was wet; and of the 2.9 rkm surveyed in Palmer Creek, 3% was dry, 7% was intermittent and 90% was wet.

Discrete measurements of DO and water temperature were taken during the wetted habitat surveys in all streams except for Wallace Creek, which was nearly completely dry. The reach of Mill Creek below the falls was also almost entirely dry, so no measurements were taken in that reach.

Suitable DO concentrations, which generally decrease under low flow conditions during the dry season, are essential for fish survival and fitness. The North Coast Regional Water Quality Control Board (NCRWQCB) has listed 6.0 mg/L as a daily minimum DO objective for the Russian River Hydrologic Unit (NCRWQCB 2015), and decreases in swimming speed and growth rate occur below this concentration (U.S. Environmental Protection Agency 1986). Juvenile salmonids consistently avoid waters with DO concentrations below 5.0 mg/L (Washington State University Department of Ecology 2002). The lower limit to avoid mortality in salmonids is 3.0 mg/L (U.S. Environmental Protection Agency 1986), though juvenile fish have been observed surviving in lower concentrations within Russian River streams (Obedzinski et al. 2018).

DO concentrations were variable between pools and within stream reaches sampled. Minimum values measured in individual pools ranged from 0.3 mg/L in upper Felta Creek to 10.8 mg/L in upper Mill Creek (Table 1). DO averaged 6.9 mg/L in Mill Creek, 5.2 mg/L in Felta Creek and 7.2 mg/L in Palmer Creek, respectively (Figure 234). Stream-scale average DO was above the 3.0 mg/L salmonid mortality threshold in all cases, but average concentrations in Felta Creek were below the 6.0 mg/L minimum daily objective. It should be noted that the discrete DO measurements taken on the survey days only capture a single point in time and do not reflect variation in concentrations within and between days. In this context, comparisons to the daily minimum objective and other thresholds only indicates whether targets were met at the time of measurement.

There were notable differences in water quality conditions between different spatial extents of stream. California Coastal Monitoring Program (CMP) reach designations were used to summarize the DO and water temperature data and evaluate differences on a reach scale (Table 1, Figure 245). On average, the eight wet pools in Mill Creek below the confluence with Wallace Creek (MIL 1.5-MIL 2) had DO concentrations below impairment levels and just slightly above the mortality threshold, with just 13% of discrete measurements exceeding the regional objective and 37% above mortality levels.

On average, the reaches of Mill Creek above Wallace Creek (MIL 3-MIL 5) had DO concentrations above the regional thresholds and sufficient to support rearing fish, with 90% of the 28 pools measured exceeding the objective and 100% exceeding the mortality threshold. Average DO in lower Felta Creek (FEL 1) was above the regional objective and notably higher than in upper Felta Creek (FEL 3), where DO concentrations were below the objective in 60% of the 10 pools sampled and below the mortality threshold in 40%. In Palmer Creek, 80% of the eight discrete DO measurements in the single survey reach exceeded the regional minimum daily DO objective and 100% exceeded the mortality threshold.

The optimum summer water temperature range for juvenile coho salmon is 10° to 15°C (McMahon 1983). At water temperatures greater than 20°C, significant decreases in swimming speed and increases in mortality due to disease have been noted, and water temperatures exceeding 25.5°C are lethal to coho salmon (McMahon 1983). In the nearby Mattole River watershed, coho salmon were not present in suitable rearing habitat when the maximum weekly average temperature (MWAT) exceeded 16.7°C and maximum weekly maximum temperature (MWMT) exceeded 18°C (Welsh et al. 2001).

When averaged at a stream scale, water temperatures on the survey dates were essentially within the optimal temperature range for juvenile coho in all streams (Table 1). At a reach scale, temperatures were near or below optimal in all reaches except for the two uppermost reaches of Mill Creek (MIL 4 and MIL 5), where they were still below the 18°C MWMT avoidance threshold. Maximum measured water temperatures were generally suitable for rearing fish in all reaches except for those above the confluence with Palmer Creek (MIL 4 and MIL 5), where they were slightly above the avoidance threshold. Note that discrete temperature measurements only capture a single point in time and do not reflect variation within and between days, MWAT or MWMT. In this context, comparisons to the above thresholds only indicate whether targets were met at the time of measurement.

The wetted habitat and discrete water quality measurement data from the Mill Creek watershed in 2021 and previous years can be viewed in the online dashboard that CSG created for this and other WCB-funded projects.

