APPENDIX B – WATER QUALITY

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Managing Water in the West

WATER QUALITY REPORT
CATHERINE CREEK TRIBUTARY ASSESSMENT – GRANDE RONDE RIVER BASIN
Tributary Habitat Program, Oregon

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region
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U.S. DEPARTMENT OF THE INTERIOR

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Cover Photograph: View looking east (downstream) along Catherine Creek, Reach 2 at river mile 26.0, in the Cove area, Mt. Fanny (upper left) and Phys Point (upper right) can be seen in the background. **Catherine Creek Tributary Assessment-Grande Ronde River Basin-Tributary Habitat Program, Oregon – July 29, 2010.**

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1. Summary

Several water quality parameters currently limit fish survival and reproduction in Catherine Creek. Land management activities have contributed to riparian and instream habitat degradation with the primary issues being temperature, sediment, water withdrawal, and riparian condition (Nowak 2004). An extensive literature search was conducted to gather information and data pertaining to water quality in Catherine Creek. Water quality in this tributary is being assessed to provide information for implementing salmonid habitat improvement projects to meet commitments in the 2008 Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp) (NOAA Fisheries 2008).

Catherine Creek is comprised of an upstream high gradient reach and a downstream low gradient reach with the transition in gradients occurring near Pyles Creek, which joins Catherine Creek in the town of Union. Below Union, Catherine Creek is a highly modified meandering channel that flows through heavily irrigated agricultural land (Favrot et al. 2010). The lower reaches are characterized by floodplains and old lakebeds (NRCS 2005). As elevation begins to increase above Union, land use changes from cultivated crops to more pasture and rangeland within grasslands and shrublands (Bach 1995). Grazing also occurs in the high gradient reaches of the subbasin, where mixed conifer forests on steeper slopes are the dominant vegetation type.

Spring- run Chinook salmon and steelhead trout spawn at high elevations in the headwater tributaries of Catherine Creek (NOAA Fisheries 2008). Spawning is complete by the second week of September. The majority of juvenile spring Chinook salmon and steelhead move out of natal rearing areas to overwinter in downstream areas of Catherine Creek, while fewer remain in the upper reaches through the winter before migrating toward the ocean as smolts the following spring or later (Yanke et al. 2008).

The Grande Ronde Basin historically produced large runs of native spring Chinook salmon (Bach 1995). Historical information from 1811 to 1908 characterized the Grande Ronde River through the Grande Ronde Valley as being: 1) cold, clear, and a consistent source of water in all seasons; 2) habitat for salmon and crayfish; and 3) habitat for beaver, with Tule Lake being created by beaver dams (Beckham 1995). Historical accounts on riparian conditions describe the Grande Ronde and its tributaries as lined and shaded with dense vegetation that included species such as cottonwoods, willows, hawthorn, alder, and rosebush (Beckham 1995; Duncan 1998; ODEQ 2000).

European settlers moved into the area in the mid-1800s and significant timber harvest, livestock grazing, and agricultural production began (Bach 1995). Wetlands and floodplains were drained and transformed into productive farmland. Large-scale changes in vegetation occurred as early as the 1870s with the introduction of livestock (ODEQ 2000). Logging has increased steadily in the Grande Ronde Basin since 1896, with demand and production of timber surging in the period following World War II (McIntosh et al. 1994; Duncan 1998). Following this surge, intensive road building took place in remote areas, particularly from the 1970s onward (Duncan 1998).

As a result of land use practices, a number of water quality parameters in Catherine Creek exceed standards established by the Oregon Department of Environmental Quality (ODEQ). Due to water quality standards violations, Catherine Creek is included on Oregon's 1998 Section 303(d) list as shown in Table 1 (ODEQ 2000). Temperatures exceed standards throughout the entire stream; however, most of the water quality standard violations occur on the lower reaches of Catherine Creek, from the mouth to Catherine Creek Adult Collection Facility (CCACF) (reaches 1, 2, 3, and the lower segment of reach 4). The CCACF is referred to as "Union Dam" in the ODEQ TMDLs. The exception is sedimentation, which only exceeds ODEQ standards in the North and South Forks of Catherine Creek. Although these upper tributaries are not specifically included in this assessment, they contribute sediment to the lower reaches of the creek, where siltation has degraded salmonid habitat.

Table 1. Reaches in Catherine Creek included in the 1998 Section 303(d) list for violating water quality standards (ODEQ 2000).

Parameter	**Boundary**
Temperature	Mouth to CCACF CCACF to N.F./S.F. Catherine Cr. N. Fork, Mouth to Middle Fork S. Fork, Pole Cr. to S. Catherine Ditch Diversion
Aquatic weeds or algae	Mouth to CCACF
DO	Mouth to CCACF
Flow modification	Mouth to CCACF
Habitat modification	Mouth to CCACF
Nutrients	Mouth to CCACF
pH	Mouth to CCACF
Sedimentation	N. Fork, Mouth to Middle Fork
Sedimentation	S. Fork, Mouth to South Catherine Ditch Diversion

A number of factors limiting water quality in Catherine Creek have been identified and include (GRMWP 1994; Nowak 2004; NOAA Fisheries 2008):

- Substandard riparian conditions
- Low summer flows
- High summer temperatures
- Limited dilution flows
- Excess sediment
- Streambank erosion

Temperature data are probably the most comprehensive of water quality data for Catherine Creek and exist in the form of continuous monitoring data and thermal imagery. Existing temperature data confirms that summer temperatures typically exceed the ODEQ standard of 64.0^{0}F, which was established based on optimal temperatures for salmonid species. Temperatures are particularly high in the lower reaches of the creek, where they can reach 80^{0}F in August (Justice, McCullough, and White 2011b; McCullough et al. 2011; Watershed Sciences 2000). The only sections of the creek that did not consistently exceed 64.0^{0}F were the North and South Forks and the very upper reaches of main stem Catherine Creek (Justice, McCullough, and White 2011b; McCullough et al. 2011; Watershed Sciences 2000; ODEQ 2000).

Sediment is only included on the Section 303(d) list for the North and South Forks, although there appears to be a problem throughout the stream in regards to salmonid habitat. The estimated percent function is egg survival to emergence of 30 percent of potential due to fine sediment levels (CRITFC 2009). Bank stability was below reference condition levels along 85 percent of Catherine Creek and levels of fine sediment in the streambed were above reference criteria along 79 percent of the stream (Huntington 1994). Surface sediment fines were found to be highest at the mouth of North Fork and lowest in the upper reaches of South Fork out of five sites sampled in Catherine Creek (Justice, McCullough, and White 2011a; McCullough et al. 2011).

Data on nutrients, pH, DO, ammonia toxicity, and bacteria were only found for the segment of the stream below RM 43, just upstream of Union. This lower portion of Catherine Creek typically exceeds the ODEQ standard of 6 µ/L of orthophosphate as P (USWCD nd; Miles nd; ODEQ 2007). Dissolved inorganic nitrogen (DIN) levels standards of 26 µ/L are usually only exceeded below the town of Union, but not upstream or further downstream, which is probably due to excessive algal and aquatic weed growth consuming nitrogen (USWCD nd; Miles nd). Bacteria levels also occasionally exceed ODEQ standards, which require that a 30-day log mean for a minimum of five samples cannot exceed 126 organisms per 100mL, particularly just downstream of Union. The Union Wastewater Treatment Plant (WWTP) stopped discharging effluent into Catherine Creek during summer months in 2001 per ODEQ recommendations. Ammonia levels appeared to decrease but the excessive nutrient and bacteria levels detected below town suggest that the urban land use area that the stream flows through is a significant NPS of nutrient and bacteria loading. Catherine Creek has large diel fluctuations in pH and DO with levels very near violations of water quality standards due to considerable aquatic plant and algae activity (Miles nd).

Flow and habitat modification are parameters included on Oregon's 1998 Section 303(d) list for violating water quality standards on Catherine Creek. Flow and habitat (i.e., riparian condition) modifications are not the direct result of a pollutant load, although they are closely related to water quality conditions. Water quality standard violations occur from June to September when flows in Catherine Creek are lowest. Water withdrawals for irrigation reduce flows starting in June. Between mid-July and late September irrigation demand often exceeds the water supply in Catherine Creek, reducing summer flows that are already naturally very low late season. This results in insufficient flows to support anadromous fish migration and to meet water quality standards (Huntington 1994; ODEQ 2000; Reclamation 2002). While not the only issue, riparian habitat degradation has been identified as the most serious problem in the subbasin (Nowak 2004). Riparian vegetation is especially sparse and provides little shade cover in lower Catherine Creek (Favrot et al. 2010). Stream shade was below reference condition levels along 56 percent of miles surveyed on Catherine Creek (Huntington 1994).

Most water quality problems in the Grande Ronde subbasin derive from past forestry, grazing and mining activities as well as current improperly managed livestock grazing, cumulative effects of timber harvest and road building, water withdrawals for irrigation, agricultural activities, industrial discharge, and urban and rural development (Nowak 2004). The landscape has been drastically altered by human activities since the mid-1800s due to large-scale disturbances to the riparian vegetation (ODEQ 2000).

Long-term degradation of riparian areas has reduced shade, which has led to chronic stream temperature problems in Catherine Creek (Huntington 1994). Solar radiation loading was determined to be the primary source of elevated stream temperatures in the Grande Ronde River (ODEQ 2000). Poor riparian vegetation conditions have also contributed to bank erosion, sedimentation, and nutrient loading.

Although flows are naturally low in summer due to the local climate, water withdrawal for irrigation has caused severe water depletions in Catherine Creek. Low summertime streamflows have caused temperatures to increase. Nutrients and bacteria entering the stream are less diluted. These conditions have led to increased algal growth, which in turn affects DO concentrations and pH levels.

Riparian and instream habitat degradation has severely affected spring Chinook salmon production potential in the subbasin (Nowak 2004). Significant changes in many salmonid habitat attributes have occurred in Catherine Creek relative to historic conditions (NOAA Fisheries 2008).

Overall changes in water temperatures between historic and existing conditions appear to have had the greatest contribution in reducing spring Chinook productivity (Duncan 1998). Flow and temperature patterns have been altered with much reduced flow caused by irrigation withdrawals in summer and increased temperatures due to low flows and the loss of streamside shade (Duncan 1998; NOAA Fisheries 2008). These factors have significantly influenced adult and juvenile migration opportunity and created heat sinks in what would be prime rearing habitat. Lower flows and warmer water temperatures have likely shifted and reduced variability of adult migration and spawn timing relative to historic timing (NOAA Fisheries 2008). The opportunity for fry and summer parr downstream migration in Catherine Creek has also been reduced. Lower than optimum winter temperatures resulting from the disconnect between streams and moderating groundwater supplies may adversely affect overwintering juvenile fish (Duncan 1998).

2. Introduction

2.1 Purpose of Study

Catherine Creek is a known spring Chinook salmon and steelhead-spawning tributary of the Grande Ronde River and is a highly regulated stream (Favrot et al. 2010). Land management activities have contributed to riparian and instream habitat degradation with the primary issues being high temperatures, sediment, water withdrawal, and riparian condition (Nowak 2004).

Several water quality parameters currently limit fish survival and reproduction in Catherine Creek. Catherine Creek has low survival rates of juvenile spring Chinook salmon emigrants in comparison to the Snake and Columbia River systems (Favrot et al. 2010). Water quality in this tributary is being assessed to provide information for implementing salmonid habitat improvement projects to meet commitments in the 2008 FCRPS BiOp (NOAA Fisheries 2008).

For the purposes of this assessment, water quality parameters are addressed under four headings: temperature; sediment; nutrients; and flow and riparian conditions. Discussions on nutrients include nitrogen, phosphorous, dissolved oxygen (DO), pH, and algal growth because these parameters are so closely linked. Physical attributes of flow and riparian conditions, though not specifically water quality issues, are directly related to water quality conditions and are therefore discussed briefly. Optimal water quality conditions for salmon are summarized in Table 2. Water quality parameters and their effects on the life cycle of cold-water fish, such as salmon and steelhead are discussed below.

Table 2. General water quality habitat requirements for salmon (WCSRSC 1999).

Parameter	Optimal Habitat Condition for Salmon
Temperature	[1] Adult migration: 38 - 68ºF Spawning and incubation: 40 - 57º Rearing 39 - 68ºF (juvenile fish prefer 54 -57ºF)
Dissolved oxygen	[1] Adult migration: > 7.0 ppm Spawning and incubation: > 8.0 ppm Rearing: > 7.0 ppm
pH	Oregon State Standard of 6.5 – 8.5
Turbidity	[1] Turbidity should be limited and not sustained
Surface fines on stream bottom	[2] Good = < 20 percent Fair = 10 – 20 percent Poor = > 20 percent
Cobble embeddedness	[2] Good = < 20 percent Fair = 20 – 35 percent Poor = > 35 percent
Streamflow	Streamflow should provide access to adequate spawning gravel, and stream depth should be no less than 7 inches [1] Spawning velocity: 1.0 to 2.5 ft/s Adult migration velocity: maximum of 8.0 ft/s

[1]Bjornn and Reiser 1991 [2]BLM 1993

2.1.1 Temperature

Stream temperature is largely a function of riparian vegetation and the amount of stream shading it creates. Water temperature tends to be a parameter that generally increases downstream, with an irregular pattern of variation occurring at tributary junctions, entry points for seeps, and zones of groundwater-surface water exchange (CRITFC 2009). Variability in stream temperatures may be important for the existence of cold-water fish in relatively warm water streams. Variations in the spatial distribution of water temperature affect the spatial distribution and potential survival of summer-rearing juveniles (CRITFC 2009). Cold-water fish commonly inhabit cooler reaches when many portions of streams maintain stressful and/or lethal warm water temperatures (McIntosh et al. 1995; ODEQ 2000).

Groundwater inflow has a cooling effect on summertime stream temperatures (ODEQ 2000). Subsurface water is insulated from surface heating processes and most often groundwater temperatures fluctuate little and are cool (45°F to 55°F). Groundwater inflow not only cools summertime stream temperatures, but also augments summertime flows. Many land use activities that disturb riparian vegetation and associated floodplain areas affect the connectivity between river and groundwater sources. Reductions or elimination of groundwater inflow will have a warming effect on the river. The disconnect between streams and moderating groundwater supplies can also lower winter temperatures. Winter temperatures are critical to timing of egg hatch and the availability of food for emerging juvenile fish and, if too low, may adversely affect overwintering fish (Duncan 1998).

Stream temperature often controls the distribution of fish and other aquatic organisms and affects salmonids during all life history stages (Bach 1995). Water temperature appears to be a migration stimulus associated with movement during fall migration and overwinter rearing (Favrot et al. 2010). For Chinook salmon, adult migration, spawning, egg incubation, and rearing are all subject to reduced success at temperatures that are not optimal. A desired temperature range for each of these life cycles is shown in Table 2. The upper limit for growth of most salmonid species is around 66°F (Bach 1995). Temperatures in the mid- to high- 70°F range cause death of cold-water fish species during exposure times lasting a few hours to a day (ODEQ 2000). The incipient lethal limit (i.e., the temperature at which fish mortality is caused) for Chinook salmon appears to be 77°F (ODEQ 2000), when the regulation of vital processes such as respiration and circulation break down (ODEQ 2000). The Environmental Protection Agency (EPA) and National Marine Fisheries Service (NOAA Fisheries Service) reported 50 percent mortality to adult salmon and steelhead trout with a constant water temperature of 70°F (ODEQ 2000). The sub-lethal limit causes a more delayed thermally induced mortality and occurs weeks to months after the onset of elevated temperatures (mid-60°F to low-70°F).

2.1.2 Sediment

Streambed material classification defines fines as sand, silt, and organic material that have a grain size of 0.25 inches or less (ODEQ 2000). Human disturbances, such as grazing, road construction, and vegetation removal, may lead to increased delivery of fine sediment to streams (CRITFC 2009). Controlling erosion not only reduces the amount of sediment that enters streams, but also affects the amount of pesticides, fertilizer, and other substances that move into the Nation's waters (NRCS 2005). Fine sediments can adversely affect fish and other aquatic organisms. Increased fine sediment deposition in spawning gravel can impair the success of juvenile emergence from gravel redds (ODEQ 2000). Sedimentation may affect egg survival through entombment or through reduction of intergravel DO delivery. Other impacts to salmonids caused by sedimentation include mortality, reduced growth or disease resistance, modified natural movements and migration, and reduced abundance of food organisms (ODEQ 2000).

Increases in bed sediments alter habitat complexity for aquatic species. Landscape and bank mass failures that lead to increased sediments are often accompanied by channel widening and braiding resulting in increased bank erosion and decreased pool riffle amplitude (ODEQ 2000). Pool volumes can also be reduced, which can affect the thermal buffering capacity of a reach (CRITFC 2009).

2.1.3 Nutrients

Among other factors, elevated nutrient levels in streams can lead to excessive algal growth (ODEQ 2000). In turn, growth of algae can result in significant diel fluctuations in DO and pH, which may adversely impact aquatic life. During the day, when algae perform photosynthesis and grow, carbon dioxide is consumed and oxygen produced. At night respiration dominates, carbon dioxide is produced, and oxygen consumed. Carbon dioxide affects pH because it combines with water to form carbonic acid. Therefore, during the day as algae consume carbon dioxide the pH increases, while at night as algae produce carbon dioxide the pH declines. This process also affects oxygen concentrations, with DO increasing in the day while algae produce oxygen through photosynthesis, and decreasing at night while respiration consumes oxygen.

Ammonia toxicity is a potential concern in the Upper Grande Ronde subbasin because of elevated pH and temperature levels (ODEQ 2000). Ammonia is present in two states in natural waters: ammonium ion ($NH4+$) and un-ionized ammonia ($NH3$). Un-ionized ammonia is much more toxic to aquatic life than the ammonia ion state. Since the fraction of ammonia that is un-ionized increases as pH increases, systems with high pH, such as Catherine Creek, are highly susceptible to ammonia toxicity.

DO and ammonia concentrations and pH levels all affect fish habitat. When DO concentrations get too low, fish begin to suffocate (Bach 1995). Eggs and embryos are particularly sensitive to DO. If a particular segment of a stream develops a low DO saturation that is sustained for an extended period, it can create a barrier to fish passage. DO saturations as low as 75 percent will generally support a diverse population of aquatic organisms; however this is not the most favorable condition for salmonids. For optimal development and hatching, salmonids require DO in excess of 95 percent saturation.

High pH levels (greater than 9.0) can lead to increased fish mortality (Bach 1995). In addition, both high and low pH (above 8.5 and below 6.5) can increase the toxicity of some other compounds. As with DO problems, high pH is often associated with excessive algae growth.

Ammonia can cause a number of problems in aquatic systems. Ammonia is converted to nitrate in a process that consumes oxygen, and thus reduces DO concentrations in the water column (Bach 1995). Ammonia is also a nutrient that contributes to excessive algae growth. Finally, ammonia is toxic to most aquatic animals. Toxicity increases when pH levels exceed 8.5 (Bach 1995).

2.1.4 Flow and Riparian Conditions

Streamflows have a large effect on water quality. When streamflows are low, the thermal buffering capacity of the stream is reduced (CRITFC 2009). Subsequently, stream temperatures increase and DO concentrations are lowered (Bach 1995). In addition, chemicals and toxic substances that enter the stream are not as diluted under low flow conditions.

Water temperature is controlled by solar radiation, which in turn is influenced by riparian condition (CRITFC 2009). Shading from riparian vegetation largely moderates stream temperatures. Riparian vegetation is also important in controlling sedimentation. Roots of riparian plants, particularly woody stemmed species, help to stabilize banks. Vegetation in riparian buffers adjacent to the stream prevents soil runoff.