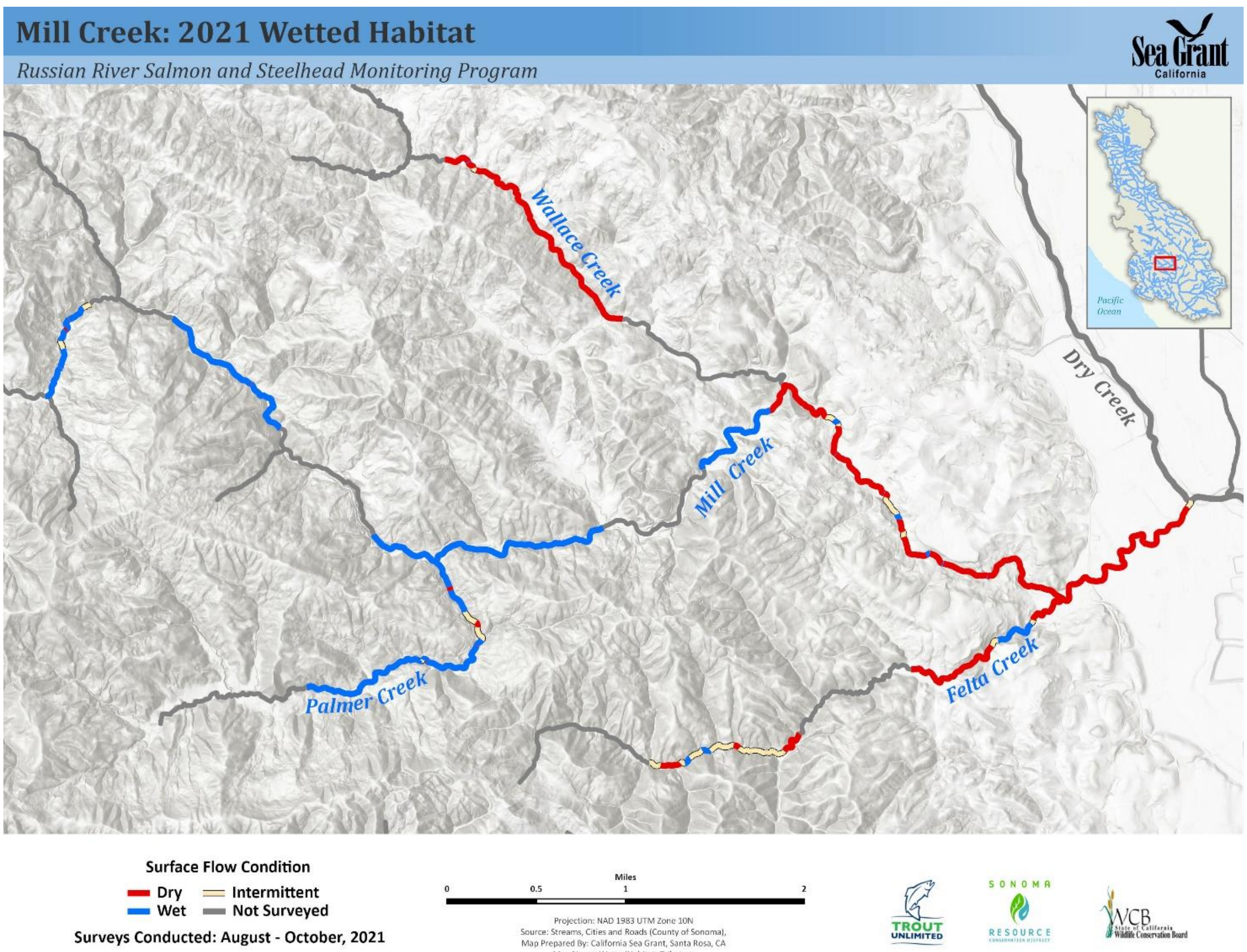

Figure 21. Wetted habitat conditions in the Mill Creek watershed, summer 2021. Wallace Creek was sampled on August 18, and the remaining streams were sampled between September 27 and October 4, 2021.

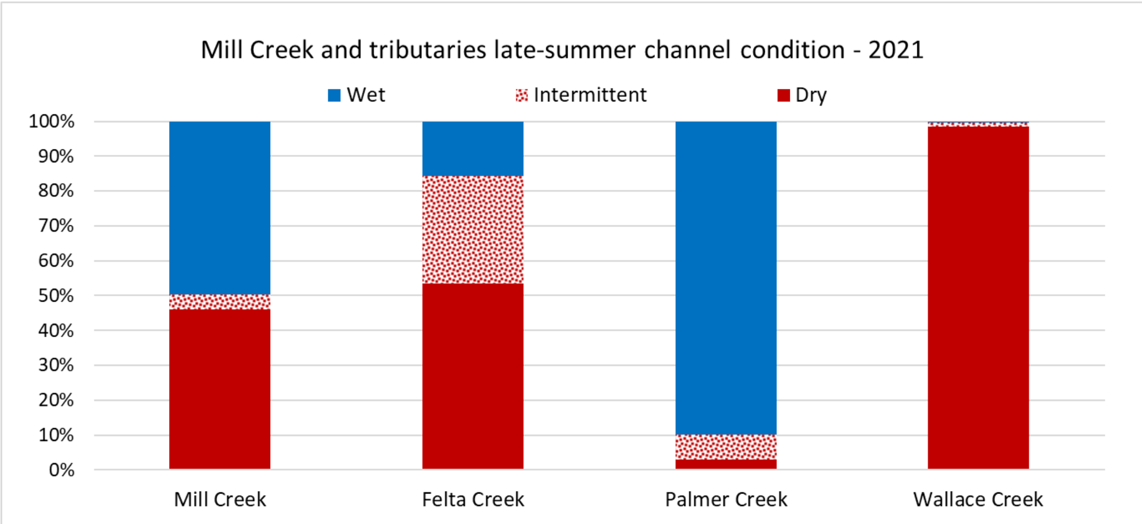

Figure 22. Total proportion of late-summer wet, dry and intermittent habitat present in accessible reaches of Mill, Felta, Wallace and Palmer creeks, 2021.

Table 1. Minimum and average dissolved oxygen and average and maximum water temperature from sampled pools in Mill, Felta and Palmer creeks, September 27-29 and October 4 (FEL 3 only), 2021. Reaches are named according to CMP reach designations and rkm range includes both surveyed and unsurveyed (no access permission) sections of stream. There were no wet units to sample in Wallace Creek or in the first reach of Mill Creek (MIL 1).

Stream/reach	Rkm range	Number of pools sampled	Minimum DO (mg/L)	Average DO (mg/L) +/- 1 SD	Average water temperature (°C) +/- 1 SD	Maximum water temperature (°C)
Mill Creek	**All**	**36**	**0.4**	**6.9 +/- 2.5**	**15.5 +/- 1.7**	**19.0**
MIL 1	0-2.55	0	NA	NA	NA	NA
MIL 1.5	2.56-3.16	1	4.0	4.0	13.4	13.4
MIL 2	3.17-6.06	7	0.4	3.1 +/- 2.4	15.2 +/- 1.3	17.0
MIL 3	6.07-10.67	13	4.9	7.8 +/- 1.3	14.3 +/- 1.4	17.0
MIL 4	10.68-15.01	10	7.7	8.7 +/- 0.9	16.5 +/- 1.2	19.0
MIL 5	15.02-16.59	5	5.7	7.0 +/- 1.2	17.6 +/- 0.8	18.4
Felta Creek	**All**	**15**	**0.3**	**5.2 +/- 3.2**	**13.8 +/- 0.6**	**15.1**
FEL 1	0-2.05	5	1.9	7.0 +/- 2.9	14.1 +/- 0.3	14.6
FEL 3	3.53-5.18	10	0.3	4.3 +/- 3.1	13.7 +/- 0.7	15.1
Palmer Creek	**All**	**8**	**3.7**	**7.2 +/- 1.8**	**13.9 +/- 0.5**	**14.7**

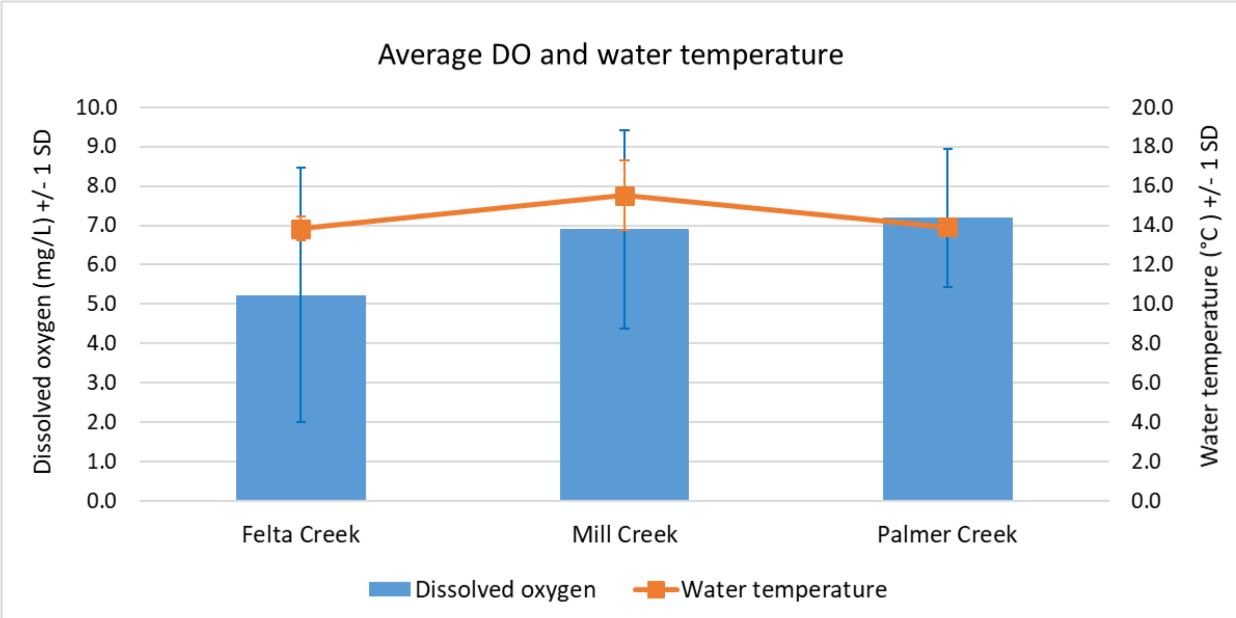

Figure 23. Average dissolved oxygen concentrations and water temperatures in pools sampled in Mill, Felta and Palmer creeks, September and October 2021. There were no wet units to sample in Wallace Creek.

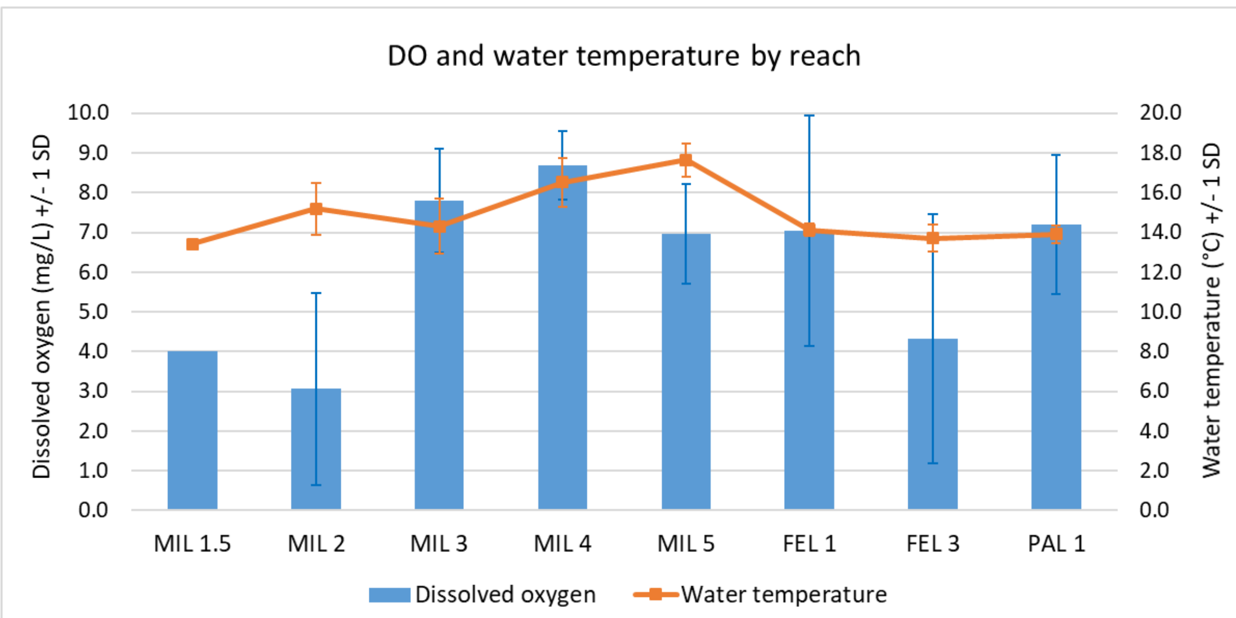

Figure 24. Average dissolved oxygen concentrations and water temperatures in pools sampled in CMP reaches of Mill, Felta and Palmer creeks, September and October 2021. There were no wet units to sample in Wallace Creek or in the first reach of Mill Creek (MIL 1). There was only one pool available to sample in MIL 1.5, therefore standard deviation could not be estimated.

6. Salmonid distribution in relation to wetted habitat

Salmonid redds

In the winter of 2020/21, spawner surveys were conducted in accessible reaches of Mill, Felta, Wallace and Palmer creeks by CSG and Sonoma Water for CMP, with financial support provided by California Department of Fish and Wildlife. Survey methods followed procedures outlined in *Russian River Coho Salmon and Steelhead Monitoring Report: Winter 2020/21* (California Sea Grant 2021a).

A total of 34 salmonid redds were observed in Mill Creek — one coho, 28 steelhead and five unknown salmonid species. One steelhead redd was seen in Felta Creek, no redds were seen in Wallace Creek and four redds (one coho and three steelhead) were seen in Palmer Creek (California Sea Grant 2021a).

The 2020/21 redd distribution data were spatially joined to the late-summer 2021 wetted habitat data in order to evaluate the suitability of summer rearing habitat in relation to spawning activity. Of all redds observed in Mill Creek, 62% were in locations that dried, 6% were in locations that became intermittent and 32% were in locations that remained wet (Figure 256, Figure 267). The single redd observed in Felta Creek was in a location that dried completely and all redds observed in Palmer Creek were in locations that remained wet and connected through the dry season.