2.2 Project Area

Catherine Creek is a tributary of the Grande Ronde River in northeastern Oregon that is considered important to Chinook salmon populations within the Columbia River Basin (NOAA Fisheries 2007). Catherine Creek is comprised of an upstream high gradient reach and a downstream low gradient reach with the transition in gradients occurring near Pyles Creek, which joins Catherine Creek in the town of Union. Below Union, Catherine Creek is a highly modified meandering channel that flows through agricultural land (Favrot et al. 2010). The area is heavily irrigated, with approximately 6,800 acres of irrigated farmland within the total 8,000 acres of Catherine Creek's fan (Reclamation 2002). There are three irrigation dams (upper and lower Davis and Elmer Dams) that partially impound water in the stream from late summer to mid winter. The lower reaches are characterized by floodplains and old lakebeds (NRCS 2005). The soils are well drained to somewhat poorly drained. As elevation begins to increase above Union, land use changes from cultivated crops to more pasture and rangeland within grasslands and shrublands (Bach 1995). The middle reaches are characterized by shallow and moderately deep soils on gently sloping to steeply sloping hills and mountains adjacent to forestland (NRCS 2005). Grazing also occurs in the high gradient reaches of the subbasin, where mixed conifer forests on steeper slopes are the dominant vegetation type.

Spring- run Chinook salmon and steelhead trout spawn at high elevations in the headwater tributaries of Catherine Creek (NOAA Fisheries 2008). Spawning is complete by the second week of September. There are currently two primary life history pathways for the freshwater juvenile life stages: fish rear from fry to smolt in the upper reaches of Catherine Creek or fish leave the upper reaches of Catherine Creek in the fall and overwinter in the Grande Ronde valley reaches (NOAA Fisheries 2007). "Early" migrant juveniles start moving downstream in autumn between late-September and mid-January with a peak in the fall. "Late" migrants overwinter in streams, leaving upper rearing areas from late-January to late-June with a peak in the spring (Yanke et al. 2008). The majority of juvenile spring Chinook salmon migrate out of upper rearing areas (e.g., 78 percent in 2008) as early migrants, while fewer steelhead (e.g., 36 percent in 2008) leave as early migrants (Yanke et al. 2008).

Microhabitat availability in Catherine Creek is considerably different in the high gradient reaches (i.e., upstream of the mouth of Pyles Creek) than in the low gradient reaches (i.e., downstream from the mouth of Pyles Creek (Favrot et al. 2010). High gradient reaches have shallower depths and faster flows with coarser substrates compared to low gradient reaches. Substrates available in the high gradient reach range from clay to boulder, while available substrates ranged from clay to sand in the low gradient reaches. Low gradient reaches are considerably wider than high gradient reaches; however, both have generally small bank angles. Land use conditions within a 164-foot buffer are similar between high and low gradient reaches. The majority of land use is agriculture, with forested and developed categories less than or equal to 25 percent each.

To the extent possible, water quality conditions will be assessed within seven reaches spanning from the mouth of Catherine Creek at RM 0 to the bifurcation of the North and South Forks of Catherine Creek at RM 54.9. The reaches are designated as follows:

- Reach 1 (RM 0 to 22.5) begins at the mouth of Catherine Creek where it intersects State Ditch to the junction with the Grande Ronde.
- Reach 2 (RM 22.5 to 37.2) continues to the outskirts of Union, just north of the town.
- Reach 3 (RM 37.2 to 40.8) flows through the town of Union.
- Reach 4 (RM 40.8 to 45.8) enters the foothills and proceeds into the canyon.
- Reach 5 (RM 45.8 to 50.1) increases in elevation and becomes a confined channel, ending at the confluence with Little Catherine Creek.
- Reach 6 (RM 50.11 to 52.0) ending at the confluence with Milk Creek.
- Reach 7 (RM 52.0 to 54.9) continues to the mouths of the North and South Forks.

Stream characteristics, grouped by relatively similar reaches and documented by Kavanagh, Jones, and Stein (2011), are described below:

2.2.1 Reaches 1 and 2

The lower reaches of Catherine Creek consist of a continuous homogenous channel, constrained by terraces, which meanders through agriculture land use. The stream is deep (average 3.0 feet), approximately 65.6 feet wide, with little defined habitat. The gradient of the section averages 0.0 percent. Water visibility is low. The stream substrate and streambanks are primarily composed of fine sediment (hardpan clay, silt, some sand), some of which is actively eroding. Shrubs (hawthorn, willow, dogwood) and grasses line the streambank, providing little in the way of shade or woody structure. Oxbows have been cut off from the main stem with only a control structure connecting the creek with the oxbow. Elmer's Dam (RM 12.4) is a seasonal dam for irrigation. Boards are either placed or removed to control the water height and availability. When all the boards are in place, the water may pool for 69 feet (Kavanagh, Jones, and Stein 2011).

2.2.2 Reaches 3 and 4

The middle reaches transition from an agriculture landscape to a section with agriculture and urban (i.e., town of Union) land uses. The stream is shallower (average 1.6 feet) above the Davis Dam pool and characterized by more defined habitat, a mix of land use influences, and an increase in streamside trees. Catherine Creek is primarily a single channel through these reaches, with little off-channel habitat. The stream habitat includes low gradient riffles as well as scour pools and glides. The substrate is a mix of fine sediments, gravel, and cobble. Large willows and other deciduous trees contribute to shading. Little Creek, Pyles Creek, and Brinkler Creek are named tributaries, which enter these reaches. There are at least five dams/fish ladders/diversions which fish encounter at RM 40.1, 40.3, 40.4, 41.2, and 43.0. Streamside shade, coarse substrate, and stream gradient increase in the middle reaches.

2.2.3 Reaches 5, 6, and 7

Catherine Creek State Park and Whitman National Forest are within the upper reaches of the creek. The surrounding area is forested with deciduous and coniferous trees of all size classes. Trees in the riparian areas shade the creek, add stability to stream banks, and are a source of large wood for the channel. The upper reaches have long stretches of riffles with some rapids and pools; the average depth is 1.2 feet. The average gradient is 1.3 percent. The upper reaches maintain the riffle/pool habitat ratio of the middle reaches; however, the character of the upper reaches changes dramatically with a sharp increase in the number of multiple channels. The secondary and off-channel habitat increases from approximately 1,969 feet in the middle reaches to close to 16,404 feet in the upper reaches. The upper section has the most wood and the most opportunity for large woody debris contribution.

3. Methods

An extensive literature search was conducted to gather information and data pertaining to water quality in Catherine Creek. Readily available literature was obtained and local agencies contacted to prepare this report. A bibliography listing all references used is provided at the end of this report.

4. Historic Conditions

Native Americans inhabited the valleys and canyons of the Grande Ronde for thousands of years before the 19th century arrival of Euro-Americans (Duncan 1998). In pre-settlement times, the middle Grande Ronde River meandered in a wide circle (a “grande ronde”) through an open bowl of valley occupied by grasslands, wetlands, and lakes. Tule

Lake – “a vast lake covered with tules” – was located on the lower reaches of Catherine Creek (Duncan 1998).

The Grande Ronde Basin historically produced large runs of native spring Chinook salmon (Bach 1995). Historical information from 1811 to 1908 characterized the Grande Ronde River through the Grande Ronde Valley as being: 1) cold, clear, and a consistent source of water in all seasons; 2) habitat for salmon and crayfish; and 3) habitat for beaver, with Tule Lake being created by beaver dams (Beckham 1995).

There is very little quantitative data available to describe the historical vegetation conditions in the Upper Grande Ronde basin; however, some qualitative descriptions are documented (ODEQ 2000). Riparian trees and shrubs were undoubtedly more abundant than today. Historical accounts describe the Grande Ronde and its tributaries as lined and shaded with dense vegetation that included species such as cottonwoods, willows, hawthorn, alder, and rosebush (Beckham 1995; Duncan 1998; ODEQ 2000). In fact, the first name for the Grande Ronde Valley was Kup-Kup-Pa, or “Place of the Cottonwood” (ODEQ 2000).

European settlers moved into the area in the mid-1800s and significant timber harvest, livestock grazing, and agricultural production began (Bach 1995). Wetlands and floodplains were drained and transformed into productive farmland. Fred Nodine, a farmer and land developer, began draining Tule Lake in 1870 (Beckham 1995; Duncan 1998). Water was withdrawn from an estimated 2300 acres of wetland and the land was placed under cultivation within 20 years. This project involved turning Catherine Creek, carrying it around the eastern side of the lake in a new channel, and finally turning it into one of the lake’s numerous outlets (Duncan 1998). A huge canal was constructed in order to do this. In 1860s, the first excavations for what would become State Ditch took place in the area west of Tule Lake. During pre-settlement times, an estimated 72,000 acres in the valley were subject to flooding and up to 60 percent of the valley floor might be inundated for as long as 5 months (Duncan 1998). In 1894, around 50,000 acres were flooded; in 1949 flood, only 5,900 acres were inundated.

Historical accounts indicate that large-scale changes in vegetation occurred as early as the 1870s with the introduction of livestock (ODEQ 2000). By the 1880s, there were signs of overgrazing in parts of the upper Grande Ronde basin (McIntosh et al. 1994; Duncan 1998). In the early 1900s, domestic livestock peaked. Records from Wallowa-Whitman National Forest from 1911 to 1990 indicate that over that period, grazing by livestock declined 78 percent, which was largely due to the collapse of the sheep industry in northeast Oregon (McIntosh et al. 1994).

Logging began in the upper Grande Ronde basin in the late 1880s. Harvest has increased steadily since 1896, with demand and production of timber surging in the period following World War II (McIntosh et al. 1994; Duncan 1998). Following this surge, intensive road building took place in remote areas, particularly from the 1970s onward (Duncan 1998). Miles of road doubled from 1954 to 1978, and doubled again from 1978 to 1989 (McIntosh et al. 1994). Harvest in the early part of the century was restricted to riparian areas and adjacent hillslopes. More recently, logging has occurred in higher elevation and headwater sections as road construction increased access (McIntosh et al. 1994).

From 1934 to 1946, the Bureau of Fisheries (BOF) conducted stream surveys in the Columbia River Basin that included the Upper Grande Ronde Basin (McIntosh, Clarke, and Sedell 1990). Catherine Creek was surveyed August 9 to 12, 1941. Although the Upper Grande Ronde Basin had already experienced considerable human-induced disturbance at the time of the surveys, these are the earliest and most comprehensive records available on the condition and extent of anadromous fish habitat prior to hydropower development in the Columbia River Basin. These documents therefore provide baseline data for future fish habitat restoration throughout the watershed.

BOF surveys were conducted at five stations. Although these stations do not clearly correspond to the current assessment reaches, an attempt will be made to discuss stream conditions at the time of the surveys in terms of the current reach designations. Throughout the entire stream, 29 diversions and 19 “artificial obstructions” (i.e., dams) were noted. Apparently, the entire surveyed portion of the stream was inaccessible to spawning during low water because Lower Benson Dam (currently at the confluence with the Grande Ronde between reach 1 and 2) became impassible, even though it was equipped with a makeshift fish ladder. Width and depth of the creek varied from 45 feet and 30 inches, respectively, at the lower reaches (1 and 2) to 20 feet and 10 in at the confluence with the North and South Forks (reach 7). Substrate was predominately mud and sand within present day reaches 1 and 2. Above Union, substrate became coarser, dominated by medium sized rubble (3 to 6 inches) at all of the upper stations BOF surveyed. Stream temperature data collected mid-August ranged from 74^0F in the lower reaches to 59^0F at the confluence with North and South Forks.

BOF records on stream characteristics in the lower reaches (reach 1 and 2) noted that rubble was present for only four miles below the town of Union, but that scarcely any of the rubble in this section was usable because of heavy silt on the riffles. From this point to the mouth of the stream, the bottom contained nothing but mud and an occasional large stone. There were many good pools below Union, but they were probably unsuitable for salmon because of the high water temperatures in summer, which reportedly reached into the 80^0F range. Carp appeared as soon as mud comprises most of the bottom, and continued in abundance to the mouth of the stream. This portion of the river meandered through a broad floodplain continuous with that of the Grande Ronde River. Gradient was documented as very shallow, being only one to a few feet per mile.

Above the town of Union (reaches 4 to 7), BOF records note that the gradient begins to get steeper and that all spawning activities of salmon and steelheads occurred here.

Between Union and BOF Station D (reaches 4 and 5), the report describes two agricultural valleys, the lower and larger one continuing almost to Union, separated by a narrow V-shaped valley. In these valleys, especially the lower one, some good spawning riffles and fair resting pools occurred. The V-shaped valleys were described as having a gradient too steep to permit good spawning areas for the most part.

The 1941 survey reported that steelhead and Chinook ran in Catherine Creek. According to a local sportsman, the run of steelheads appeared to have been increasing over the past 4 years, while that of the Chinook has been steadily decreasing. The Chinook appeared from May 10 to June 1 and spawned in late August or early September.

BOF identified a number of factors that contributed toward making conditions in Catherine Creek unfavorable for migratory fish at the time. The majority of issues were related to dams and diversions. Of the 19 irrigation dams on Catherine Creek, 11 were fish barriers at low water and some of the dams were even impassible at high water. Snagging and gigging were still allowed in the stream, and fishing was popular below each dam as fish were temporarily blocked. Diversions not only had large impacts on flows, but only 2 of 29 were screened and many fish were said to swim down the ditches in spring. High stream temperatures were a problem by 1941, with summer water temperatures reaching the low 80^{o}F range in August. It was noted that temperature conditions were possibly a result of timber removal in the headwaters of the tributaries. Finally, sedimentation caused by erosion appeared to be an issue. Flash floods caused by cloudbursts in the headwaters brought down mud and muddy water, which could be very harmful to Chinook runs.

5. Existing Conditions

A number of water quality parameters exceed standards established by ODEQ. ODEQ developed a Total Maximum Daily Load (TMDL) for all streams in the Upper Grande Ronde subbasin that addresses salmonid fisheries concerns (ODEQ 2000). The TMDL analyzes the factors affecting water quality and identifies the amount of pollution that can be present without causing state water quality standards to be violated. Load allocations associated with this TMDL are designed to reduce the input of pollutants into streams. Water quality conditions are typically a result of interactions between variables. The standards of concern include stream temperature, DO, and pH. The pollutants responsible for these water quality problems include excess heat, nutrients, and sediments. In turn, excess heat is caused by limited shade and low flows. Pollutants that enter the streams are a result of human induced changes to streamside vegetation and to the stream channel (ODEQ 2000).

As a result of water quality standards violations, Catherine Creek is included on Oregon's 1998 Section 303(d) list shown in Table 3 (ODEQ 2000). Catherine Creek is on the

303(d) Stream List based on primary concerns of high temperatures, habitat and flow modifications, and low DO (Nowak 2004). Most of the water quality standard violations occur on the lower reaches of Catherine Creek, from the mouth to CCACF at RM 42.5 (reaches 1, 2, 3, and the lower segment of reach 4). The CCACF was referred to as “Union Dam” in the ODEQ TMDLs. The exception is sedimentation, which only exceeds ODEQ standards in the North and South Forks of Catherine Creek. Although these upper tributaries are not specifically included in this assessment, they contribute sediment to the lower reaches of the creek, where siltation has degraded salmonid habitat. Temperatures exceed standards throughout the entire stream.

Table 3. Reaches in Catherine Creek included in the 1998 Section 303(d) list for violating water quality standards (ODEQ 2000).

Parameter	**Boundary**
Temperature	Mouth to CCACF CCACF to N.F./S.F. Catherine Cr. N. Fork, Mouth to Middle Fork S. Fork, Pole Cr. to S. Catherine Ditch Diversion
Aquatic weeds or algae	Mouth to CCACF
DO	Mouth to CCACF
Flow modification	Mouth to CCACF
Habitat modification	Mouth to CCACF
Nutrients	Mouth to CCACF
pH	Mouth to CCACF
Sedimentation	N. Fork, Mouth to Middle Fork
Sedimentation	S. Fork, Mouth to South Catherine Ditch Diversion

Stream shade and bank stability are two indicators of riparian health that are deficient in Catherine Creek and are particularly acute below the town of Union (GRMWP 1994). Below Union, Catherine Creek has been severely altered and mostly functions only seasonally as salmonid habitat due to channel modifications and severe flow depletion. By early summer, passage conditions are poor for adult salmon and downstream migrant juveniles face unscreened or poorly screened diversions. Juvenile fish may overwinter within these reaches, but habitat has been much reduced by channelization. The lower reaches are unsuitable for juvenile salmon during summer due to high water temperatures. General issues and concerns with respect to water quality are listed by reach in Table 4.

Table 4. Water quality issues in Catherine Creek by reach (GRMWP 1994).

Reach	Boundary	Issues
1 and 2	Mouth to Union	Substandard riparian conditions Low summer flows High summer temperatures Poor water quality – limited dilution flows Streambank erosion
3 and 4	Union to State Park	Low summer flows High water temperatures Locally substandard riparian conditions Streambank erosion
5 through 7	State Park to N and S Forks	Locally substandard riparian conditions Fine sediment
	North and South Forks	Fine sediment Streambank erosion Locally substandard riparian conditions

The FCRPS BiOp (NOAA Fisheries 2008) identified the major factors that have limited the functional use of tributary habitat by Snake River spring-summer Chinook salmon, which includes headwater tributaries of the Grande Ronde:

- Physical passage barriers (culverts; push-up dams; low flows)
- Reduced tributary streamflow, which limits usable stream area and alters channel morphology by reducing the likelihood of scouring flows (water withdrawals)
- Altered tributary channel morphology (bank hardening for roads or other development and livestock on soft riparian soils and streambanks)
- Excess sediment in gravel (roads; mining; agricultural practices; livestock on soft riparian soils and streambanks, and recreation)
- Degraded tributary water quality including high summer temperatures and in some cases, chemical pollution from mining (water withdrawals; degraded riparian condition)

From this list, reduced flows, excess sediment, and high summer temperatures (among other water quality issues) are all factors that impact water quality conditions in Catherine Creek. These limiting factors were also identified in the *Grande Ronde Subbasin Plan* (Nowak 2004), which used the Ecosystem Diagnosis and Treatment (EDT) model to analyze habitat attributes within the Grande Ronde subbasin. The plan recognized four attributes as being the most limiting: sediment, temperature, flows, and channel condition (i.e., Key Habitat Quantity and Diversity). Although EDT identified other factors, these four were determined to be the most important to address, with all other limitations dependent upon these. The EDT model was also used to analyze factors limiting survival for each spring Chinook population (Watershed Professionals Network 2004). Table 5 shows limiting factors listed for Catherine Creek.

Table 5. EDT identified the highest priority Geographic Areas for restoration and key factors limiting survival for each Grande Ronde subbasin spring Chinook population (Watershed Professionals Network 2004).

Geographic Area	Key Limiting Factors
Mid Catherine Creek	Habitat Diversity, Key Habitat Quantity, Temperature
South Fork Catherine Creek	Sediment
North Fork Catherine Creek	Habitat Diversity, Key Habitat Quantity, Sediment

Existing water quality data is discussed by parameter and by reach. Most of the data comes from completed activities; however, data collection is still ongoing in some cases. The Columbia River Inter-Tribal Fish Commission (CRITFC) has begun monitoring recovery trends in key spring Chinook habitat including Catherine Creek (CRITFC 2009; McCullough et al. 2011) and results of some of their studies are included here. The monitoring project is proposed for 10 years and therefore, will continue to provide water quality data for Catherine Creek. The Grande Ronde Model Watershed Program (GRMWP) will be conducting a channel reconstruction project just below Union around RM 37near the break between reaches 2 and 3 (Kuchenbecker 2011). Water quality monitoring data will likely be collected in association with the project.