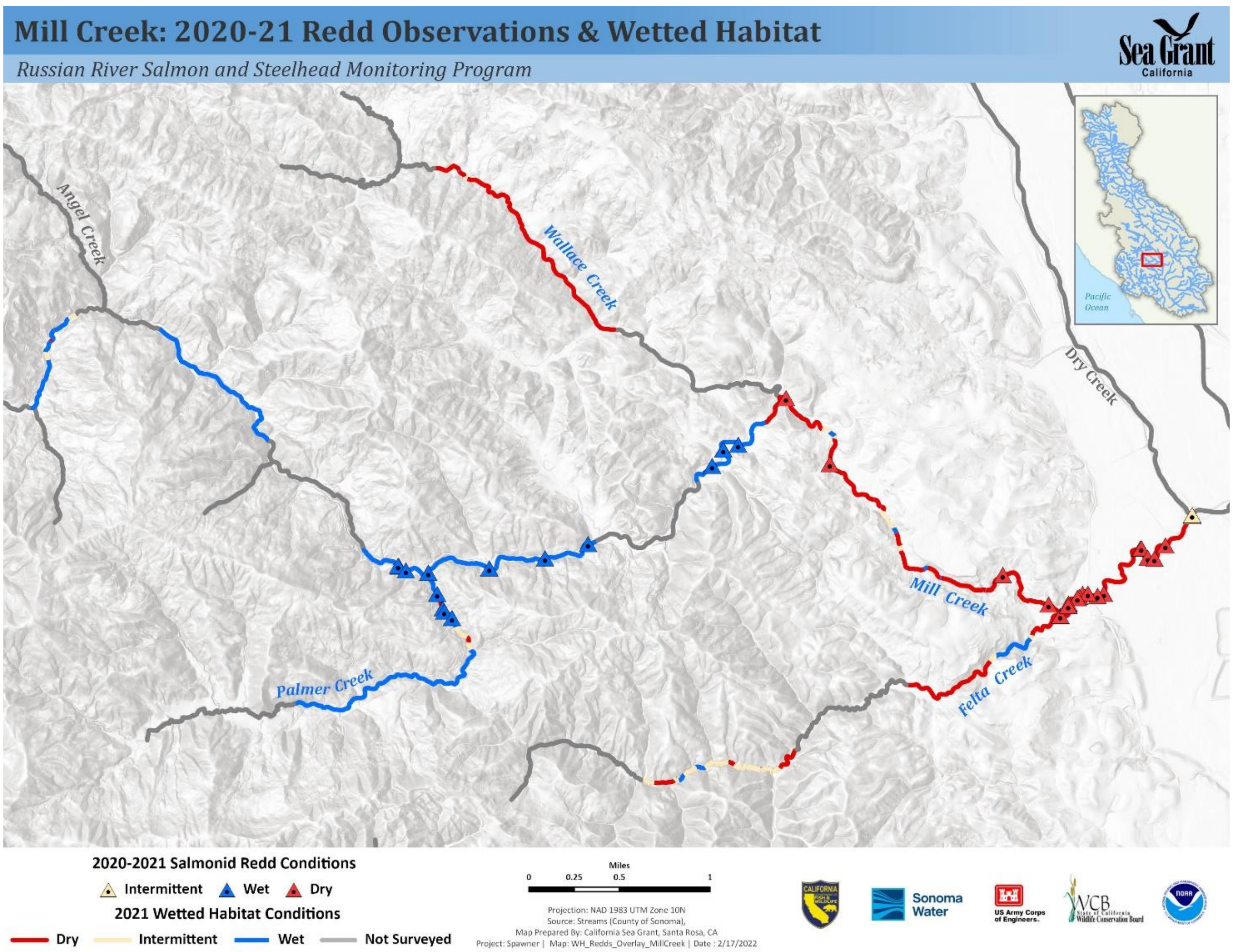

Figure 25. Winter 2020/21 salmonid redd observations in relation to late-summer 2021 wetted habitat conditions in the Mill Creek watershed.

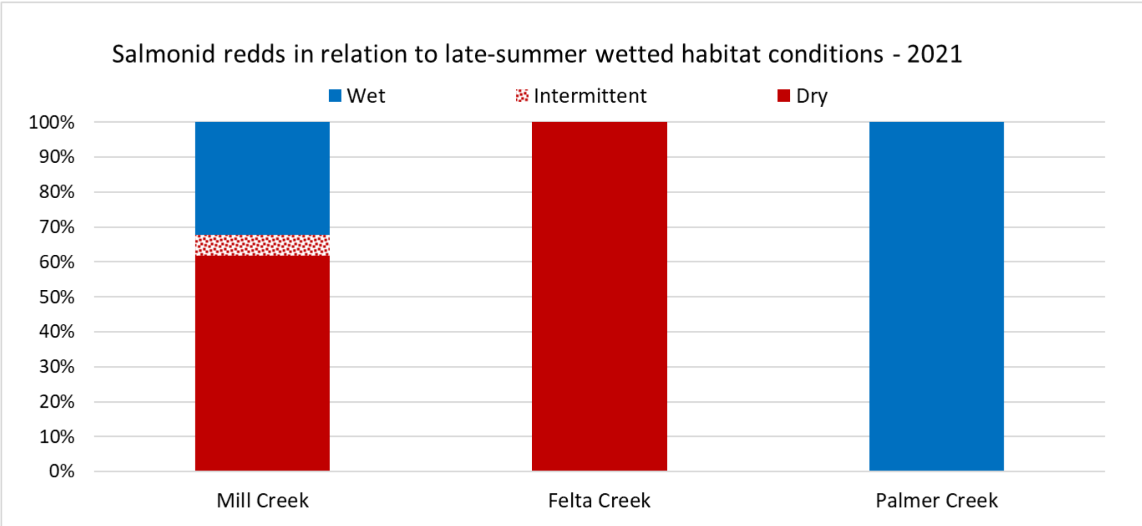

Figure 26. Proportion of winter 2020/21 salmonid redd observations in Mill, Felta and Palmer creeks that occurred in locations later documented as wet, dry or intermittent habitat during late summer 2021. No redds were observed in Wallace Creek.

Juvenile salmonids

Snorkeling surveys were conducted in Mill, Felta, Wallace and Palmer creeks by CSG and Sonoma Water for CMP between May and July, 2021 in order to document the relative abundance and spatial distribution of coho salmon and steelhead young-of-the-year (yoy). Salmon and steelhead yoy were counted in every second pool using methods outlined in *Coho Salmon and Steelhead Monitoring Report: Summer 2021* (California Sea Grant 2022).

In total, 160 coho and 274 steelhead were observed in Mill Creek, zero coho and 44 steelhead in Felta Creek, 1 coho and 78 steelhead in Palmer Creek, and no salmonids in Wallace Creek. Since counts were from every second pool, these numbers were doubled to generate an expanded estimate of 868, 88 and 158 salmonid yoy in each stream, respectively.

Juvenile salmonid distribution data from early summer 2021 were spatially joined with the end-of-season wetted habitat data and the total proportion of all yoy counted in each habitat condition — wet, dry and intermittent—was calculated in order to estimate the effect of stream drying and wetted habitat condition on juvenile rearing fish (Figure 278 and Figure 289). In Mill Creek, 69% of salmonid yoy were observed in pools that later dried and 31% in pools that remained wet. In Felta Creek, 37.5% were in pools that dried and 62.5% in areas that became intermittent. In Palmer Creek, 19% were in locations that became intermittent and 81% were in pools that stayed wet.