5.1 Temperature

Oregon's water temperature standards are determined based on the biological temperature limitations of sensitive indicator species by stream (ODEQ 2000). In Catherine Creek, a temperature standard of 64^0F was established for downstream reaches 1 through 3 using salmonid rearing requirements as criteria (Table 6). In the upper reaches 4 to 7, bull trout was the indicator species used to establish a temperature standard of 50^0 F (although literature always uses 64^0 as standard). A 7-day moving average of daily maximums (7-day statistic) was adopted as the measure for stream temperature.

Table 6. The 1998 Section 303(d) listed segments and applicable numeric temperature criterion for Catherine Creek. (ODEQ 2000)

Segment	Criterion
Mouth to CCACF	Rearing(7/1 – 9/30); 64ºF
CCACF to N.F./S.F. Catherine Cr.	Oregon Bull Trout; 50ºF
N. Fork, Mouth to Middle Fork	Oregon Bull Trout; 50ºF
S. Fork, Pole Cr. to S. Catherine Ditch Diversion	Oregon Bull Trout; 50ºF

Stream temperatures exceed State water quality standards in summer and early fall months from June through September (ODEQ 2000). High stream temperatures correlate with low flows caused by water withdrawals for irrigation during this time. High temperatures can impact anadromous fish survival during egg depositing, rearing, and early migration periods (Yanke et al. 2008). Temperatures that are too low can impact winter incubation (CRITFC 2009).

Water temperature was estimated to currently function at 20 percent, which is expected to increase to 30 percent function in 10 years (CRITFC 2009).

Two types of temperature data exist for the Grande Ronde River and tributaries: continuous measurements (i.e., temporal) and thermal imagery (i.e., spatial) (ODEQ 2000). A range of temperature data exists for Catherine Creek - mostly temporal - that covers various periods. Temporal data is presented by reach in the sections below. Spatial data – in the form of forward-looking infrared radiometer (FLIR) and thermal infrared (TIR) imagery – is discussed on a streamwide basis and also examined by reach.

FLIR longitudinal temperature profiles were collected by Watershed Sciences for ODEQ on Catherine Creek, North Fork Catherine Creek, and South Fork Catherine Creek between 1:38 PM and 2:57 PM on August 21, 1999 (ODEQ 2000; Watershed Sciences 2000). As would be expected, stream temperatures increased continuously downstream (Figure 1). Table 7 lists the average median temperature by reach. Temperatures by the number of miles and percentage of stream they occurred along 53.8 miles of Catherine Creek (from the confluence of the North and South Forks to the mouth at State Ditch) are shown in Table 8. Within the Catherine Creek system, 29 percent of temperatures were below the sub-lethal limit of 64°F (ODEQ 2000). These cold-water areas were exclusively in the North and South Forks and the uppermost 3.6 miles of Catherine Creek (reaches 6 and 7). Almost no cold-water “refugia” areas were observed in the 1999 FLIR temperature profiles for Catherine Creek. Thermal stratification was an intermittent process in the Grande Ronde River and several tributaries. In Catherine Creek, these conditions were due to the impounding of water by dams in the lower reaches.

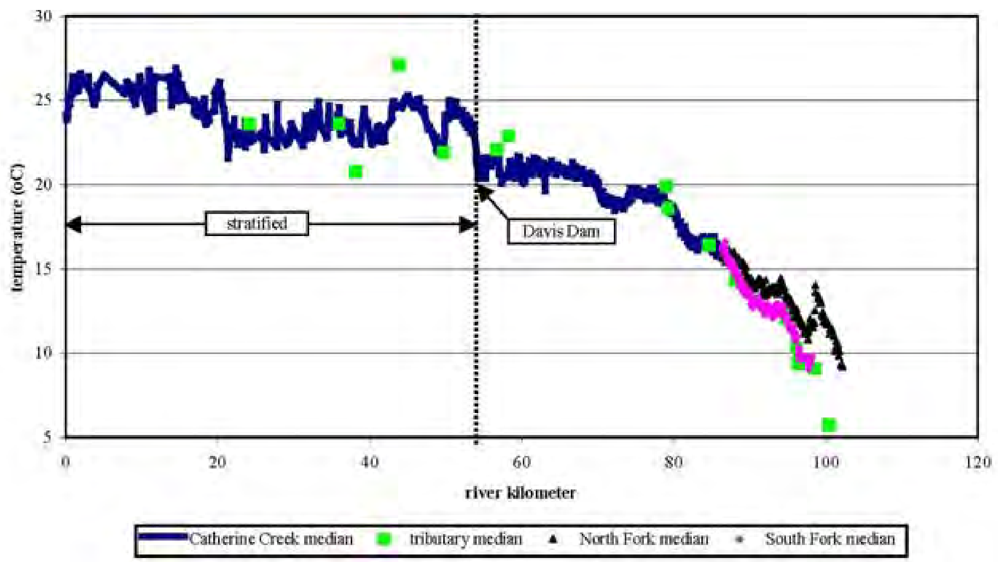

Figure 1. Longitudinal temperature profile of the Catherine Creek, North Fork, and South Fork Catherine Creek (Watershed Sciences 2000).

Table 7. Average median temperature °F by reach in Catherine Creek, August 1999.

Reach	1	2	3	4	5	6	7
Average median temperature °F	76.1	73.2	69.6	68.2	66.7	62.1	61.5

Table 8. Temperatures in Catherine Creek, August 1999 (ODEQ 2000).

Temperature (°F)	Distance (miles)	Percentage of total	Mode of thermal mortality
59.5 – 64.0º	3.6	6.7 percent	
64.0 - 68.5º	7.0	13.0 percent	Sub-lethal
68.5 – 73.0º	9.4	17.4 percent	Sub-lethal
Thermally stratified	33.8	62.9 percent	

Ten tributaries contributing flow to the main stem of Catherine Creek were detected (Watershed Sciences 2000). Four were contributing warmer flow, four were cooler, and two were the same as the main stem. Tributary temperatures did not appear to influence main stem temperatures, however (ODEQ 2000).

CRITFC contracted with Watershed Sciences to provide thermal infrared (TIR) imagery for Catherine Creek in August 2010 (Watershed Sciences 2010; McCullough et al. 2011). These data will be used to establish baseline conditions and direct future ground level monitoring by CRITFC. Approximately 31 miles were surveyed from the mouth at the

Old Grande Ronde River (at the boundary between reach 1 and 2) upstream to the confluence of North and South Fork Catherine Creek (upstream boundary of reach 7). Seven tributaries, one seep, five ponds/sloughs, and two canals were sampled in the imagery. Six active diversions and two dams were seen in the imagery. Bulk water temperatures ranged from 59.4°F near the North and South Fork confluence (RM 53.8) to 88.5°F at RM 29.7 along the low water reach below Ladd Creek in reach 2.

A thermal profile comparison between the 1999 ODEQ FLIR analysis and the 2010 CRITFC TIR analysis for Catherine Creek is shown in Figure 2 (Watershed Sciences 2010; McCullough et al. 2011). Air temperatures were 3 to 5°F warmer during the period of the 1999 flights.

The thermal profile comparison for Catherine Creek shows slightly higher water temperatures in 1999 upstream of the dams and significantly lower, more stable temperatures downstream of the dams (Figure 2). This suggests that flows were higher downstream of the dam in 1999. No discharge data was found near the survey for the 1999 flight; however, the downstream flow gage at Troy, Oregon showed higher flow rates in 1999. It is unclear how well the gage, located 35 miles downstream, reflects the upper Grande Ronde flow rates. With the more stable temperatures in 1999, the impact of Ladd Creek as a cooling point source is more obvious.

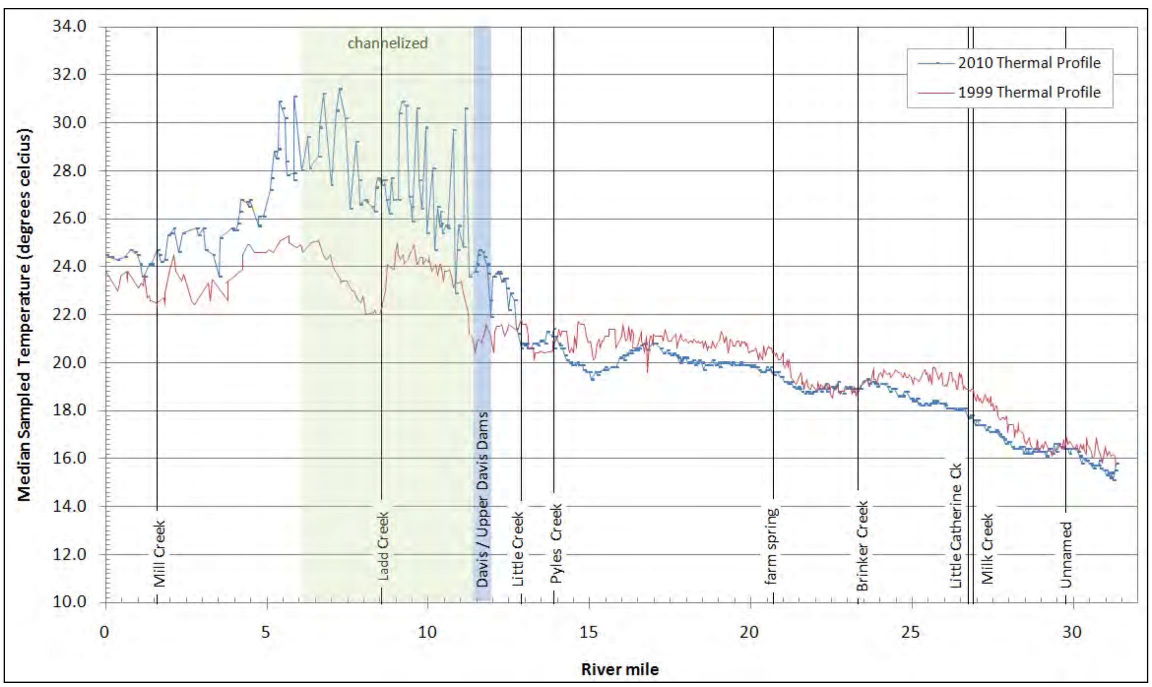

Figure 2. A comparison of the 1999 and 2010 thermal longitudinal profiles for Catherine Creek. Note that RM 0 in the graph is the confluence with Catherine Ck. and Old Grande Ronde River (Watershed Sciences 2010).

In association with the 2010 TIR survey, continuous stream temperature data were collected to provide a ground truth for temperature measurements (Justice, McCullough, and White 2011b; McCullough et al. 2011). Temperature data were collected at 27 sites in Catherine Creek and selected tributaries of Catherine Creek. Average summer stream temperatures (mean from 15 July to 15 September) ranged from 45.3 to 70.2°F with a mean of 57.2°F. Maximum weekly maximum temperatures (MWMT) ranged from 52.5°F in upper North Fork Catherine Creek to 80.6°F in lower Catherine Creek at the Booth Road Bridge in reach 1. Stream temperatures peaked between the last week of July and first week of August at most sites. Of all the sites sampled, only headwater tributaries including Middle Fork Catherine Creek, North Fork Catherine Creek, South Fork Catherine Creek, and upper Milk Creek met the ODEQ water temperature standard of 64.0°F MWMT (ODEQ 2000). The number of days that maximum temperatures exceeded 75.2°F in the Catherine Creek basin ranged from 0 to 29 (mean = 2).

Reclamation funded more recent FLIR flights on Catherine Creek in March 2011. These data were not available at the time of this report documentation. Reclamation also measured temperatures along Catherine Creek in summer 2010 (Didricksen 2011). See the Groundwater section of this report for thermal profiling of the temperature data collected.

5.1.1 Reach 1

In 1997, stream temperature data was collected by the Union Soil and Water Conservation District (USWCD) at six sites on Catherine Creek from June 1 to September 30 (Ballard 1999). The site in reach 1 at approximately RM 21.5 shown in Figure 3 (i.e., Highway 237) exceeded the ODEQ standard of 64.0^0F in the beginning of August. Temperatures at this site were only recorded for August and September of that year.

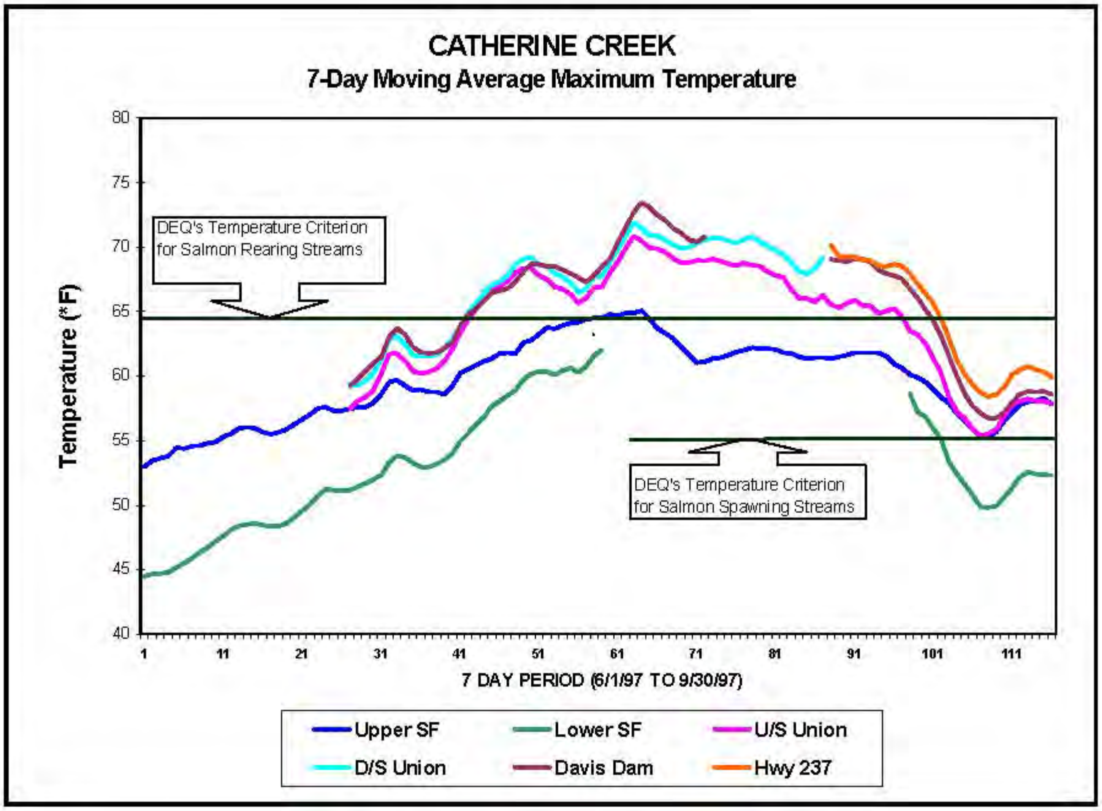

Figure 3. Stream temperatures from six sites in Catherine Creek, June to September 1997 (Ballard 1999).

USWCD has conducted monitoring on Catherine Creek to assess conservation/restoration project effectiveness as a requirement for OWEB grant agreements (USWCD nd; Miles nd). Temperature data were collected within reach 1 in 2000, when onset temperature loggers were deployed at three sites: upstream of Union at RM 43 (reach 4), downstream of Union at RM 38 (reach 3), and under the Hwy. 237 bridge at RM 21 (reach 1). Sites were chosen to provide representative data on long-term stream temperature patterns in relation to land uses (Miles nd). In reach 1, RM 21 falls within agricultural land uses.

Seven-day moving averages of daily maximums were calculated and plotted in Figure 4. Concerning the monitoring point located within reach 1, stream temperature exceeded the ODEQ basic absolute criteria (7-Day Statistic ≤ □64°F) in 2000 at RM 21 for all of August into the end of September.

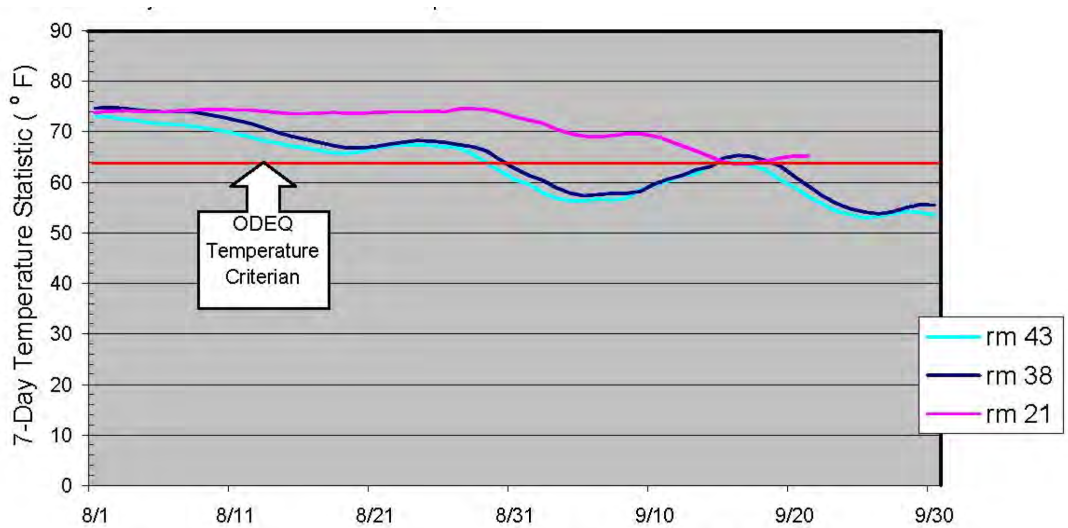

Figure 4. Catherine Creek 2000, 7-day moving average of daily maximum stream temperature (USWCD nd).

Based on 1999 FLIR data, the average median temperature within reach 1 was 76.1°F Table 6). Surface water temperatures below Davis Dam always exceeded the maximums recorded above the dam, reaching a maximum of 80.4^{0}F at RM 9.0 (Figure 1) (Watershed Sciences 2000). Below Davis Dam (reaches 1 and 2), thermal stratification of the water column was a common feature due to low, stagnant streamflows. Thermal stratification was identified because FLIR temperature increases downstream of Davis Dam did not match temperatures measured by continuous monitors at the bottom of the water column. Therefore, caution should be used when interpreting FLIR water temperature data in reaches 1 and 2 because it likely does not reflect water column temperatures below the stratified surface layer (ODEQ 2000). At the mouth of Catherine Creek, the deviation from Grande Ronde temperature was -1.4^{0}F. Figure 5 shows the difference in the Catherine Creek tributary temperatures where it joins with the State Ditch and Old Grande Ronde as captured with FLIR photography.

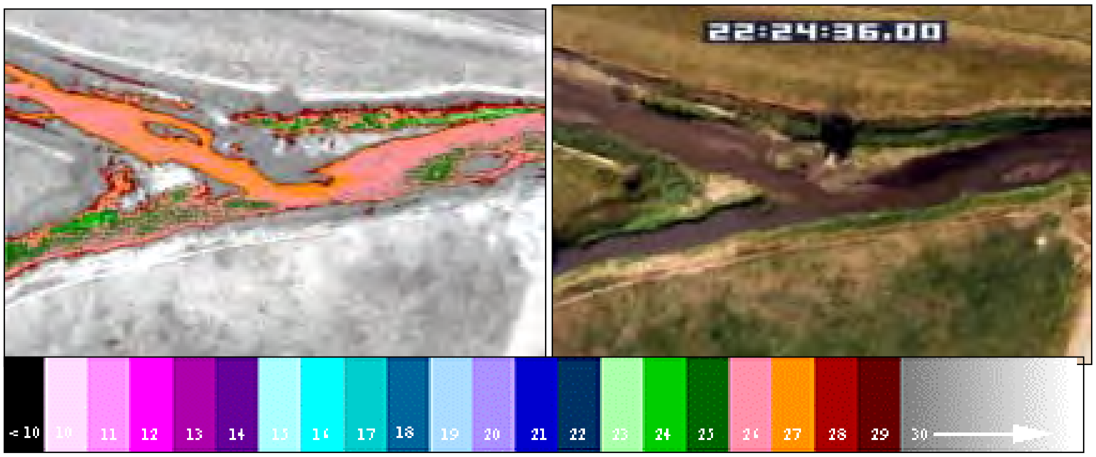

Figure 5. Downstream end of the State Ditch at confluence with old Grande Ronde River channel. The state ditch is flowing in diagonally from the top left corner while Catherine Creek is flowing in from the bottom left corner. Alicel Road is just visible in the bottom right of the image (August 22, 1999 at 3:24 pm) (Watershed Sciences 2000).