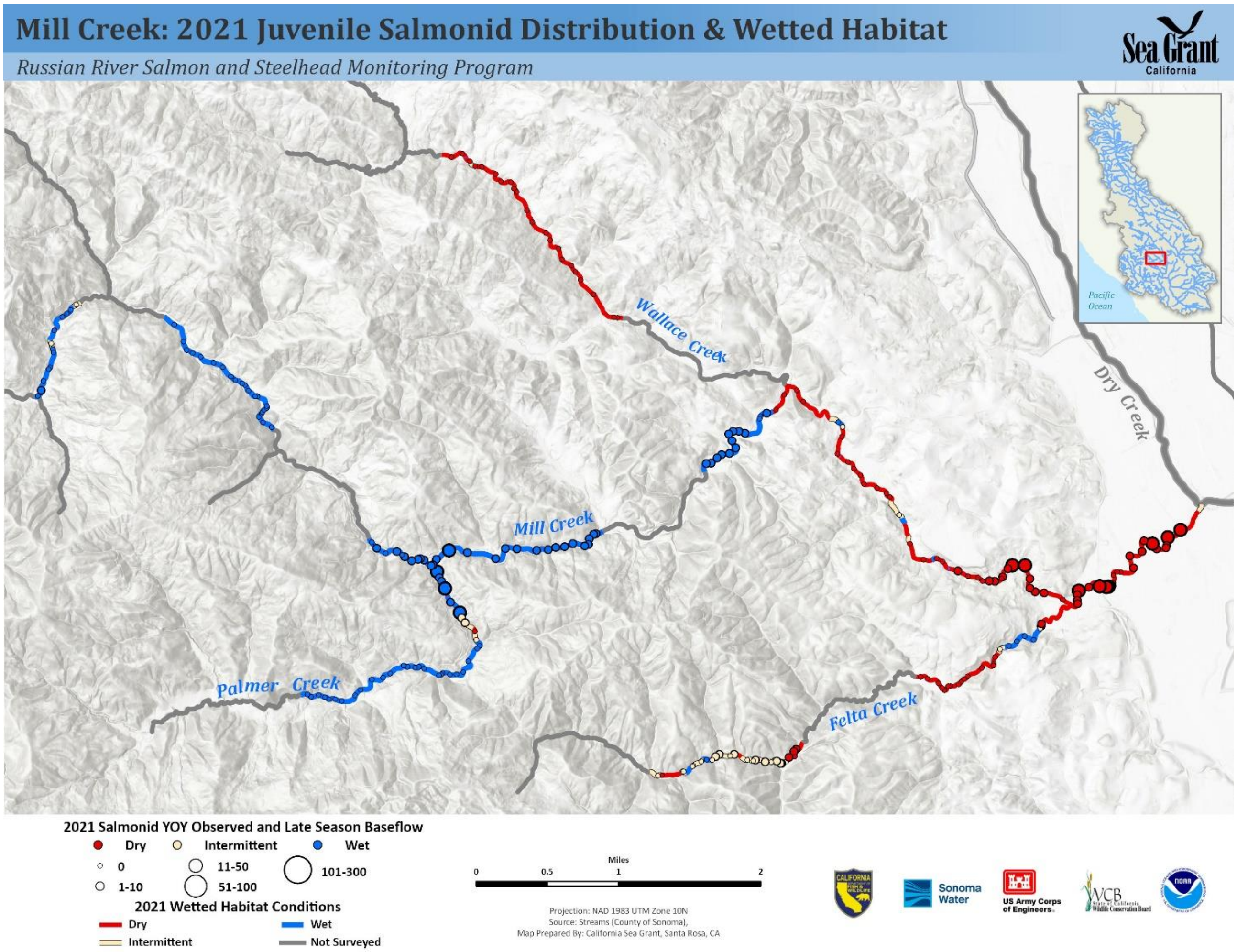

Figure 27. Early-summer salmonid young-of-the-year observations in relation to late-summer wetted habitat conditions in the Mill Creek watershed, 2021.

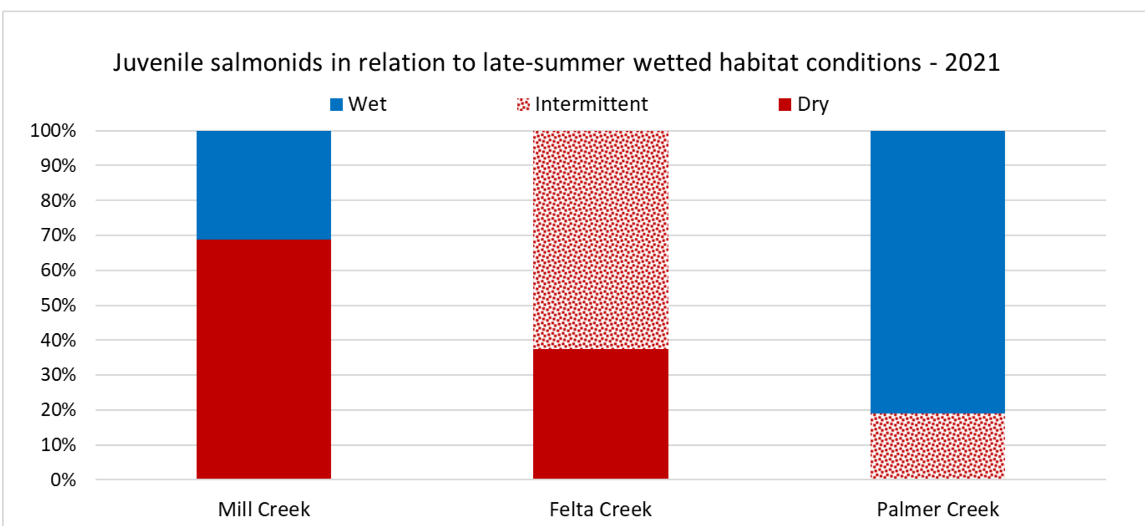

Figure 28. Proportion of early-summer salmonid young-of-year observations in Mill, Felta and Palmer creeks that occurred in locations later documented as wet, dry or intermittent habitat during late-summer 2021. No juvenile salmonids were observed in Wallace Creek.

7. Discussion

In 2021, the Russian River watershed, like much of the western region of the United States, experienced exceptional drought conditions on the heels of the severe drought of 2020 (https://droughtmonitor.unl.edu/Maps/MapArchive.aspx). Water Year 2021 was the second driest year in state record (California Department of Water Resources 2021) and the driest on record at the Healdsburg station. Some Russian River tributaries began disconnecting as early as February, and as the dry season progressed most streams experienced extensive drying and water quality impairment. Overall, stream conditions in the greater Russian River basin were drier than in 2015, when the driest in-stream conditions were documented during the recent historic drought (on average over all streams sampled; CSG unpublished data). Of the 45 streams where CSG conducted wetted habitat mapping in the lower Russian River basin in 2021, only 51% of the 120 miles sampled remained wet and connected through the dry season (CSG unpublished data).