In association with the 2010 TIR survey, continuous stream temperature data were collected at 27 sites in Catherine Creek and selected tributaries to provide a ground truth for temperature measurements (Justice, McCullough, and White 2011b; McCullough et al. 2011), although reach 1 was not actually surveyed for TIR data. A summary of stream temperatures collected during continuous monitoring at the Booth Road bridge site in reach 1 is shown in Table 9. A MWMT of 80.1°F exceeded the ODEQ temperature standard of 64.0°F. The warmest temperatures observed from the 27 monitoring sites were at the Booth Road Bridge. This site also had the highest cumulative days exceeding 75.2°F of all sites monitored.

Table 9. Summary of stream temperatures °F in reach 1 of Catherine Creek during the summer of 2010 (July 15 through September 15) (Justice, McCullough, and White 2011b).

		Temperature °F (°C)					Consecutive Days Daily Max Exceeded[6]			
Approximate RM	**Site Description**	**Avg[1]**	**Max[2]**	**Min[3]**	**MWAT[4]**	**MWMT[5]**	**60.8°F**	**64.4°F**	**68°F**	**75.2°F**
16.0	Booth Rd bridge	70.2	81.1	59.4	75.9	80.1	67	59	48	29

[1] average daily temperature; [2] the highest instantaneous temperature recorded; [3] the lowest instantaneous temperature recorded; [4] maximum weekly average temperature; [5] maximum weekly maximum temperature; [6] the greatest consecutive number of days that the daily maximum temperature exceeded thresholds of 60.8, 64.4, 68 and 75.2°F

5.1.2 **Reach 2**

Monitoring data from ODEQ's web database (ODEQ 2007) provided temperature data collected from various times for Catherine Creek (Table 10 and Table 11). Typically, anywhere from one to five temperature measurements were taken per month. Less often, data were collected at a site continuously over 1 to 3 days. Therefore, values shown in the table may be an average of a few to numerous temperatures collected. From 1961 to 1968, samples were collected every year at the confluence of Catherine Creek and Grande Ronde River, but during various months in each year. As is still the case, temperatures consistently exceeded 64.0°F (the current standard) in July and August. More recent data collected from June to October in 1991 to 1993 at the Grande Ronde confluence and upstream in reach 2 also showed that standards were violated in July, August, and sometimes in September.

Table 10. ODEQ temperature data at the confluence of Catherine Creek and old Grande Ronde River, which is located at the break between reaches 1 and 2.

Year	Avg. Temperature F◦ by month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961						75.2	77.0					
1962							75.2 (24)			48.2		
1963	35.6			42.8			69.8					
1964	33.8					51.8		68.0			46.4	
1965			44.6		59.0			68.0				
1966			39.2						64.4			
1967		32.0						71.6				32.0
1968				44.6				79.7				
1991							72.5		68.0			

Table 11. ODEQ temperature data in reach 2.

Station Location	Year	Avg. Temperature F◦ by month				
		Jun	Jul	Aug	Sep	Oct
Gekeler Rd	1991	59.0				
Godley Rd	1991		72.9		68.5	
	1992				55.9	
Wilkerson Ln	1991	56.3	71.6		75.7	
	1992				56.3	
Hwy 203 & Hawkins	1991		69.8		38.9	
	1992				54.5	
	1993				65.8	
Miller Rd	1991		71.2		63.3	
	1992				58.1	
	1993			68.0	61.3	50.4

In 1997, stream temperature data was collected by the USWCD at six sites on Catherine Creek from June 1 to September 30 (Ballard 1999). The site in reach 2 at Davis Dam shown in Figure 3, exceeded the ODEQ standard of 64.0^0F from approximately mid-July to mid-September.

During the summer of 1999, ODEQ deployed a Vemco thermistor at Godley Lane on Catherine Creek (ODEQ 2000). The calculated 7-day temperature statistics for this station using the 1999 data is presented in Table 12. Temperatures taken in August were well over the standard.

Table 12. Calculated 7-day temperature statistics for reach 2 using summer 1999 data (ODEQ 2000).

	Max temp		7-day statistic	
Temperature site	**Date**	**Degrees F**	**Date**	**Degrees F**
Catherine Cr. at Godley Rd (RM 26.5)	08/28/99	80.8	08/23/99	77.8

USWCD has conducted monitoring on Catherine Creek to assess conservation/restoration project effectiveness as a requirement for OWEB grant agreements (USWCD nd; Miles nd). Temperature data were collected within reach 2 in 2001, 2004, and 2006. To monitor stream temperature patterns in 2001 and 2004, the USWCD deployed temperature loggers at four sites: RM 43 (reach 4), RM 38 (reach 3), above the Mill Ck. confluence at RM 24 (reach 2), and the mouth at the confluence with the Grande Ronde River (boundary between reach 1 and 2). In 2006, temperature data were collected at three locations (RM 43, RM 38, and at the mouth). Sites were chosen to provide representative data on long-term stream temperature patterns in relation to land uses (Miles nd). The site at the mouth was selected to represent the lower boundary of intensive agricultural land uses in the Grande Ronde Valley. The site at RM 24 falls within agricultural land uses and was selected to isolate the stream temperature pattern of that Catherine Creek reach from the influence of Mill Creek, a major tributary.

Seven-day moving averages of daily maximums were calculated and plotted in Figures 6 through 8 (USWCD nd; Miles nd). Concerning the monitoring plot located at RM 24, stream temperature exceeded the ODEQ basic absolute criteria (7-Day Statistic ≤ □64°F) from the end of June through September in 2001 and from the end of June to the end of July in 2004 (the only timeframe that data exists for RM 24 in 2004). At the mouth (i.e., confluence with Old Grande Ronde), temperatures were in violation of ODEQ standards from the end of June through September in 2001 and 2004 and from July to early September in 2006.

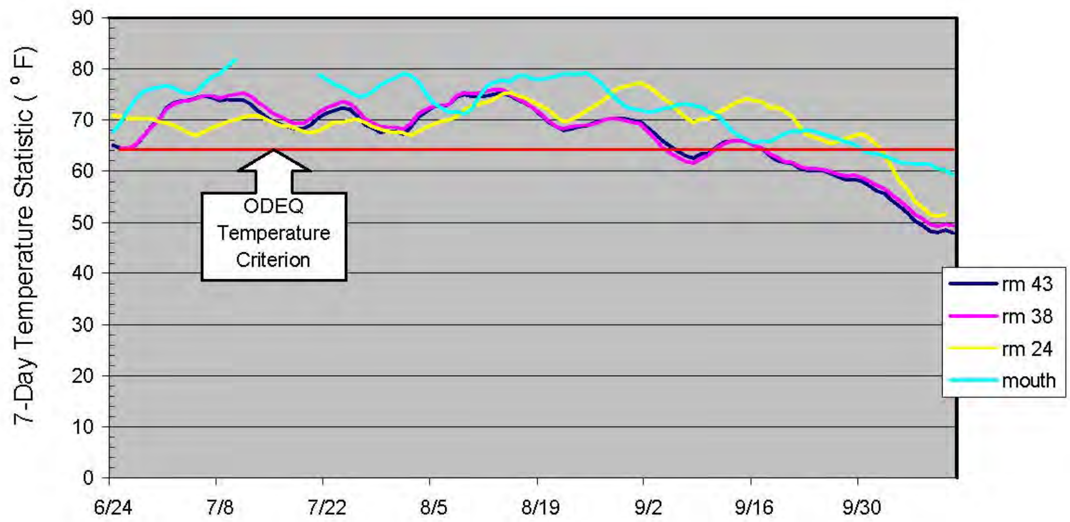

Figure 6. **Catherine Creek 2001, 7-day moving average of daily maximum stream temperature (USWCD nd).**

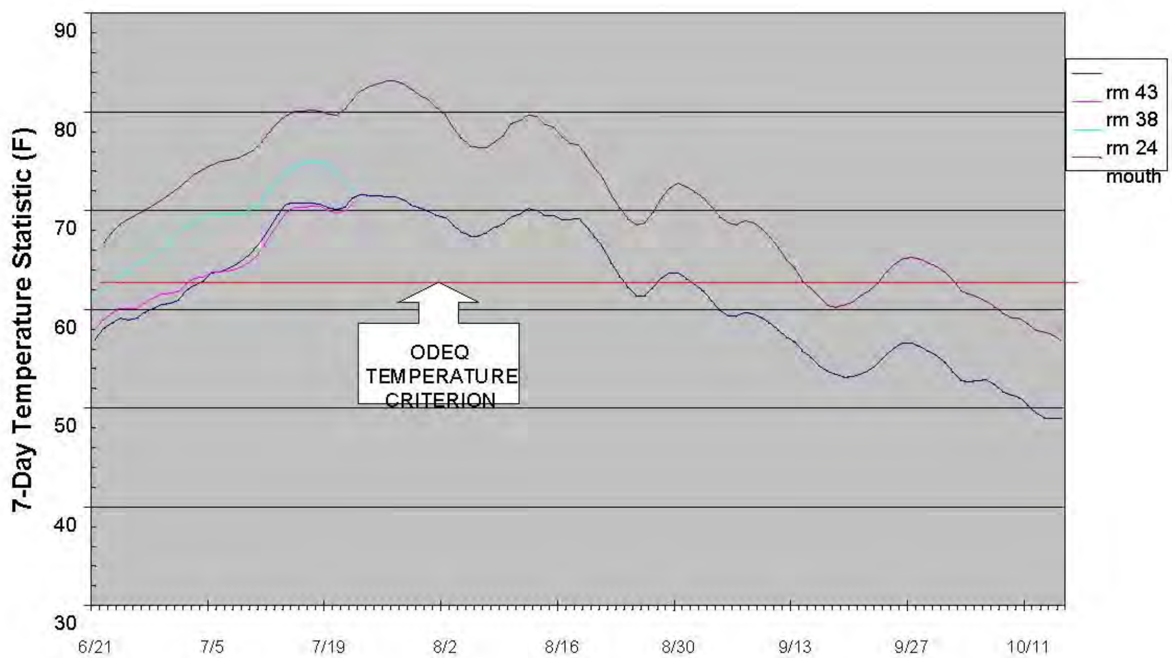

Figure 7. **Catherine Creek 2004 7-day moving average of daily maximum stream temperature. (Data screening protocols removed points from the final data sets of RM 38 and RM 24) (Miles nd; USWCD nd).**

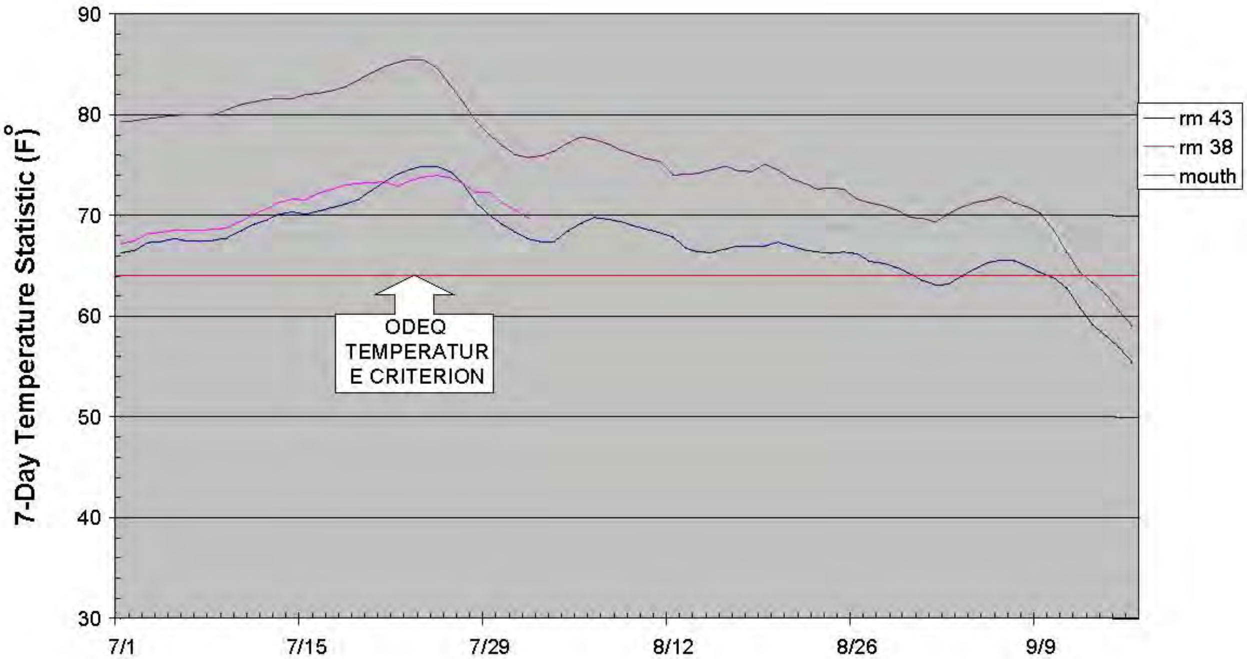

Figure 8. Catherine Creek 2006 7-day moving average of daily maximum stream temperature. (Data screening protocols removed points from the final data sets of RM 38) (Miles nd; USWCD nd).

The 1999 FLIR data indicated that the average median temperature in reach 2 was 73.2^{0}F (Table 7). Surface water temperatures below Davis Dam (which is located in the upper section of reach 2 at RM 33.8) always exceeded the maximums recorded above the dam (Figure 1) (Watershed Sciences 2000). Below Davis Dam (reaches 1 and 2), thermal stratification of the water column was a common feature due to low, stagnant streamflows. Thermal stratification was identified because FLIR temperature increases downstream of Davis Dam did not match temperatures measured by continuous monitors at the bottom of the water column. Therefore, caution should be used when interpreting FLIR water temperature data in reaches 1 and 2 because it likely does not reflect water column temperatures below the stratified surface layer (ODEQ 2000). From RM 41.6 (reach 4) to Davis Dam in reach 2, stream temperatures were relatively constant, fluctuating between 67.3 and 70.9^{0}F (Watershed Sciences 2000).

The lower boundary of the 2010 TIR data was the confluence with Old Grande Ronde River where reach 2 begins. Data indicated that as the stream gradient flattened downstream of RM 37.6 in the lower portion of reach 3, temperatures began to increase (Figure 2) (Watershed Sciences 2010; McCullough et al. 2011). A short stretch of cooling was seen downstream of Pyles Creek (RM 36.4), though it appeared to be contributing warmer surface water (72.7°F). A significant point source warming (75.7°F) was seen at the confluence with Little Creek at RM 35.4.

When Catherine Creek reaches Upper Davis Dam (RM 34.5) and Davis Dam (RM 33.9), a significant amount of flow is diverted out of the main channel. The low flows seen below the dams resulted in highly variable temperatures and potentially stratified water conditions (Watershed Sciences 2010; McCullough et al. 2011). The river is also highly channelized for 4.8 miles below the dam. The increase in the warming rate downstream of the Davis Dams indicates that these diversions do have an impact on the temperature profile of the stream. The Ladd Creek confluence appeared to have a significant impact on bulk water temperatures, though it was not contributing enough surface water for accurate sampling.

Near RM 29.1, the river resumes a more natural meandering flow, and water levels begin to rebound below RM 27.9. In this more natural flow regime, a 6.4°C temperature decrease is seen in the lower 5 miles of reach 2 (Figure 9).

5.1.3 Reach 3

At the time TMDLs were developed for the Upper Grande Ronde Basin, the Union Waste Water Treatment Plant (WWTP) in the town of Union was identified by ODEQ as an NPDES permitted facility that discharged surface water during critical summertime temperature period (ODEQ 2000). System potential temperatures and waste load allocations were derived by ODEQ for all point sources. At the time the loading capacities were determined, no data existed for August discharge temperatures at the Union WWTP. A new plant was built in 2001, when the town of Union removed its wastewater discharge during low flows (Ramondo 2011). The current discharge schedule is from October 1 to approximately June 1 to June 15. Certain specifications must be met, however, in order for the plant to discharge effluent: 1) Catherine Creek flows must be at least 17 cubic feet per second (cfs); 2) stream temperatures cannot exceed 57.2^{0}F; and 3) effluent temperatures must be below 55.3^{0}F. These specifications are not always met during the allowable time frame. For example, in 2010 the creek temperatures and flows did not meet criteria required for the plant to discharge into the creek until November (Ramondo 2011). Union WWTP monitors daily stream temperature about 0.5 miles above the plant.

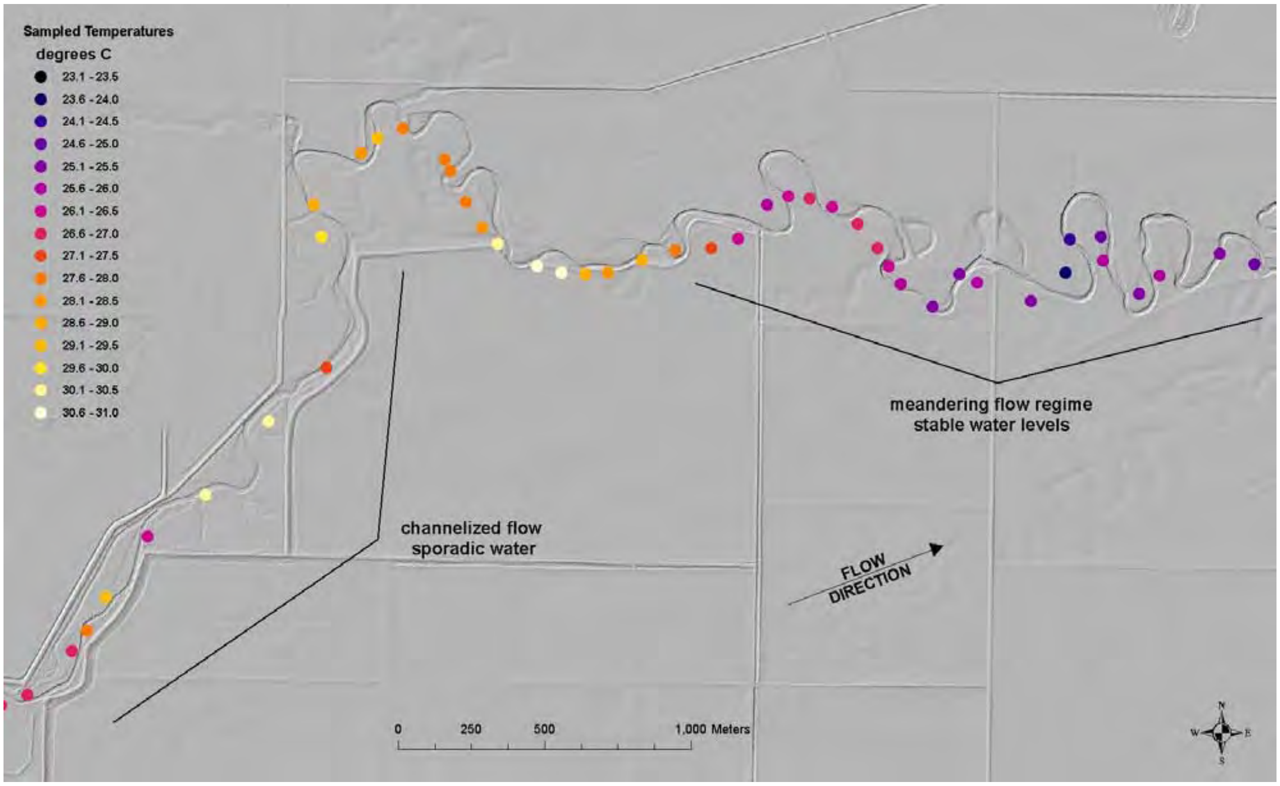

Figure 9. LiDAR bare earth hillshade that shows the transition between the confined, channelized river and the sinuous meandering channel near RM 29.1. Along this portion of Catherine Creek, water levels begin to rebound and a 6.4°C temperature decrease is seen in the lower 5 miles of reach 2 as the river returns to a more natural flow regime. The point color ramp is exaggerated for this image (Watershed Sciences 2010).