Late-summer habitat conditions in Mill Creek were proportionally similar to the average of all streams sampled in the lower Russian River basin, with just 50% of the channel wet and connected by the end of September and most remaining habitat (46%) drying completely. End-of-season available wetted habitat in the tributary streams varied considerably, with virtually no wet habitat in Wallace Creek, very little in Felta Creek (16%) and the vast majority of Palmer Creek (90%) remaining wet and connected.

In response to the historically dry conditions of WY2021, very low flows were observed at the five streamflow gaging stations in the watershed. In late March of WY2021 flows at the streamflow gages were between approximately 4.5 and 1.6 ft^3/sec; by early May flows at all sites had dropped to approximately 1 ft^3/sec or lower. Early in the spring and summer, the lower reaches gained water from the upper reaches of the watershed, but this relationship reversed by mid-July. At this time, the further downstream sites Mi03 (Mill above the Falls) and Mi08 (Mill Creek at Mill Creek Lane) dried and stayed dry for the remainder of the summer, while Mi06 (Mill creek above Wallace) became intermittent. Higher in the watershed, Mi01 (Mill Creek at Bear Flat) and Mi03 (Mill Creek above the falls) remained wetted though the WY2021 dry season.

Surface water diversions were detected at three of the five gage sites, with multiple surface water diversion signatures shown in the hydrographs. Gage data also show drops in flow that could be attributed to pumping from shallow groundwater wells. The drops in flow indicate that, on average, surface water diversions are causing streamflow to drop between 0.05 – 0.2 ft^3/sec. The Coho Partnership has determined that flows ≤ 0.2 ft^3/sec are sufficient to maintain surface flow connectivity in the reaches of Mill Creek above the falls at rkm 2.99 (California Sea Grant 2020). This indicates that streamflow conditions could be improved through the implementation of storage and forbearance projects, if the project team worked with the landowners pumping from the stream.

The relatively low numbers of salmonid yoy present in Mill Creek and its tributaries in 2021 corresponded to generally low numbers observed throughout the Russian River basin, but the fish that did spawn and rear in the Mill Creek system had a relatively low occurrence of doing so in habitat that remained wet through the dry season. Overall, only 38% of all redds and 35% of all juvenile salmon and steelhead observed in the watershed remained wet through the dry season. Just 32% of redds and 31% of salmonid yoy observed in Mill Creek were in locations that stayed wet and connected, while the remainder dried completely. The single redd and small number of steelhead yoy observed in Felta Creek were in locations that later went dry. In Palmer Creek, 100% of redds and 81% of yoy observed were in locations that remained wet through the dry season, with 19% in locations that became intermittent.

Mortality can be presumed for juvenile fish observed in a pool that was later documented as dry. Opportunities for fish to migrate from drying reaches to better habitat in the period after the snorkel surveys were extremely limited due to shallow riffle depths or pool disconnection. Juvenile salmon may survive in intermittent pools for a period of time (Obedzinski et al. 2018) but if pools become disconnected from surface flow early in the dry season, deteriorating dissolved oxygen conditions and/or increased vulnerability to predators generally lead to mortality prior to the end of the season. While we don't know the precise onset of intermittency throughout all reaches of Mill Creek and its tributaries, a camera installed by CSG to monitor disconnection in lower Mill Creek during the smolt outmigration window showed that initial disconnection occurred at a critical riffle just upstream of the mouth on April 18, 2021 — nearly one month earlier than in 2015 when earlier-than-average disconnection was documented on May 13. We can, therefore, assume that most fish in intermittent reaches were not likely to have survived the summer in this exceptional drought year. In reaches that retained surface flow connectivity, rates of oversummer survival were likely dependent on water quality and habitat conditions, competition and predation. Furthermore, surviving is not equivalent to thriving and fish rearing in suboptimal habitat conditions related to low streamflow may struggle to achieve adequate growth and conditioning needed for success in subsequent life stages (Obedzinski et al. 2018).

There was a sharp contrast in wetted habitat available to rearing fish between the lower and upper extents of Mill Creek, with the transition point a short distance upstream of the Wallace Creek confluence. After disconnection began in the lower extent of Mill Creek main stem in April, that reach continued to dry at a rapid pace and by late-September nearly all of the stream channel below the confluence with Wallace Creek was dry and nearly all of the channel surveyed above Wallace Creek was still wet.

Dry summer-season conditions characterize Wallace, where in the wettest year in which wet/dry mapping occurred (2018), just 2% of the channel remained wet at the end of the season (CSG unpublished data). We conclude that Wallace Creek is not able to support rearing fish and does not provide hydrological inputs into the Mill system. While Felta Creek was not able to adequately support rearing salmonids or provide hydrologic inputs into Mill Creek in the exceptional drought year of 2021, there is considerable variability in end-of-season wetted habitat among previous years, depending on the water year type. For example, in the wettest year sampled of 2019, 65 % of the surveyed reaches in Felta Creek remained wet through the summer season (CSG unpublished data). Even under the relatively wet conditions of 2019, Felta Creek was disconnected from Mill Creek and dry for approximately ¼ kilometer above the mouth. This information indicates that Felta Creek is able to provide some support for rearing salmonids in the wettest water years, but is likely not contributing flow inputs to the Mill system. Palmer Creek, on the other hand, has sufficient streamflow to provide summer habitat refugia for fish and contributes valuable hydrologic inputs into Mill Creek.

In general, Mill Creek below the confluence with Wallace Creek was DO impaired where water was present, while DO concentrations in the reaches upstream of Wallace Creek were sufficient to support rearing fish and exceeded the regional minimum daily objective established by the NCRWQCB. Average DO in lower Felta Creek was suitable, but DO was generally impaired in upper Felta Creek. Palmer Creek had relatively high DO concentrations, which were adequate to support rearing fish. It should be noted that the discrete DO measurements taken on the survey days only capture a single point in time and do not show variation in concentrations within and between days or the minimum daily values, which generally occur during the very early morning hours.

Water temperatures in all stream reaches sampled were generally suitable for fish, with reach-scale average temperatures in the optimal range and maximum temperatures in the furthest upstream reaches of Mill Creek (above Palmer Creek) slightly above the avoidance threshold for salmon, but still below known impairment thresholds. This upper extent of Mill Creek experienced intensive burning along the riparian corridor during the 2020 Walbridge Fire (Figure 2) and lost much of its riparian cover, leaving this area exposed to far greater solar radiation than most of the stream channel within the watershed — even as compared to other areas within the fire footprint, like the Palmer Creek subwatershed, which sustained less damage. This increased UV exposure likely contributed to the higher water temperatures observed in upper Mill Creek. The relatively low water temperatures measured in the disconnected reaches of Mill Creek downstream of Wallace Creek suggest that those pools may have inputs of cold groundwater; however, investigating groundwater contributions is beyond the scope of this study. Interestingly, DO conditions did not appear to correlate with water temperature and the highest average and minimum DO concentrations were observed in the upper reaches of Mill Creek (above the Palmer Creek confluence) that also had the highest water temperatures. This could suggest that, in this particular instance, streamflow has a stronger influence over DO concentrations than water temperature.