Temperature data from ODEQ's web database (ODEQ 2007) collected within reach 3 of Catherine Creek are shown in Table 13. Temperature was measured at some time between June and October from 1991 to 1993, with the most consistent data from the month of September. Three of the collection sites were located directly downstream of the WWTP and two were located upstream of the plant. Unfortunately, there is not enough data to determine if the WWTP was influencing stream temperatures during critical periods of low flow and high temperatures. In August, all temperatures exceeded the ODEQ standard of 64.0^{0}F.

Table 13. ODEQ temperature data in reach 3.

Station Location	Year	Avg. Temperature F◦ by month				
		Jun	Jul	Aug	Sep	Oct
At Union WWTP outfall	1991	64.4	63.1		63.5	
	1992				60.4	
	1993				60.8	
100 feet downstream of Union WWTP	1993				61.3	
0.25 miles downstream of Union WWTP	1991					50.0
	1993				63.9	50.4
0.5 miles downstream of Union WWTP	1993			71.2		
5th St in Union	1993				60.4	50.9
Highway 203 (E of Union)	1991	53.6	72.9		64.9	
	1992			64.4	54.9	
	1993			70.7	59.0	

In 1997, stream temperature data was collected by the USWCD at six sites on Catherine Creek from June 1 to September 30 (Ballard 1999). Results from two sites presumed to be in reach 3 – upstream and downstream of Union - are shown in Figure 3. Temperatures exceeded the ODEQ standard of 64.0^{0}F from approximately mid July to early September, although there is not a complete record for the upstream site.

Temperature data were collected by USWCD downstream of Union at RM 38 in reach 3 in 2000, 2001, 2004, and 2006 (USWCD nd; Miles nd). Sites were chosen to provide representative data on long-term stream temperature patterns in relation to land uses (Miles nd). The site at RM 38 was selected to represent a transition between urban land uses upstream and predominantly agricultural uses downstream. It was also important that this site be near the location of the OWRD gauging station so that data could be correlated to flow rate and total discharge.

Seven-day moving averages of daily maximums were calculated and plotted in Figures 4, 6, 7, and 8. With regards to the monitoring plot located at RM 38 within reach 3, stream temperature exceeded the ODEQ basic absolute criteria (7-Day Statistic $\leq 64^{0}$F) through August and a few days in mid-September in 2000 and 2001 and in July in 2004 and 2006 (the only timeframe that temperature data exists for RM 38 in 2004 and 2006).

Continuous and FLIR temperatures collected in August of 1999 correlated well upstream of Davis Dam (reaches 3 to7) (ODEQ 2000). These data indicated that from RM 41.6 (reach 4) to Davis Dam RM 33.8 (reach 2), which encompasses reach 3, stream temperatures were relatively constant, fluctuating between 67.3 and 70.9^{0}F (Figure 1)

(Watershed Sciences 2000). The average median temperature in reach 3 was 69.6^{0}F (Table 6).

Temperature data collected in the August 2010 TIR surveys showed a gradual increase from the mouth of the North and South Forks (RM 53.8) downstream to RM 39.4 (reach 3) from 59.4°F to 69.4°F (Figure 2) (Watershed Sciences 2010; McCullough et al. 2010). At RM 38.8 in reach 3, bulk water temperatures decreased 2.7°F from 69.4°F to 66.7°F over 1.88 miles. It was unclear what causes this decrease in temperatures as the stream flows through Union, Oregon. No significant inflows or outflows, no changes in stream gradient, morphology or vegetation type were identified along this reach. The diversion at RM 39.9 did not appear to have a quantifiable effect on temperatures in Catherine Creek.

In association with the 2010 TIR survey, continuous stream temperature data were collected at 27 sites in Catherine Creek and selected Catherine Creek tributaries to provide a ground truth for temperature measurements (Justice, McCullough, and White 2011b; McCullough et al. 2011). A summary of stream temperatures collected during the 2010 continuous monitoring at a site east of Union in reach 3 is shown in Table 14. A MWMT of 71.2°F exceeded the ODEQ temperature standard of 64°F. The daily average, maximum, and minimum stream temperatures at this site are graphed in Figure 10.

Table 14. Summary of stream temperatures in reach 3

		Temperature °F					Consecutive Days Daily Max Exceeded[6]			
Approx RM	**Site Description**	**Avg[1]**	**Max[2]**	**Min[3]**	**MWAT[4]**	**MWMT[5]**	**60.8°F**	**64.4°F**	**68°F**	**75.2°F**
40.5	East of Union	60.4	72.7	47.3	65.3	71.2	48	43	12	0

[1] average daily temperature;
[2] the highest instantaneous temperature recorded;
[3] the lowest instantaneous temperature recorded;
[4] maximum weekly average temperature;
[5] maximum weekly maximum temperature;
[6] the greatest consecutive number of days that the daily maximum temperature exceeded thresholds of 60.8, 64.4,68, 75.2°F

Figure 10. Daily average, minimum, and maximum stream temperatures (°C) in Catherine Creek at the east end of Union in reach 3 from 10 July to 20 September, 2010 (Justice, McCullough, and White 2011b).

5.1.4 **Reach 4**

Temperature data from ODEQ's web database (ODEQ 2007) collected within reach 4 of Catherine Creek is shown in Table 15. Temperature was measured in August and September 1992. The ODEQ temperature standard of 64.0^{0}F was slightly exceeded in August.

Table 15. ODEQ temperature data in reach 4.

Station Location	Year	Avg. Temperature ^{0}F by month	
		Aug	Sept
RM 41.5 (E Of Union)	1992	64.4	62.6

ODEQ deployed a Vemco thermistors upstream of Union in reach 4 during the summer of 1999 (ODEQ 2000). Calculated 7-day temperature statistics for these stations using the 1999 data is presented in Table 16. Temperatures in August were well above the ODEQ standard of 64.0^{0}F.

Table 16. Calculated 7-day temperature statistics for reach 4 using summer 1999 data (ODEQ 2000).

	Max temp		7-day statistic	
Temperature site	Date	Degrees F	Date	Degrees F
Catherine Cr. upstream Union	08/06/99	75.2	07/31/99	71.7

Temperature data were collected by USWCD upstream of Union at RM 43 in reach 4 in 2000, 2001, 2004, and 2006 (USWCD nd; Miles nd). Sites were chosen to provide representative data on long-term stream temperature patterns in relation to land uses (Miles nd). The site at RM 43 was selected to represent a transition between forestry and grazing land uses upstream and urban land uses downstream. Seven-day moving averages of daily maximums were calculated and plotted in Figures 4, 6, 7, and 8. With regards to the monitoring plot located at RM 43 within reach 4, stream temperature exceeded the ODEQ basic absolute criteria (7-Day Statistic 64^{0}F) through August in 2000 (no data for July), in July and August in 2001, from the beginning of July until the end of August in 2004, and July through September in 2006.

Yanke et al. (2008) conducted fish studies in Catherine Creek below spawning and upper rearing areas upstream of the town of Union where traps were place and temperatures measured. A cohort of juvenile spring Chinook salmon were examined from brood year (i.e., the year eggs were fertilized) 2006. Temperature statistics were correlated with Chinook life history phases for the period between 2006 and 2008. Daily mean water temperature typically fell within DEQ standards while the 2006 brood year (BY) of spring Chinook salmon occupied the Grande Ronde River subbasin (1 August 2006 to 30 June 2008), with the daily mean water temperatures exceeding the standard of 64.0°F for 44 of 650 days in Catherine Creek. Daily mean water temperatures in excess of 64.0°F occurred while eggs may have been being deposited in redds (August 2006), intermittently during parr rearing stages (June to August 2007), and for several days during early dispersal (August to September 2007). Temperatures preferred by juvenile Chinook salmon (50-60.1°F) occurred for 16 percent of the hours logged for Catherine Creek. The temperature considered lethal to Chinook salmon (77°F) was encountered less than 2 of 662 days.

The moving mean of maximum daily water temperature showed that temperatures below the limit for healthy growth (39.9 °F) occurred more often than temperature above the limit for healthy growth 66.0°F in Catherine Creek. Moving mean temperatures exceeded 66.0°F 95 days while this cohort was in-basin. During this period, a total of 26 days (4 August to 7 September 2006) occurred during parental spawning and 69 days (30 June to 6 September 2007) occurred while the majority of young of year were rearing and dispersing. Moving mean temperatures were less than 39.9°F 64 days (12 November

2006 to 4 March 2007) during incubation and emergence, and 97 days (20 November 2007 to 24 February 2008) during dispersal and spring migration.

The 1999 continuous and FLIR temperatures correlated well upstream of Davis Dam in reaches 3 through 7 (ODEQ 2000). Within reach 4, stream temperatures increased slowly downstream from RM 44.7 to about RM 41.6 where they reached a local maximum of 69.8^0F (Figure 1) (Watershed Sciences 2000). From that point to Davis Dam (RM 33.8 in reach 2, stream temperatures were relatively constant, fluctuating between 67.3 and 70.9^0F). The average median temperature in reach 4 was 68.2^0F (Table 6).

The 2010 TIR temperatures showed a gradual increase from the North and South Forks downstream to RM 39.4 in reach 3 from 59.4°F to 69.4°F (Watershed Sciences 2010; McCullough et al. 2010). Localized cooling was seen at three different locations along Catherine Creek including the farm spring at RM 43.2 in reach 4. The spring did not have a visible surface water contribution to Catherine Creek, but subsurface interaction is suggested by the plateaus seen in the longitudinal profile (Figure 2). The diversions at RM 41.8 in reach 4 did not appear to have a quantifiable effect on temperature in Catherine Creek.

5.1.5 **Reach 5**

Continuous and FLIR temperatures collected in August 1999 correlated well upstream of Davis Dam from reaches 3 to 7, which encompasses reach 5 (ODEQ 2000). From the confluence with the North and South Forks in reach 7, Catherine Creek warms steadily in the downstream direction to Little Catherine Creek at RM 49 in reach 5 (Figure 1) (Watershed Sciences 2000). From RM 49 to 46.6 in reach 5, stream temperatures were relatively constant at just under 68.0^0F. At RM 46.6, stream temperatures were cooler over the next several kilometers for no apparent reason. The average median temperature in reach 5 was 66.7^0F (Table 6).

Temperature data from the 2010 TIR surveys showed a gradual increase from the Forks downstream to RM 39.4 in reach 3 from 59.4°F to 69.4°F (McCullough et al. 2010; Watershed Sciences 2010). Localized cooling was seen at Brinker Creek, which is located at approximately RM 45.8 where the break between reach 4 and 5 occurs. Brinker Creek did not have a visible surface water contribution to Catherine Creek, but subsurface interaction is suggested by the plateaus seen in the longitudinal profile (Figure 2). The slight inflection seen at the confluence of Little Catherine Creek between reaches 5 and 6 indicates a decrease in the rate of warming which also suggests groundwater interaction.

In association with the 2010 TIR survey, continuous stream temperature data were collected at 27 sites in Catherine Creek and selected Catherine Creek tributaries to provide a ground truth for temperature measurements (Justice, McCullough, and White 2011b; McCullough et al. 2011). A summary of stream temperatures collected during the 2010 continuous monitoring at the site on Hwy 203 in reach 5 is shown in Table 17. A MWMT of 69.6°F exceeded the ODEQ temperature standard of 64.0°F.

Table 17. Summary of stream temperatures °F in reach 5 of Catherine Creek during the summer of 2010 (July 15 through September 15) (Justice, McCullough, and White 2011b).

		Temperature °F					Consecutive Days Daily Max Exceeded[6]			
Approx RM	Site Description	Avg[1]	Max[2]	Min[3]	MWAT[4]	MWMT[5]	60.8°F	64.4°F	68°F	75.2°F
46.0	Hwy. 203	57.7	70.9	44.1	62.4	69.6	44	27	11	0

[1] average daily temperature;
[2] the highest instantaneous temperature recorded;
[3]the lowest instantaneous

5.1.6 Reach 6

Continuous and FLIR temperatures collected in August 1999 correlated well upstream of Davis Dam from reaches 3 to 7 which encompasses reach 6 (ODEQ 2000). From the confluence with the North and South Forks in reach 7, Catherine Creek warms steadily in the downstream direction to Little Catherine Creek at RM 49 in reach 5 (Figure 1) (Watershed Sciences 2000; ODEQ 2000). Further downstream, water temperatures continued to warm between Milk Creek confluence in reach 6 and upstream of Davis Dam (66.0°F to 69.6°F, respectively). The average median temperature in reach 6 was 62.1°F (Table 6).

The 2010 TIR temperatures showed a gradual increase from the North and South Forks downstream to RM 39.4 in reach 3 from 59.4°F to 69.4°F (Watershed Sciences 2010; McCullough et al. 2011). The slight inflection seen in the longitudinal profile (Figure 2) at the confluence of Milk Creek between reaches 6 and 7 indicates a decrease in the rate of warming, which suggests groundwater interaction.

In association with the 2010 TIR survey, continuous stream temperature data was collected at 27 sites in Catherine Creek and selected Catherine Creek tributaries to provide a ground truth for temperature measurements (Justice, McCullough, and White 2011b; McCullough et al. 2011). A summary of stream temperatures collected during continuous monitoring at two sites in reach 6 is shown in Table 18Table 18. Summary of stream temperatures °F in reach 6 of Catherine Creek during the summer of 2010 (July 15 through September 15) (Justice, McCullough, and White 2011b).

Table 18. Summary of stream temperatures ^{0}F in reach 6 of Catherine Creek during the summer of 2010 (July 15 through September 15) (Justice, McCullough, and White 2011b).

		Temperature °F					Consecutive Days Daily Max Exceeded[6]			
Approx RM	Site Description	Avg[1]	Max[2]	Min[3]	MWAT[4]	MWMT[5]	60.8°F	64.4°F	68°F	75.2°F
50.2	Above Little Ck.	56.1	68.5	43.0	60.4	67.1	43	13	2	0
50.5	Above Milk Ck	55.9	68.4	43.2	60.4	66.9	43	13	2	0

[1] average daily temperature;
[2] the highest instantaneous temperature recorded;
[3]the lowest instantaneous temperature recorded;
[4]maximum weekly average temperature;
[5]maximum weekly maximum temperature;
[6]the greatest consecutive number of days that the daily maximum temperature exceeded thresholds of 60.8, 64.4, 68, and 75.2^{0}F

The MWMTs of 67.1 and 66.9^{0}F exceeded the ODEQ temperature standard of 64.0^{0}F.

5.1.7 Reach 7

In 1997, stream temperature data was collected by the Union Soil and Water Conservation District (USWCD) at six sites on Catherine Creek from June 1 to September 30 (Ballard 1999). Results from two sites upstream of reach 7 in the upper and lower South Fork are shown in Figure 3. Temperatures generally remained below the ODEQ standard of 64.0^{0}F except for a few days in early August in the upper S. Fork, although there is not a complete record for the lower South Fork site.

ODEQ deployed two Vemco thermistors at the mouths of North and South Forks at the upper boundary of reach 7 of Catherine Creek during the summer of 1999 (ODEQ 2000). Calculated 7-day temperature statistics for these stations using 1999 data is presented in Table 18. Seven-day moving averages of daily maximums in August were below ODEQ standards at these sites.

Table 19. Calculated 7-day temperature statistics for reach 7 using summer 1999 data (ODEQ 2000).

	Max temp		7-day statistic	
Temperature site	Date	Degrees F	Date	Degrees F
North Fork Catherine Cr. at mouth	08/19/99	64.4	07/27/99	62.5
South Fork Catherine Cr. at mouth	08/04/99	64.4	07/27/99	62.0

Continuous and FLIR temperatures correlated well upstream of Davis Dam, from reaches 3 through 7 (ODEQ 2000). Based on FLIR data, the temperature below the Catherine Creek forks was 61°F. Rapid stream heating was observed in Catherine Creek between the confluence of Scott Creek and Milk Creek in reach 7. Stream temperatures rose above 64°F within this reach.

From the confluence with the North and South Forks in reach 7, Catherine Creek warms steadily in the downstream direction to Little Catherine Creek at RM 49 in reach 5 (Figure 1) (Watershed Sciences 2000). The average median temperature in reach 7 was 61.5°F (Table 6).

The 2010 TIR temperature data showed a gradual increase from the mouth of the North and South Forks at the upper end of reach 7 downstream to RM 39.4 in reach 3 from 59.4°F to 69.4°F (Watershed Sciences 2010; McCullough et al. 2010). Localized cooling can be seen downstream of the unnamed stream at RM 52.3 in reach 7. The stream does not have a visible surface water contribution to Catherine Creek, but subsurface interaction is suggested by the plateaus seen in the longitudinal profile (Figure 2).

5.2 Sediment

For listing sedimentation standards, the PACFISH target of 20 percent streambed fines was utilized as an indicator of fine sediment impairment to salmonids (ODEQ 2000). Thus, the loading capacity for sedimentation is defined as 20 percent streambed area fines. Sediment levels in Catherine Creek violate 1998 ODEQ standards only within North and South Forks. However, inputs from these upper tributaries contribute to sedimentation in the lower reaches of Catherine Creek.

Roads, grazing, agricultural practices, and urban development are main sources of excessive fine sediment in the Grande Ronde River subbasin (USFWS 2002). Many farmers and ranchers have applied conservation practices to reduce the effects of erosion by water (NRCS 2005). As a result, erosion rates on croplands and pasturelands fell 24 percent, from 2.5 tons/acre/year to 1.9 tons/acre/year, from 1982 to 1997 in the Upper Grande Ronde. However, estimates indicate that 17,700 acres of agricultural lands still had water erosion rates above a sustainable level in 1997.

Sediment in the basin is currently estimated to operate at a percentage function of 30 percent, increasing to 40 percent in 10 years (CRITFC 2009). The estimated percentage function is essentially a current egg survival to emergence of 30 percent of potential due to fine sediment levels that is expected to improve to 40 percent of potential survival after a 10-year restoration program.

In the Upper Grande Ronde subbasin, high fine sediment distributions correlate strongly with non-woody riparian vegetation (i.e., annuals and perennials) (ODEQ 2000). Annual riparian vegetation types have median percent fine sediment distributions approaching 100 percent. Perennial riparian vegetation types have a median percent fine sediment level of 58 percent. Non-woody riparian vegetation communities correlate to fine sediment distributions that would prevent nearly all sac-fry emergence. As such, these survey reaches are degraded to a level that reduces salmonid reproductive fitness to near zero levels.

Woody riparian vegetation classifications correlate to lower fine sediment distributions (median values less than 20 percent fine sediment). Established mature deciduous/mixed/ conifer riparian vegetation correlate to the lowest median percent fine value (16 percent of the streambed substrate).

However, much of the woody riparian communities have high levels of fine sediments which suggests that sources of sediment beyond sources related to riparian vegetation are affecting the sediment distributions in the Grande Ronde River and tributaries.

Streambed substrate gravel occurrence is lowest (median gravel distribution of 21 percent) where riparian vegetation communities are annual and perennial plant species (ODEQ 2000). Woody riparian vegetation corresponds to higher gravel streambed substrate. Data show that established deciduous/mixed/conifer riparian vegetation types correlate with higher median gravel substrate (32 percent). In high gradient reaches of Catherine Creek, the dominant available substrate is gravel, while the substrate most commonly used by salmonids is cobble (Favrot et al. 2010). This indicates that the rate that coarser substrates are selected is higher than the rate that they are available. The predominance of gravel in the upper reaches could be related to geology. An outcrop of gravels is located about 11.5 miles south of Union in the upper watershed of Catherine Creek (Isaacson 2002). The average size of the gravels gets coarser upward, reaching cobble and boulder sizes near the top of the outcrop. Silt was the most available and the most utilized substrate by early migrants in the low gradient reaches (Favrot et al. 2010).

Bank stability problems on Catherine Creek were found to be common along both high- and low-gradient stream reaches, although were most extensive along unconstrained low-gradient reaches (Huntington 1994). On average, high gradient channels had high levels of sediment with mean cobble embeddedness of 48 percent and mean surface fines of 43 percent. Unconstrained low gradient reaches generally had moderate to high levels of sedimentation; mean surface fines were 18 percent. Constrained low gradient channels surveyed had moderate to extremely high levels of streambed sediment with mean surface fines of 51 percent. Huntington (1994) also developed reference conditions (RC) based on salmonid habitat requirements, which were used to compare existing habitat conditions. Habitat quality concerning sedimentation issues along streams surveyed in the Catherine Creek subbasin was frequently below RC levels. Bank stability was below RC levels along 85 percent of the streams surveyed. Levels of fine sediment in the streambed were too high to match RC criteria along 79 percent of stream miles surveyed.

Analysis of sediment size was conducted by CRITFC during the summer of 2010 at five sites in Catherine Creek (Justice, McCullough, and White 2011a; McCullough et al. 2011. Table 20 lists the sites and locations. Surface samples were collected at all sites. Subsurface samples were only collected at two sites in Catherine Creek because the other reaches did not contain suitable spawning gravels. Among the five surface samples in Catherine Creek, the mean percentage of surface fines less than 0.25 inches was 17.4 percent. The average size frequency distribution of streambed particles appeared to be bimodal, with a relatively small peak in particle frequencies occurring at 0.08 inches and a second larger peak occurring between 1.8 and 3.5 inches. Consistent with the surface sediment distributions, the frequency distributions of subsurface particles from 2 sites in Catherine Creek appeared to have a bimodal distribution with a smaller peak occurring around 0.08 inches, and a second larger peak occurring around 2.5 to 3.5 inches.

Table 20. Sediment size sampling sites on Catherine Creek, summer 2010.

Reach	Approximate river mile	Sample date	Sample type
3	40	9/16/2010	Surface, subsurface
6	50.7	7/21/2010	Surface, subsurface
Just upstream of 7 at the mouth of North Fork	-	7/29/2010	Surface
North Fork at confluence with Middle Fork	-	9/16/2010	Surface
South Fork	-	9/14/2010	Surface

Results of the sediment size analysis and soils and erosion hazard ratings are discussed by reach below.

5.2.1 Reaches 1 and 2

Soils are predominately silt loams and silty clay loams. Erosion hazard is slight (NRCS 2009).

5.2.2 Reach 3

Soils are composed of silt loams and silty clay loams. Erosion hazard is mostly slight, with some moderate ratings (NRCS 2009).

The average percentage of surface sediment particles finer than 0.08 inches and 0.25 inches from sampling conducted in summer 2010 are listed in Table 21 (Justice, McCullough, and White 2011a; McCullough et al. 2011). Of the sites sampled, reach 3 had some of the lowest percentages of fine sediment. The surface size sediment distribution for the sample site in reach 3 near Union is graphed in Figure 11. The bimodal distribution, with peaks around 0.08 inches and between 1.3 and 5.0 inches, is apparent in the graph. The percentage of fine sediment in subsurface bulk samples based on four particle sizes is listed in Table 22. The predicted egg to fry survival for reach 3 based on sediment size sampling was 64.4 percent for particle size < 0.03 and 0.27 inches and 76.4 percent for particle size < 0.25 inches (Table 23).

5.2.3 Reach 4

Soils are stony and cobbly silt loams (NRCS 2009). Erosion hazards are moderate to slight (NRCS 2009).

Table 21. Percentage of surface sediment particles finer than 0.08 inches and 0.25 inches measured at 5 sites in Catherine Creek during summer 2010 (Justice, McCullough, and White 2011a).

	Percent fines < 0.08 inches			Percent fines < 0.25 inches		
Reach	**Estimate**	**LCI**	**UCI**	**Estimate**	**LCI**	**UCI**
3	9.4	5.0	15.9	13.2	7.9	20.3
6	15.0	10.3	20.9	17.8	12.7	24.0
Mouth of N. Fork	22.9	16.5	30.4	28.6	21.6	36.4
North Fork	13.7	8.4	20.8	19.1	12.7	26.9
South Fork	3.6	1.0	9.0	8.6	4.1	15.4
Average	12.9	8.2	19.4	17.4	11.8	24.6
Min	3.6	1.0	9.0	8.6	4.1	15.4
Max	22.9	16.5	30.4	28.6	21.6	36.4

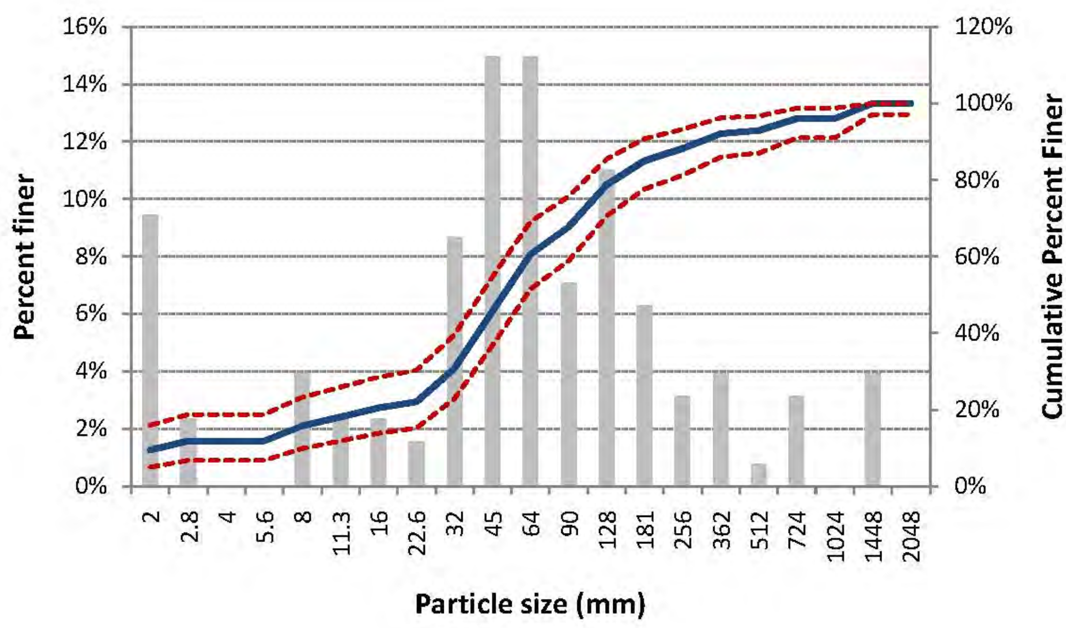

Figure 11. Surface sediment size distribution for Catherine Creek in reach 3 near Union during summer 2010. Dashed lines denote the 95 percent confidence interval for the cumulative distribution (Justice, McCullough, and White 2011a).

Table 22. Percentage of fine sediment in subsurface bulk samples measured in reach 3 of Catherine Creek during summer 2010. Calculations of percent finer are provided for four commonly used particle size criteria including 0.03, 0.13, 0.25, and 0.37 inches (Justice, McCullough, and White 2011a).

Particle size (inches)	Average percent finer	SD	LCI	UCI
< 0.03	8.4	2.6	6.0	10.8
< 0.13	23.4	4.8	18.9	27.9
< 0.25	33.7	6.3	27.8	39.6
< 0.27	42.8	7.7	35.7	49.9

Table 23. . Predicted egg-to- fry survival and associated 95 percent confidence intervals in reach 3 of Catherine Creek during summer 2010 (Justice, McCullough, and White 2011a).

percent fines < 0.03 and 0.27 inches[1]			percent fines < 0.25 inches[2]		
Survival estimate (percent)	LCI	UCI	Survival estimate (percent)	LCI	UCI
64.4	42.9	80.0	76.4	52.5	89.0

[1] Tappel and Bjornn 1983; [2] Irving and Bjornn 1984

5.2.4 Reaches 5 and 6

Soils are stony and cobbly silt loams on steeper slopes. Erosion hazards are mostly moderate, with some very severe (NRCS 2009).

The average percentage of surface sediment particles finer than 2mm and 6 mm from sampling conducted during summer 2010 in reach 6 is listed in Table 21 (Justice, McCullough, and White 2011a; McCullough et al. 2011). Of the sites sampled, reach 6 had the second highest percentages of fine sediment (Table 21). The percentage of fine sediment in subsurface bulk samples based on four particle sizes is listed in Table 24. Despite the relatively high percentages of fine sediment, the predicted egg to fry survival for reach 6 was 79.1 percent for particle size < 0.03 and 0.27 inches and 88.4 percent for particle size < 0.25 inches (Table 25).

Table 24. Percentage of fine sediment in subsurface bulk samples measured in reach 6 of Catherine Creek during summer 2010. Calculations of percent finer are provided for four commonly used particle size criteria including 0.03, 0.13, 0.25, and 0.37 inches (Justice, McCullough, and White 2011a)

Particle size (inches)	Average percent finer	SD	LCI	UCI
< 0.03	6.8	2.5	4.8	8.7
< 0.13	20.6	6.1	15.9	25.3
< 0.25	28.3	7.8	22.3	34.3
< 0.37	34.9	9.8	27.4	42.5

Table 25. Predicted egg-to- fry survival and associated 95 percent confidence intervals in reach 6 of Catherine Creek during summer 2010. (Justice, McCullough, and White 2011a)

	percent fines < 0.03 and 0.37 inches[1]			percent fines < 0.25 inches[2]		
Reach	Survival estimate (percent)	LCI	UCI	Survival estimate (percent)	LCI	UCI
6	79.1	63.8	89.4	88.4	74.6	93.6

[1] Tappel and Bjornn 1983;
[2] Irving and Bjornn 1984

5.2.5 Reach 7

Erosion hazards are moderate and severe (NRCS 2009).

The North and South Forks of Catherine Creek, upstream of reach 7 and located within the Wallowa-Whitman National Forest, are discussed since they exceed sediment standards and contribute to sediment loads downstream.

North Fork

Erosion hazard along the North Fork is mostly very severe with some severe ratings (NRCS 2009).

Although erosion hazards along the North Fork are high, this tributary is not considered to cause significant sediment problems (Platt 2011; Lovatt 2011). The Forest Service does not collect sediment load data on either fork. Land uses adjacent to the North Fork that could contribute sediment to the creek include grazing, logging, and roads. Portions of this tributary are grazed; however, Rosgen type A and B stream channels are relatively stable and the most sensitive areas along the creek are excluded from grazing (Lovatt 2011). Current Forest Service logging practices require a 300-foot buffer along fish-bearing streams (Platt 2011), although past logging may still impact slope stability. The Eagle Cap Wilderness includes the North Fork; therefore, roads are limited but trailheads are located throughout the area.

Surface sediment size sampling was conducted on the North Fork of Catherine Creek during summer 2010 near the confluence with Middle Fork and at the mouth, just upstream of reach 7 (Justice, McCullough, and White 2011a; McCullough et al. 2011). The North Fork had the highest percentages of surface fine sediment out of the five sites sampled (Table 21). Fine sediment was highest at the mouth, near where it joins the main stem of Catherine Creek.

South Fork

Erosion hazard along the South Fork is mostly severe with some severe ratings (NRCS 2009).

Although the North Fork has higher erosion hazard ratings than the South Fork, the South Fork is considered to contribute more sediment to the Catherine Creek system (Platt 2011; Lovatt 2011). This tributary is grazed from the mouth to the headwaters, experiences some logging, and contains many roads. Grazing and logging practices are the same as those described above. The largest sediment contribution in the South Fork comes from roads (Lovatt 2011). More localized issues include a head wall that, as part of a granitic system, breaks out occasionally and adds sediment to Catherine Creek. There is also an irrigation ditch at the headwaters of South Fork that diverts water to the Powder drainage and causes large problems in the form of debris flows and slope failures (Platt 2011). Finally, there was a large fire within this drainage recently that has been causing sediment concerns.

Surface sediment size sampling was conducted in the upper reaches of the South Fork of Catherine Creek during summer 2010 (Justice, McCullough, and White 2011a; McCullough et al. 2011). The South Fork had the lowest percentages of surface fine sediment out of the five sites sampled (Table 21). The relatively low rates of fine sediment may have been a result of sampling high in the watershed, where there was less cumulative sediment input.

The Forest Service is planning to carry out a restoration project in summer of 2011 and 2012 along 4.3 miles of South Fork Catherine Creek (USFS 2009; Platt 2011). A stream bottom road would be removed and woody species planted, among other things, to improve fish habitat. Expected benefits of the project include improved floodplain connectivity; increased quantity and quality of pools; fish cover and habitat complexity; and increased pieces of large woody debris in streams. The project would presumably help control sediment input as well.

5.3 Nutrients

The DO applicable standard is based on Catherine Creek providing habitat for cold-water aquatic life at all times of the year and for salmonid spawning and egg incubation during the fall, winter and spring months from October 1 through June 30 (ODEQ 2000). For periods identified as providing for salmonid spawning and egg incubation, the applicable water column standard is 95 percent of saturation. At 50°F (bull trout temperature criteria), 95 percent saturation converts to 9.7 ppm and at 55.4°F (salmonid spawning temperature criteria) it converts to 9.1 ppm. For periods other than during spawning and egg incubation, standards are specified as 8.0 ppm as a minimum 30-day average, 6.5 ppm as an absolute minimum (Table 26). For pH, targets have been set to 8.7 as an absolute maximum and 6.5 as an absolute minimum. The pH target of 8.7 for Catherine Creek is more stringent than the maximum pH of 9.0 allowed by the Oregon State standard and the DO target of 6.5 ppm is more stringent than the minimum of 6.0 ppm allowed by the standard, which provides for a margin of safety.

Table 26. DO standards for Catherine Creek.

Time period	ODEQ 1998 Standard
Oct 1 – Jun 30 (spawning & egg incubation)	95 percent saturation Mouth to CCACF (salmonid temp criteria) = 9.1 ppm CCACF to N & S Forks (bull trout temp criteria) = 9.7 ppm
Jul 1 – Sep 30	8.0 ppm minimum 30-day avg 6.5 ppm absolute minimum

The Grande Ronde River is listed for pH and DO violations due to excessive algal (i.e., periphyton) growth. Water quality modeling using the periphyton model PCM (ODEQ 2000) indicated that the pH standard is more difficult to achieve in Catherine Creek than the DO standard. Because of this, allocations which result in the pH target of 8.7 being met are calculated by the model to result in DO concentrations significantly greater than 6.5 ppm. Such allocations will result in the 30-day average standard of 8.0 ppm being met in all reaches.

Since not all nitrogen and phosphorus in a stream is available for algal growth, nutrient load allocations are provided in terms of the reactive inorganic forms. For nitrogen, this is the dissolved inorganic nitrogen (DIN), which includes ammonia, nitrite, and nitrate. For phosphorus, it is the dissolved orthophosphate (equivalent to soluble reactive phosphorus or SRP). Standards are provided for two sets of conditions (ODEQ 2000): 1) existing riparian conditions with associated high stream temperatures and solar radiation, and 2) site potential riparian conditions of reduced stream temperatures and solar radiation.

The nutrient load allocations presented in Table 27 are designed to achieve pH levels within the range 6.5 to 8.7 and DO concentrations greater than 6.5 ppm under each type of condition. Nutrient load allocations are in terms of percent reductions from current levels and apply to NPS pollution loads. Summer point source refers to the WWTP in Union.

There are two criteria for evaluating ammonia toxicity, chronic (based on a 4-day average occurring once in 3 years) and acute (based on an hourly average occurring once in 3 years). Ammonia toxicity can be calculated from pH and temperature. For a pH of 9.0 and a temperature of 77.0°F, the applicable total ammonia chronic standard (NH_4^+ plus NH_3) is 0.1 mg/L (0.0822 ppm as nitrogen) (ODEQ 2000). The 4-day average ammonia concentration may not exceed this concentration more than once every 3 years on the average. For the same pH and temperature combination, the total ammonia acute standard is 0.72 ppm (0.59 ppm as nitrogen). The 1-hour average ammonia concentration may not exceed this concentration more than once every 3 years on the average.

Table 27. Nutrient load allocations and corresponding loading capacities for Catherine Creek. (ODEQ 2000)

		Loading capacities (Water column concentrations as monthly medians)	
Mile points	**Nutrient load allocations**	**Dissolved Inorganic N ppm as N**	**Dissolved orthophosphate ppm as P**
Current riparian conditions			
Mouth to CCACF	60 percent (60 percent reduction in NPS loads plus summer point source removal)	0.026	0.006
Site potential riparian conditions			
Mouth to CCACF	50 percent (50 percent reduction in NPS loads plus summer point source removal)	0.033	0.007

Continuous monitoring data collected in 1991 and 1992 in the Grande Ronde River was the best data available for computing acute and chronic ammonia toxicity levels (ODEQ 2000). During the summer months of July to September the acute criteria is the controlling factor. During these months, the pH in the Grande Ronde ranges from 7.0 to 10.0. The high pH values result in very low acute toxicity levels. From the continuous data, hourly acute toxic levels were calculated as low as 0.25 ppm. Average daily chronic levels were calculated at 0.50 ppm. Keeping in mind the safety margin, ammonia levels below 0.2 ppm should be protective of the acute criteria during these months.

Catherine Creek experiences DO and pH water quality standards violations related to excessive algal growth (ODEQ 2000). The excessive growth is due to a number of factors including elevated nutrient concentrations, high water temperatures, excessive solar radiation, high width to depth ratios, and inadequate streamflow rates. This excessive periphyton activity causes large diel DO and pH fluctuations, which result in, DO standards violations at night and pH standards violations during the day.

Nutrients enter the system from both point and NPSs, with the non-point nutrient loads being functions of land use. The Grande Ronde Valley, where Catherine Creek is located, is comprised mostly of privately owned agricultural and urban lands. The town of Union WWTP is a significant point source for Catherine Creek and has been shown to be a major contributor to nutrient loads at the time TMDLs were established (ODEQ 2000). At that time, violations of standards for DO and pH were generally not seen above the treatment plant discharge but began to occur immediately below the discharge and continue all the way to the confluence with the Grande Ronde River.