Overall, based on wetted habitat and water quality conditions, we can conclude that Palmer Creek is providing the highest quality oversummer rearing habitat for juvenile salmonids. Mill Creek above the confluence with Wallace Creek is also providing valuable habitat refugia for fish over the dry summer months, though temperatures should continue to be monitored in fire-impacted reaches.

When compared to previous years, the relative amount of wetted habitat in the Mill Creek watershed generally corresponds to observations of post-fire increases in streamflow in the upper watershed and the tributary streams that were intensely burned in the Walbridge Fire (Figure 2). While we cannot quantify the precise increase in the volume and extent of surface flow resulting from reduced summer evaporative demand due to the vast amount of vegetation burned in 2020, our gage data do show significantly higher streamflow conditions in the upper, burned portion of the watershed in WY2021 than in WY2015, despite the fact that 2015 was a wetter year than 2021 (Figure 29). This indicates that the fire likely caused an increase in summer streamflow. Additionally, we can compare wetted habitat data from the peak of the last drought in 2015 with that from 2021 to evaluate pre- and post-fire conditions between similar water years. Late-summer habitat distribution data from both years show that there is more wetted habitat and stream connectivity in the fire-impacted areas of Mill Creek above Wallace Creek, as well as in Palmer Creek, after the fire (Figure 30 and Figure 31).

Despite the fact that 2021 was a drier water year than 2015 (Figure 3) and streams were generally drier across the Russian River basin, there was 18% more end-of-season wetted habitat in Mill Creek and 43% more in Palmer Creek in 2021 (Figure 32). Changes in Wallace Creek between 2015 and 2021 were within one percent, though it was nearly all dry in both years. Interestingly, Felta Creek showed a contrary pattern than the other streams in the Mill Creek watershed, with decreased wetted habitat in 2021. It should be noted that 18% more stream length was sampled in the relatively dry reaches of upper Felta Creek in 2015; however, the maps show that much of the wet habitat recorded in upper Felta Creek during the 2015 survey was intermittent in 2021. It is not entirely clear why Felta Creek exhibited different pre- and post-fire patterns than other impacted areas in the watershed, but it may be due to the relatively low burn intensity of that subwatershed. It is also not apparent how the long-term effects of the fire-induced changes will play out in terms of changes to streamflow and wetted habitat distribution throughout the Mill Creek watershed over time.

Moving into the second sample year, we plan to continue monitoring streamflow at all seven Mill Creek gage sites year-round and to conduct a late-summer wetted habitat survey of all accessible reaches of Mill, Felta, Wallace and Palmer creeks in order to establish patterns and trends over the three-year project period, to help inform project opportunities and to document changes after streamflow project implementation.

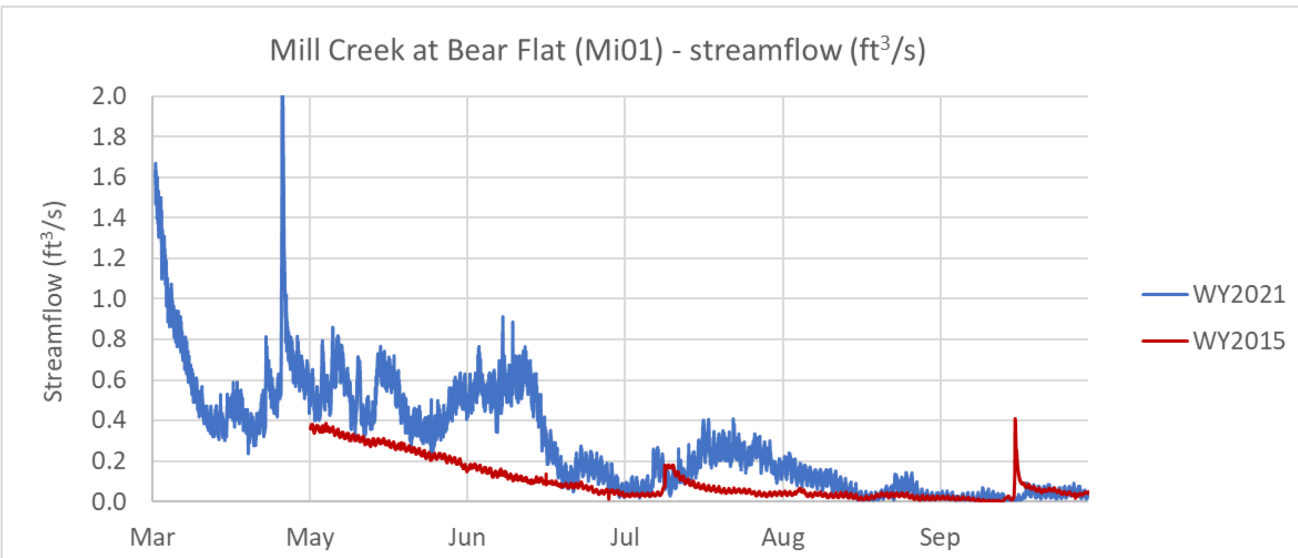

Figure 29. Streamflow conditions before (2015) and after (2021) the 2020 Walbridge Fire. Gage data shows an increase in streamflow after the fire, despite 2021 being a drier water year than 2015.