Significant summer ammonia standard exceedances also occurred near the Union WWTP discharge (ODEQ 2000). However, away from the discharge no violations were observed in samples from 1991 to 1993, as shown in Figure 12. The exceedances were caused by high ammonia concentrations in the Union effluent coupled with very poor dilution in Catherine Creek. The poor dilution was due to lack of flow because of irrigation diversions. Even though the Union discharge was recorded at 0.47 cfs, which is small relative to many other treatment plants, it was the dominant source of nutrients to Catherine Creek. Not only was the chronic criteria of 0.082 ppm (as N) exceeded near the discharge, but the acute criteria of 0.6 ppm (as N) was also frequently exceeded. The recommended "No Discharge" allocation for summer months was expected to eliminate these violations.

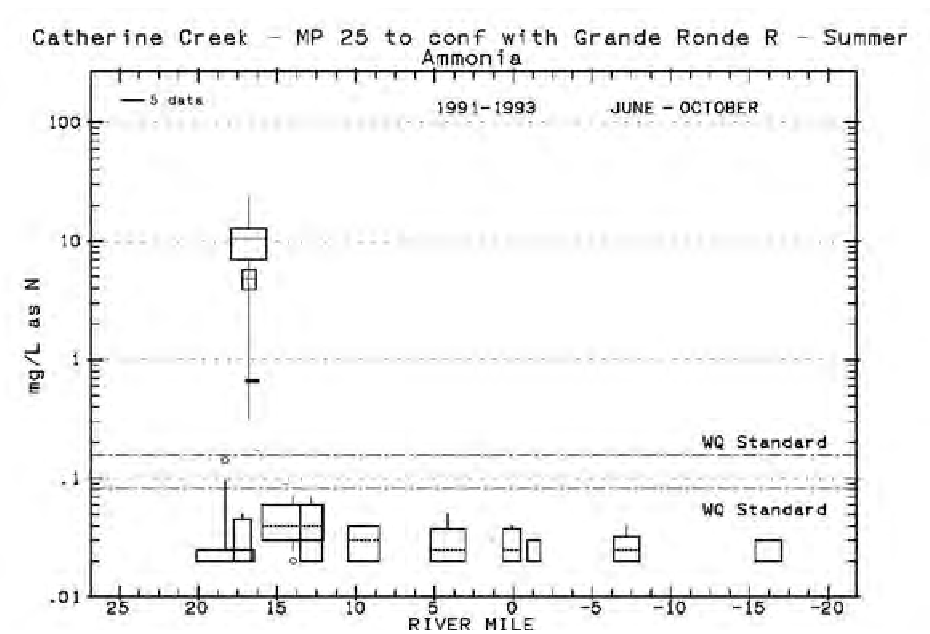

Figure 12. Catherine Creek observed Ammonia concentrations during the summer. Note that RM 0 in the graph is the confluence with Grande Ronde River, which places the WWTP at approximately RM 16 where ammonia exceeds ODEQ standards (ODEQ 2000).

Following the designation of nutrient standards by ODEQ in 1998, a new WWTP was built in 2001. The town of Union stopped discharging effluent during low flows from approximately July 1 to September 30 (Ramondo 2011) per the "No Discharge" allocation for summer months recommended in the TMDLs (ODEQ 2000). The current discharge schedule is from October 1 to approximately June 1 to June 15. Certain specifications must be met, however, in order for the plant to discharge effluent: 1) Catherine Creek flows must by at least 17 cfs; 2) stream temperatures cannot exceed 57.2^{0}F; and 3) effluent temperatures must be below 55.3^{0}F. These specifications are not always met during the allowable period. For example, in 2010 the creek temperatures and flows did not meet criteria required for the plant to discharge into the creek until November (Ramondo 2011). The plant also has a variance, in which it is allowed to discharge from June 16 to June 30 if certain conditions are met; however, Union WWTP has rarely or never discharged during this period.

Currently, effluent is held in storage ponds at the golf course during periods of non-discharge, and the golf course uses the effluent to irrigate. Because the pond nears holding capacity during the summer, and because WWTP meets requirements on effluent standards, the plant may request partial releases be allowed during summer months with issuance of the next permit (Ramondo 2011).

The Union WWTP operator informally collected water quality data from effluent and from a sample site in Catherine Creek, about 15 feet above the discharge point (Ramondo 2011). He found that total suspended solids and E. coli bacteria levels were lower in the effluent than in the stream water, although sampling was carried out in the spring, when runoff into the creek from adjacent lands may have been relatively high.

Monitoring that has been conducted in Catherine Creek, including sampling for pH, DO, nitrogen, phosphorous, and bacteria, is discussed by reach below. No specific information was found regarding these parameters above RM 43 within reach 4.

5.3.1 Reach 1

In 1997, water quality data were collected by the USWCD. These data were collected and analyzed prior to the current ODEQ standards established in 1998 (ODEQ 2000); therefore, standards for this data set were slightly different. Water chemistry and nutrient samples were collected at four sites on Catherine Creek from May through October (Ballard 1999). Samples collected at approximately RM 21.5 in reach 1 (i.e., Highway 237) did not meet ODEQ DO minimum standards in any month, and pH levels were extremely high in August, exceeding the upper pH limit of 9 set at that time (Figure 13). Nitrogen levels did not exceed ODEQ standards during 1997 at the sampling site in reach 1 but phosphorous standards were exceeded in July and August (Figure 14). Ammonia did not reach chronic toxicity levels (Figure 15) in reach 1, nor were bacteria (i.e., E. coli) levels in excess of ODEQ standards, although they were elevated in July relative to other months (Figure 16).

There was a continuous problem with DO throughout the summer of 1997 at the reach 1 site. The combination of low levels of DO, pH levels greater than 9.0, warm stream temperatures, and high levels of nutrients (nitrogen and phosphorus) often creates excessive algae growth (Ballard 1999). In addition to low DO levels, the 1997 data set showed pH levels around 10 in July with high phosphorus levels. Algae growth is a parameter also included on the ODEQ Section 303(d) list for lower Catherine Creek.

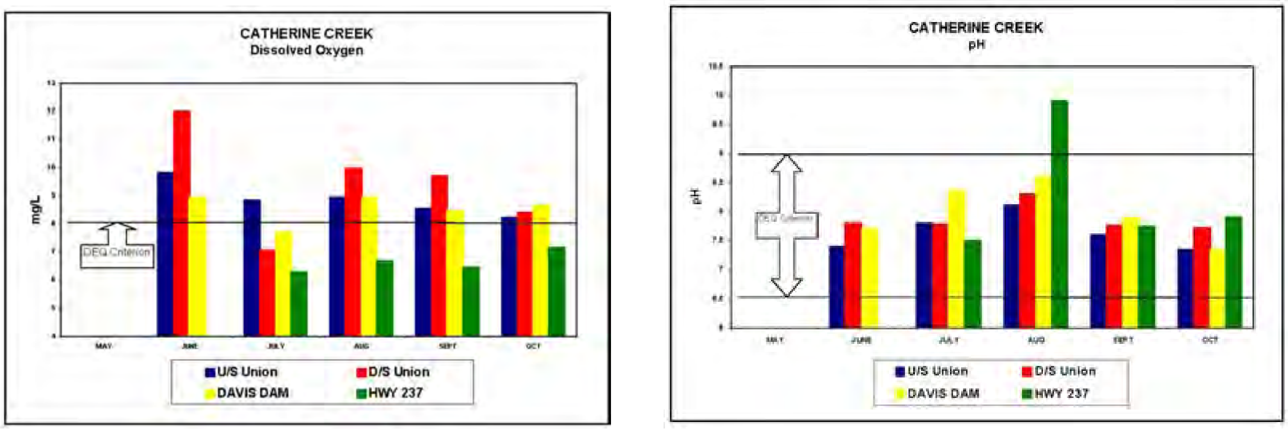

Figure 13. **DO (left) and pH (right) levels from four sites in Catherine Creek, May through October 1997 (Ballard 1999).**

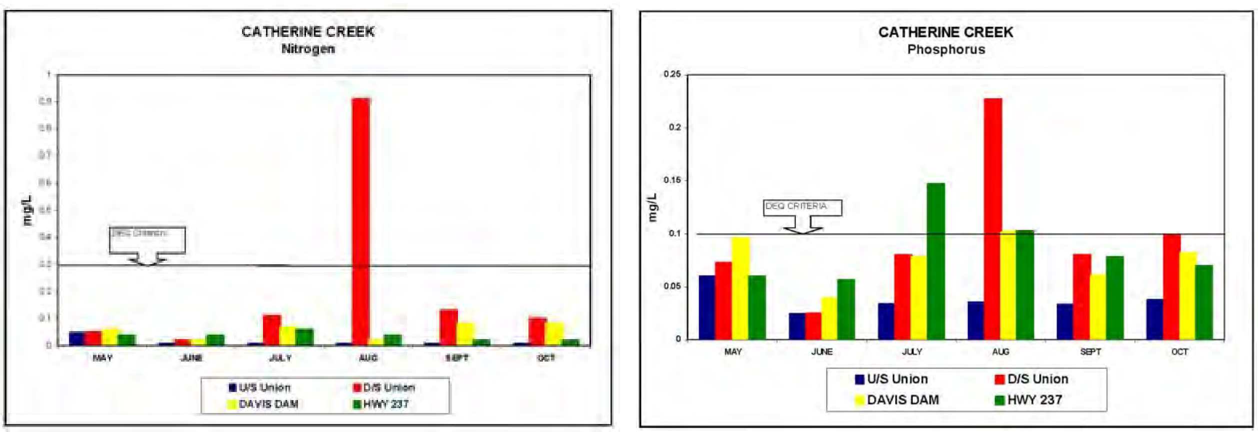

Figure 14. **Nitrogen (left) and phosphorous (right) levels from four sites in Catherine Creek, May through October 1997 (Ballard 1999).**

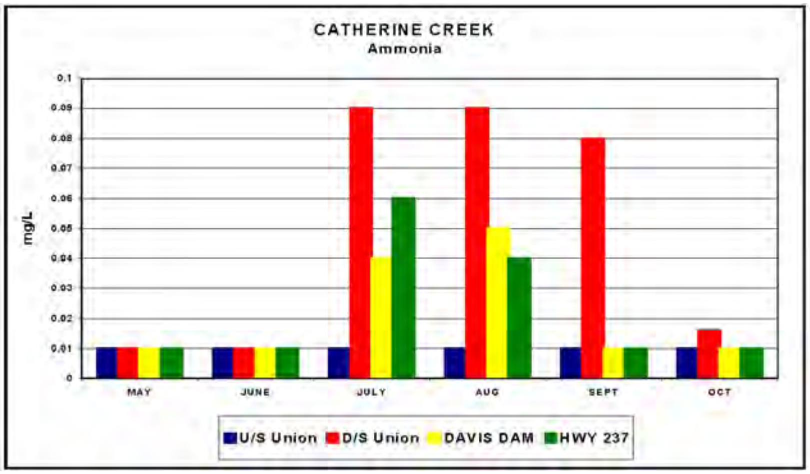

Figure 15. Ammonia levels at four sites in Catherine Creek, May through October 1997 (Ballard 1999).

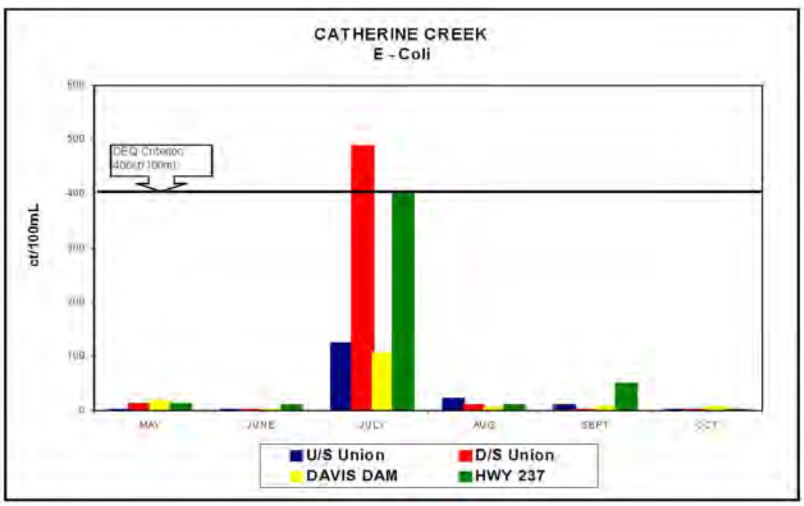

Figure 16. Bacteria levels at four sites in Catherine Creek, May through October 1997 (Ballard 1999).

USWCD collected sets of grab samples at three sites on Catherine Creek over 30-day periods in August from 2004 through 2006 (Miles nd). The three sites were chosen to provide representative data on long-term nutrient loading patterns in relation to land uses, point sources, and NPSs. The site at RM 7 in reach 1 was selected to assess the cumulative effect of intensive agricultural land uses in the Grande Ronde Valley.

Figures 17 and 18 show DIN and orthophosphate results, respectively, from these samples along with three previous years of data (Miles nd). At RM 7, in reach 1, DIN 30-day means were 0.013 ppm as N for 2004, 0.010 ppm for 2005, and 0.026 ppm for 2006, all less than the loading capacity of 0.033 ppm (0.026 ppm) as N for this reach. However, the 30-day means of orthophosphate observations were 17 as P for 2004, 0.014 (114?) ppm for 2005, and 0.125 ppm for 2006 compared to the loading capacity of 6 μg/L set for this reach. These results do not lead to the conclusion that there was a reduction in NPS loading between RM 38 and RM 7 given the high orthophosphate levels of the 2005 and 2006 samples. The evident decrease in DIN levels was most likely due to excessive algal and aquatic weed growth consuming nitrogen.

Samples from these sites were also analyzed for the E. coli bacteria. Results are shown in Figure 19 for sites at RM 7 from 2004 to 2006 and at RM 38 and RM 43 from 2001 to 2006. Samples were collected in August, when streamflows were at their lowest, providing minimal dilution for any contamination. At RM 7 in reach 1 of Catherine Creek, the state chronic standard – which requires that a 30-day log mean for a minimum of five samples cannot exceed 126 organisms per 100 mL – was violated in 2005.

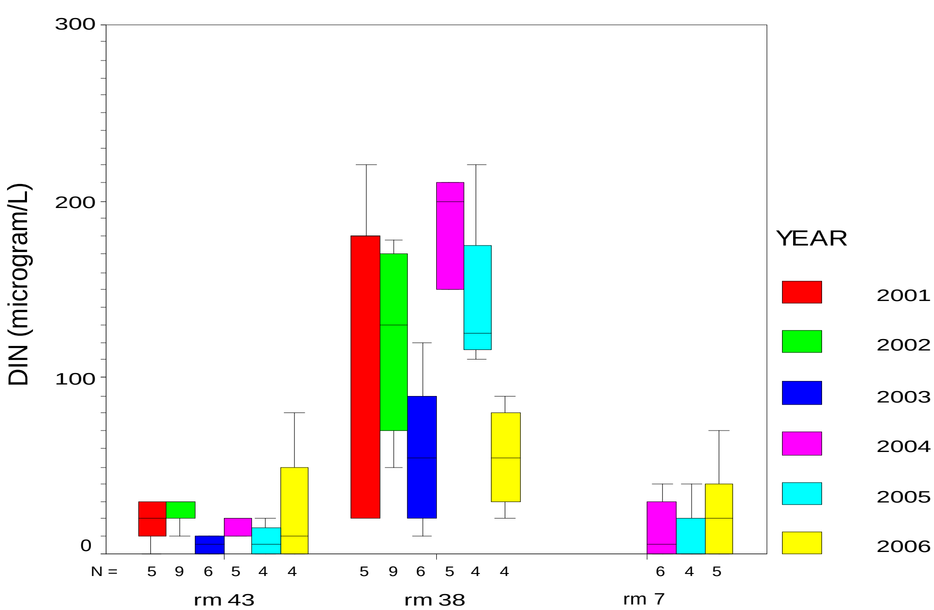

Figure 17. Catherine Creek DIN levels at RM 7, 38, and 43 from 2001 to 2006 (Miles nd; USWCD nd).

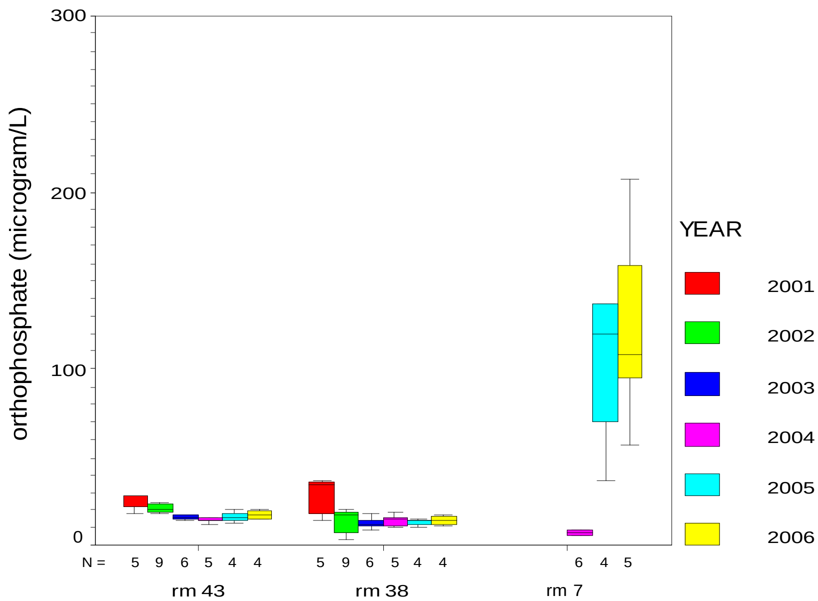

Figure 18. Catherine Creek orthosphosphate levels at RM 7, 38, and 43 from 2001 to 2006 (Miles nd; USWCD nd).

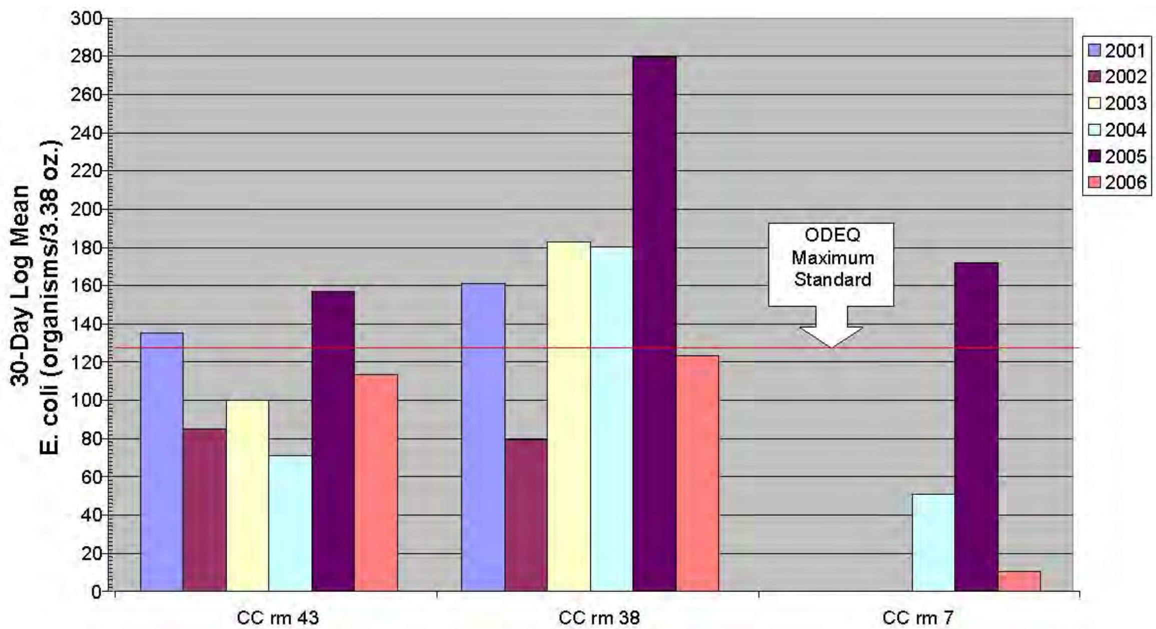

Figure 19. Catherine Creek E. coli bacteria levels at RM 7 from 2004 to 2006, and at RM 38 and 43 from 2001 to 2006 (Milds nd; USWCD nd).