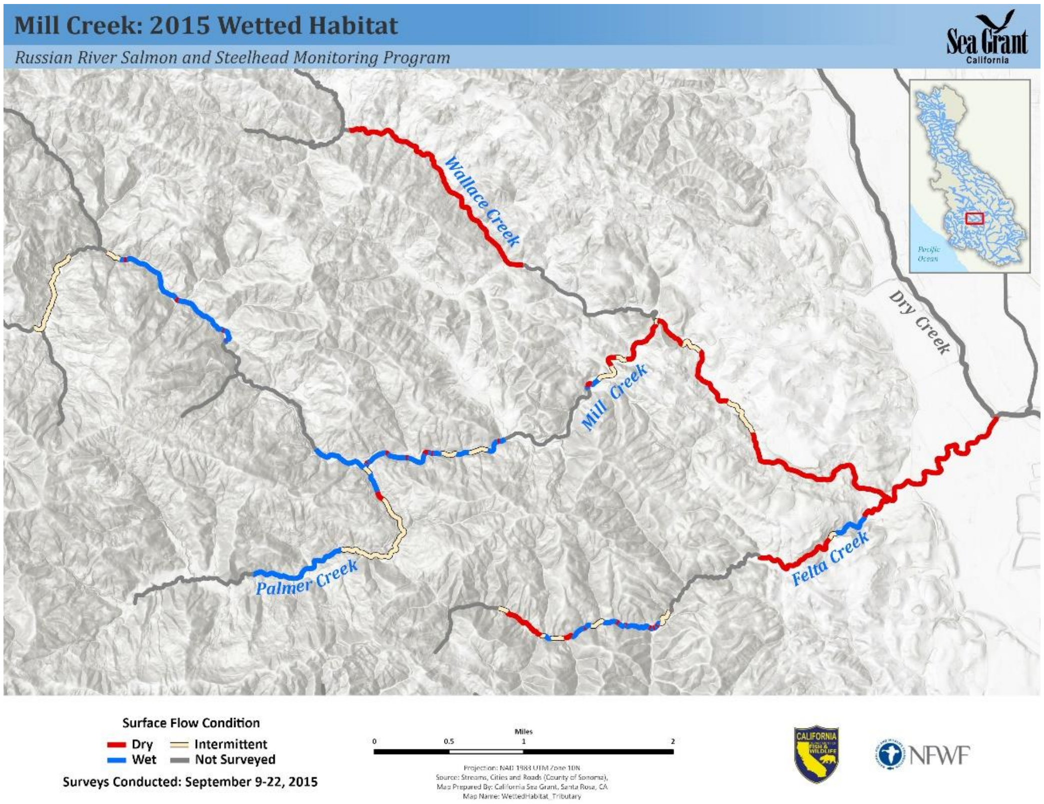

Figure 30. Pre-fire wetted habitat conditions in the Mill Creek watershed, September 9-22, 2015.

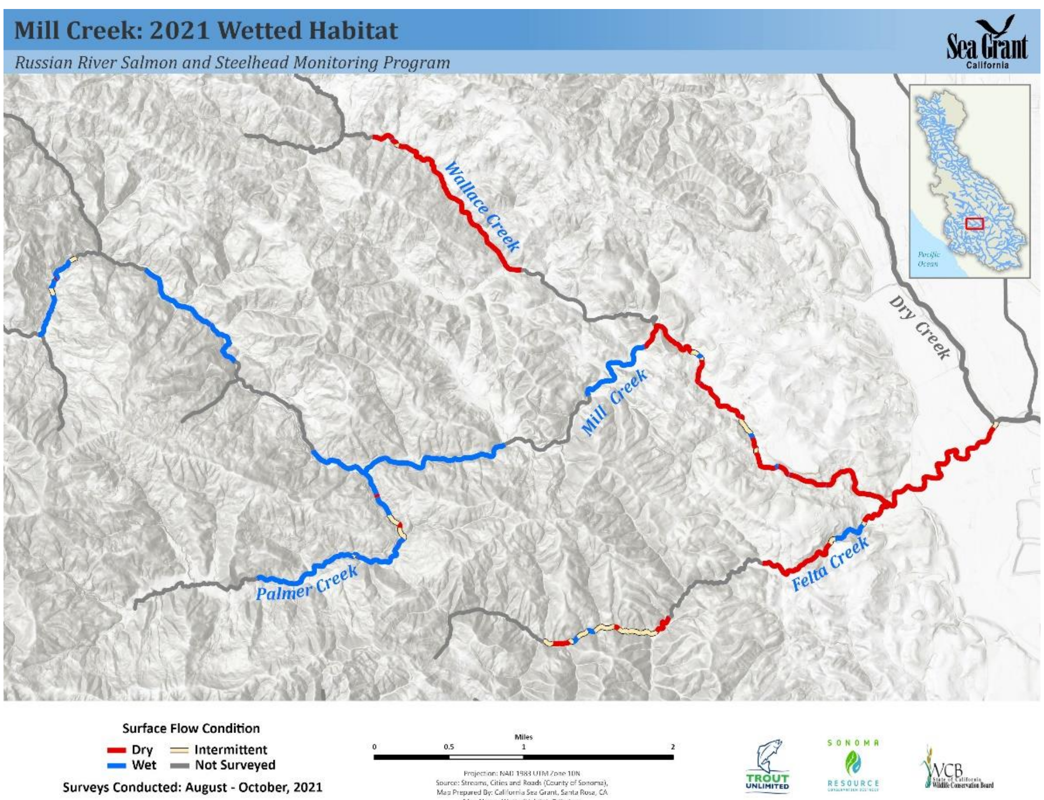

Figure 31. Post-fire wetted habitat conditions in the Mill Creek watershed, August 18-October 4, 2021. Wallace Creek was sampled on August 18, and the remaining streams were sampled between September 27 and October 4, 2021.

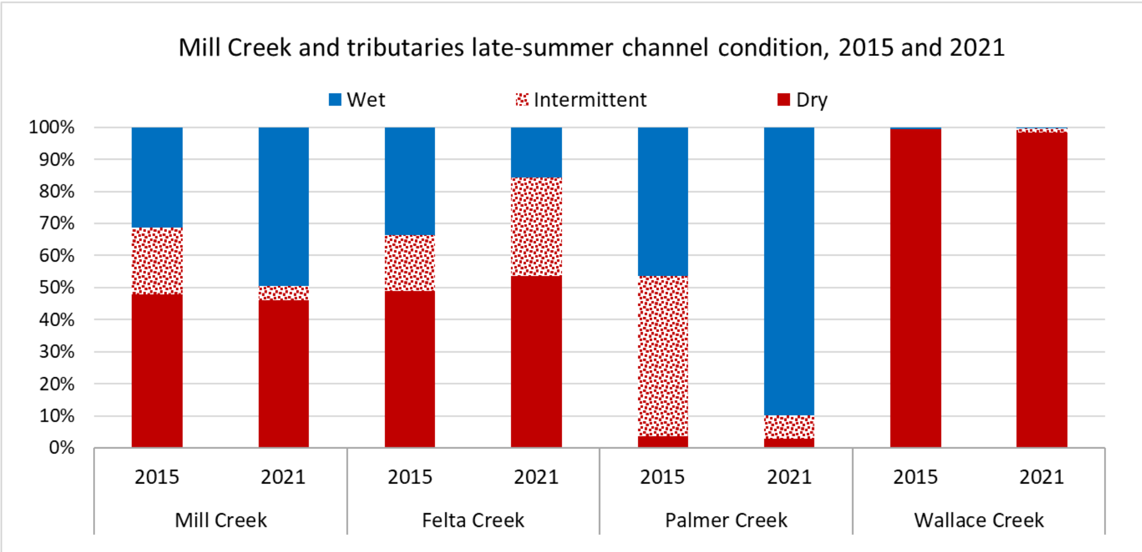

Figure 32. Total proportion of late-summer wet, dry and intermittent stream length present in survey reaches of Mill, Felta, Wallace and Palmer creeks, 2015 and 2021. Note that there was some variation in total stream length sampled between years, particularly in Felta Creek, where 18% greater length was sampled in 2015 as compared to 2021.

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