5.3.2 Reach 2

ODEQ's web database (ODEQ 2007) provides water quality data collected from various times for Catherine Creek. Parameters collected included DO, pH, N, P, and ammonia. Results for monitoring sites within reach 1 are shown in Tables 27 and 28. Typically, anywhere from one to five measurements were taken per month. Less often, data were collected at a site continuously over 1 to 3 days. Therefore, values shown in the table may be an average of a few to numerous values collected. From 1961 to 1968, samples were collected every year at the confluence of Catherine Creek and Grande Ronde River, but during various months in each year.

Within reach 2, ODEQ DO standards (95 percent saturation and 9.1 ppm for October 1 to June 30) were exceeded at least once in March, May, June, and October in the 1960s (Table 27). Sampling was only done during summer months in the 1990s. From July 1 to September 30, levels fell below the absolute minimum of 6.5 ppm once, but the 30-day average standard of 8.0 ppm could have potentially been exceeded since many measurements were below this value (Tables 27 and 28). The pH values exceeded the standard of 8.7 at one location in September of 1992 and 1993. Nutrient levels of DIN and orthophosphate exceeded the ODEQ standards of 0.026 ppm and 0.006 ppm, respectively, in all samples. Ammonia toxicity standards were never exceeded in reach 2 among these samples.

Based on ODEQ water quality data collected at sampling sites within reach 2 in the early 90s, water quality problems persisted in Catherine Creek all the way downstream to the Grande Ronde River (Bach 1995). These problems likely resulted from a combination of water impoundment and withdrawal and the nutrient load resulting from both treatment plant and downstream nonpoint source contributions. Algae growth resulting from the nutrient load was also a major problem. At the upstream end of reach 2 (approximately RM 35.3), acute pH and high DO problems were observed. At Wilkerson Lane (approximately RM 32.0), chronic pH violations were observed. At Godley Lane (approximately RM 26.0), chronic violations for both pH and high DO were noted. At the confluence of Catherine Creek with Old Grande Ronde River channel, chronic low DO problems were observed.

In 1997, water quality data were collected by USWCD. These data were collected and analyzed prior to the current ODEQ standards established in 1998 (ODEQ 2000); therefore, standards for this data set were slightly different. Water chemistry and nutrient samples were collected at four sites on Catherine Creek from May through October (Ballard 1999). Samples collected at Davis Dam in reach 2 did not meet the ODEQ minimum DO standards in July, although pH levels never exceeded standards (Figure 13). Nitrogen levels did not exceed ODEQ standards during 1997 at the sampling site in reach 2, but orthophosphate standards were exceeded in August (Figure 14). Neither ammonia nor bacteria were at levels in excess of ODEQ standards (Figures 15 and 16).

USWCD collected samples from Grande Ronde River tributaries during peak runoff and irrigation return flows to assess agriculture's contribution to water quality problems circa 2004 to 2006 (Miles nd). This effort was also intended to evaluate effects of implementing the WQMP. Results indicated that certain tributaries, including Mill Creek that joins Catherine Creek in reach 2, were still receiving significant NPS loads of nutrients and bacteria from surrounding agricultural land uses.

Table 28. ODEQ DO, pH, DIN, orthophosphate, and ammonia data at the confluence of Catherine Creek and Old Grande Ronde River located at the border between reaches 1 and 2 (ODEQ 2007).

Year	Avg. Field DO ppm (percent) by month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1960									9.8 (114)	8.5 (89)	11.2 (99)	12.3 (103)
1961		11 (95)	8.6 (102)	9.8 (95)	8.6 (93)	4.9 (66)	7.5 (101)					
1962							9.1 (126)			7.7 (75)		
1963	12.4 (101)			10.4 (95)			8.0 (102)					
1964	12.2 (101)					9.3 (94)		8.3 (103)			11.5 (109)	
1965			10.8 (101)		9.3 (103)			8.4 (104)				
1966			10.8 (93)						8.7 (103)			
1967		11 (86)						8.2 (106)				12.4 (97)
1968				10.8 (101)				8.5 (117)				
1991							8.3 (105)		6.0 (72)			
Year	**Avg. Field pH by month**											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1960									7.5	7.5	7.5	7.3
1961		7.5	7.3	7.4	7.2	7.2	8.4					
1962							8.2			7.3		
1963	8			7.4			7.8					
1964	7.4					7.1		8.4			7.7	
1965			7.6		8.4			8.4				
1966			8.0						8.3			
1967		7.5						7.3				7.5
1968				7.2				8.3				
1991							7.8		7.7			
Year	**Avg. DIN ppm by month**											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1966									0.54			
1967		0.24						0.23				0.4
1968				0.14				0.31				
1991							0.09		0.02			
Year	**Avg. Orthophosphate as P ppm by month**											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1991							0.06		0.07			

Year	Avg. Field DO ppm (percent) by month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Year	Avg. Ammonia ppm by month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1966									0.037			
1967		0.001						0.002				0.001
1968				0.001				0.035				
1991							0.001		0.001			

Table 29. ODEQ DO, pH, DIN, and orthophosphate data in reach 2 (ODEQ 2007).

Station Location	Date	Avg DO mg/L (percent sat)	Avg pH	Avg DIN mg/L	Avg Orthophosphate mg/L	Ammonia mg/L
Gekeler Rd	Jun 1991	9.7 (105)	8.0	0.06	0.025	0.001
Godley Rd	Jul 1991	8.1 (103)	7.9	0.08	0.06	0.002
	Sep 1991	10.2 (122)	8.7	0.04	0.04	0.005
	Sep 1993	11.1 (116)	9.4	0.03	0.07	0.009
Wilkerson Lane	Jun 1991	10.7 (114)	8.0	0.06	0.03	0.001
	Jul 1991	7.8 (97)	7.7	0.13	0.07	0.001
	Sep 1991	9.2 (119)	8.6	0.05	0.08	0.006
	Sep 1992	9.7 (102)	8.6	0.04	0.08	0.003
Hwy 203 & Hawkins	Jul 1991	7.8 (95)	7.8	0.13	0.078	0.002
	Sep 1991	10.4 (127)	8.4	0.05	0.074	0.003
	Sep 1992	12.7 (140)	9.0	0.04	0.07	0.004
Miller Rd.	Jul 1991	9.3 (109)	8.0	0.12	0.08	0.002
	Sep 1991	8.5 (93)	7.9	0.28	0.12	0.002
	Sep 1992	7.3 (100)	8.0	0.19	0.11	0.004
	Aug 1993	7.1 (86)	7.8	0.39	0.1	0.002
	Sep 1993	8.7 (97)	8.0	0.4	0.1	0.002
	Oct 1993	10.3 (101)	7.8	-	-	-

5.3.3 Reach 3

ODEQ's web database (ODEQ 2007) provides water quality data collected during various months from 1991 to 1993 for Catherine Creek. Parameters included DO, pH, N, P, and ammonia. Results for monitoring sites within reach 3 are shown in Table 30. Typically, anywhere from one to five measurements were taken per month. Less often, data were collected at a site continuously over 1 to 3 days. Therefore, values shown in the table may be an average of a few to numerous values collected.

Within reach 3, all but 1 sample taken at the Union WWTP outfall fell below the absolute minimum of 6.5 mg/L for DO and the sample site 100 feet downstream of the wastewater plant may have violated the 30-day average standard of 8.0 mg/L (Table 30). At the time of sampling, the WWTP was still discharging effluent into Catherine Creek. For all other samples collected between 1991 and 1993 in reach 3, DO was above 8.0 mg/L and the pH standards were never exceeded. The DIN standard of 0.026 mg/L and the orthophosphate standard of 0.006 mg/L were violated in all cases. One exception was from a sample collected above the WWTP at Hwy. 203 east of Union in which DIN detection was 0.020 mg/L. Ammonia exceeded the chronic toxicity standard of 0.082 mg/L as N in three samples taken in June and September at the Union WWTP outfall.

Based on ODEQ data from the early 1990s examining pH, DO, and ammonia toxicity, Bach (1995) reported that a sampling site bordering on reach 3 and 4 (approximately RM 40.8 just east of Union) showed chronic pH violations (>8.5 but <9.0). No violations for the three variables were detected at the 5th Street site in the town of Union (RM 39.7), just above the WWTP discharge. A site just below the treatment plant discharge (RM 39.3) showed chronic ammonia toxicity due to the plant discharge.

Table 30. ODEQ DO, pH, DIN, orthophosphate, and ammonia data in reach 3.

Station Location	Date	Avg DO mg/L (percent sat)	Avg pH	Avg DIN mg/L	Avg Orthophosphate mg/L	Ammonia mg/L
At Union WWTP outfall	Jun 1991	6.0 (70)	7.3	13.2	2.3	0.094
	Jul 1991	5.7 (61)	7.4	5.7	2.2	0.014
	Sep 1991	4.3 (43)	7.4	11.3	3.7	0.061
	Sep 1992	6.8 (74)	7.4	12.8	3.2	0.098
	Sep 1993	3.8 (37)	7.4	19.1	-	0.113
100 feet downstream of Union WWTP	Sep 1993	7.7 (86)	8.6	5.15	-	0.068
0.25 mi downstream of Union WWTP	Oct 1991	8.6 (84)	7.5	-	-	-
	Sep 1993	8.4 (96)	7.5	0.99		0.008
	Oct 1993	9.8 (96)	7.5	-	-	-
0.5 mi downstream of Union WWTP	Aug 1993	10.9 (135)	8.6	0.73	0.18	0.023
5th St in Union	Sep 1993	9.1 (101)	7.9	0.04	-	0.001
	Oct 1993	10.6 (106)	7.7	-	-	-
Hwy 203 (E of Union	Jun 1991	10.7 (111)	8.2	0.05	0.012	0.001
	Jul 1991	8.5 (107)	7.8	0.03	0.034	0.001
	Sep 1991	9.2 (98)	7.7	0.095	0.15	0.002
	Aug 1992	8.1 (93)	7.9	0.03	0.03	0.001
	Sep 1992	9.9 (102)	7.9	0.03	0.02	0.001
	Aug 1993	8.2 (101)	8.0	0.04	0.02	0.001
	Sep 1993	9.6 (103)	8.1	0.02	0.02	0.001

In 1997, water quality data were collected by the USWCD. These data were collected and analyzed prior to the current ODEQ standards established in 1998 (ODEQ 2000); therefore, standards for this data set were slightly different. Water chemistry and nutrient samples were collected at four sites on Catherine Creek from May through October (Ballard 1999). Samples collected downstream and upstream of Union (both presumed to be in reach 3) were always within ODEQ water quality standards at the upstream site (Figures 13 to 16). The downstream site, however, violated ODEQ standards for DO and bacteria in July and exceeded standards for nitrogen, phosphorus, and ammonia toxicity in

July and August of 1997. Results suggested that the town of Union was a source of excess nutrients to the stream. At the time, the WWTP was still discharging into Catherine Creek and likely contributed to the violations in water quality downstream of town.

Results of continuous monitoring studies by USWCD in 2002 at RM 38 are shown in Figure 20 (Miles nd). There were large diel fluctuations in temperature, pH and DO with levels very near violations of water quality standards due to considerable plant and algae activity.

USWCD collected sets of grab samples at three sites on Catherine Creek over 30-day periods in August from 2004 through 2006 (Miles nd). In 2001, grab samples were collected at two sites (USWCD nd). Sites were chosen to provide representative data on long-term nutrient loading patterns in relation to land uses, point sources, and NPSs. The site at RM 38 in reach 3 was selected to represent a transition between urban land uses upstream and agricultural uses downstream. It was also important that this site and RM 43 in reach 4 bracketed the section of Catherine Creek that received any discharge from the town of Union WWTP. Previous monitoring showed extreme and varied concentrations at RM 38 when compared to values at RM 43.

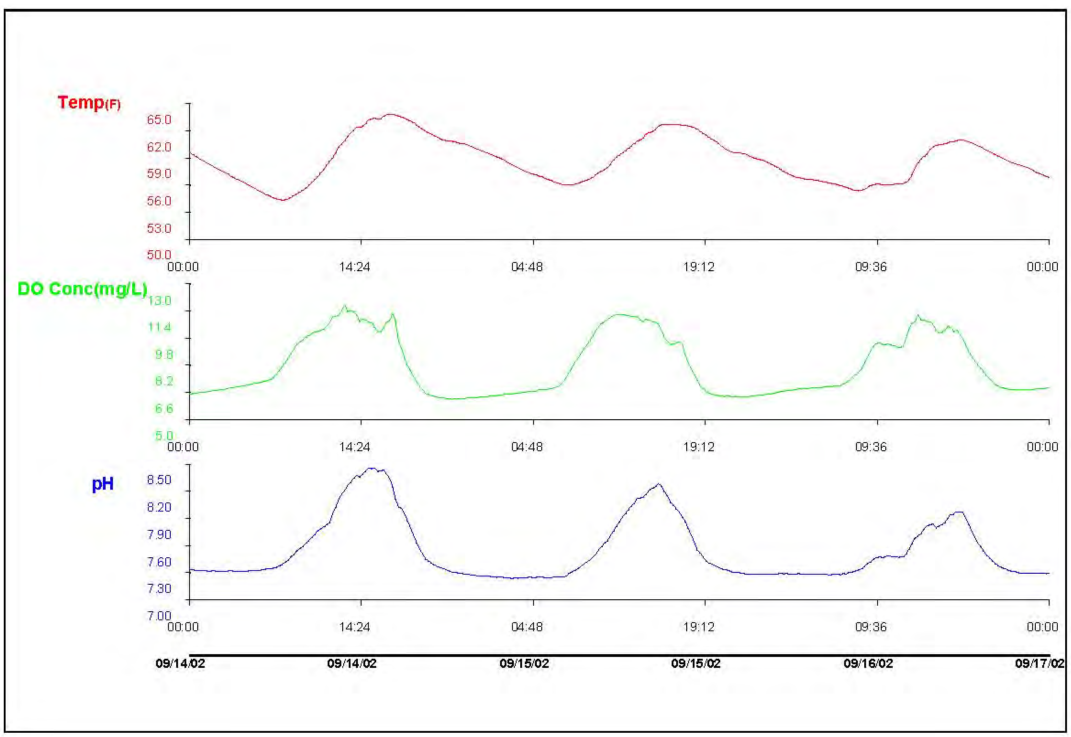

Figure 20. Catherine Creek continuous monitoring for temperature, DO, and pH at RM 38, September 2002.

At RM 38 in reach 3, DIN 30-day means were 188 μg/L as N for 2004, 145 μg/L for 2005, and 55 μg/L for 2006 as shown in Figure 17. All of these values were greater than the loading capacity of 33 μg/L (26 μg/L?) as N for this reach (Miles nd). In 2001, the 30-day median was 180 μg/L as N, which was greater than the loading capacity of 26 μg/L as N (USWCD nd). Figure 18 shows the 30-day mean of orthophosphate observations at RM 38. Levels were 35 μg/L as P for 2001 (USWCD nd), 16 μg/L as P for 2004, 13 μg/L for 2005, and 113 μg/L for 2006, all of which violated the loading capacity of 6 μg/L set for this reach (Miles nd). The sampling site at RM 38 is downstream of the town of Union, including the treated wastewater outfall. Union's WWTP operator maintained there were no discharges to the stream during the sampling periods (Miles nd; USWCD nd).

Previous monitoring in 1999, when grab samples for June through October were collected, also resulted in high nutrient levels at this site (USWCD nd). DIN ranged from 40 to 1340 μg/L as N while orthophosphate ranged from 16 to 265 μg/L as P.

Ammonia toxicity measured at RM 38 in 2001 did not exceed chronic standards (i.e., at 25 °C and at pH 9.0, a 4-day average ammonia concentration may not exceed 0.0822 mg/L as N more than once every 3 years) or the total ammonia acute standard (0.59 mg/L as N) (USWCD nd). Sampling in 1999, however, indicated a potential violation of the chronic standard, which ranged from 0.03 to 0.36 as shown in Figure 21. This was most likely due to high ammonia concentration of the effluent from the Union WWTP and poor dilution in the stream. During 1999, the plant was still discharging wastewater in low flow periods. Although ammonia toxicity sampling before and after discharge was discontinued during summer months is limited, comparisons between 1999 and 2001 appear to indicate that ammonia toxicity problems were improved.

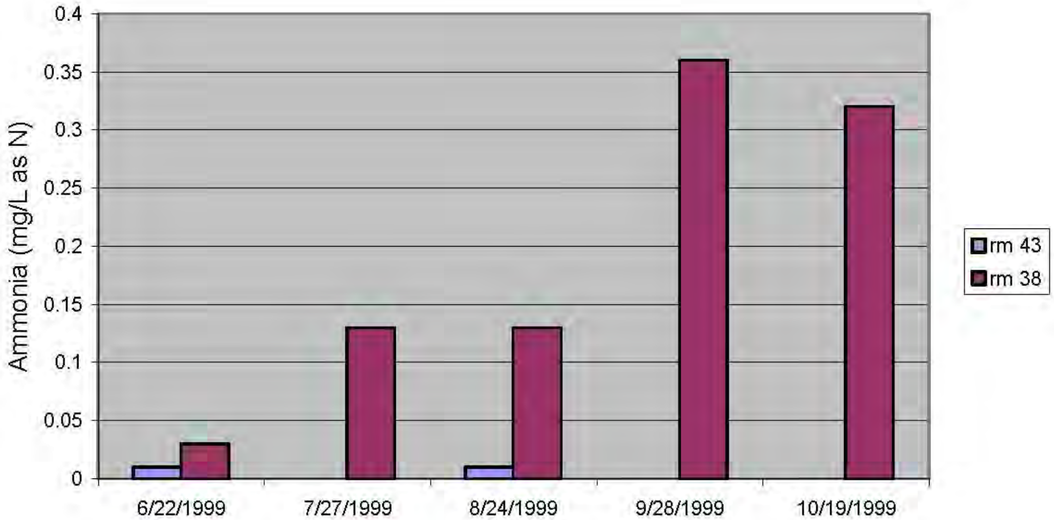

Figure 21. Catherine Creek ammonia levels at RM 43 and 38, June to October 1999.

Bacteria counts at RM 38 violated the state acute standard in 2001, 2003, 2004, and 2005 (Figure 19).

The excessive nutrient levels and E. coli bacteria counts detected at RM 38 in Catherine Creek as compared to upstream (RM 43 in reach 4) from samples collected between 2001 and 2006 suggested that the 60 percent reduction in NPS loads (ODEQ nutrient loading allocations) had not been achieved. Since no discharge from Union's wastewater treatment plant occurred during the sampling period, results indicated that the urban land use area that the stream flows through is a significant NPS of nutrient and bacteria loading.

5.3.4 Reach 4

Results of continuous monitoring studies by USWCD in 2002 at RM 43 are shown in the Figure 22 (Miles nd). As expected, given the high nutrient levels of samples from the RM 43 site and visual observation of abundant algae, pH and DO levels fluctuate significantly. However, these fluctuations were not as pronounced as those documented at RM 38 (Figure 20).

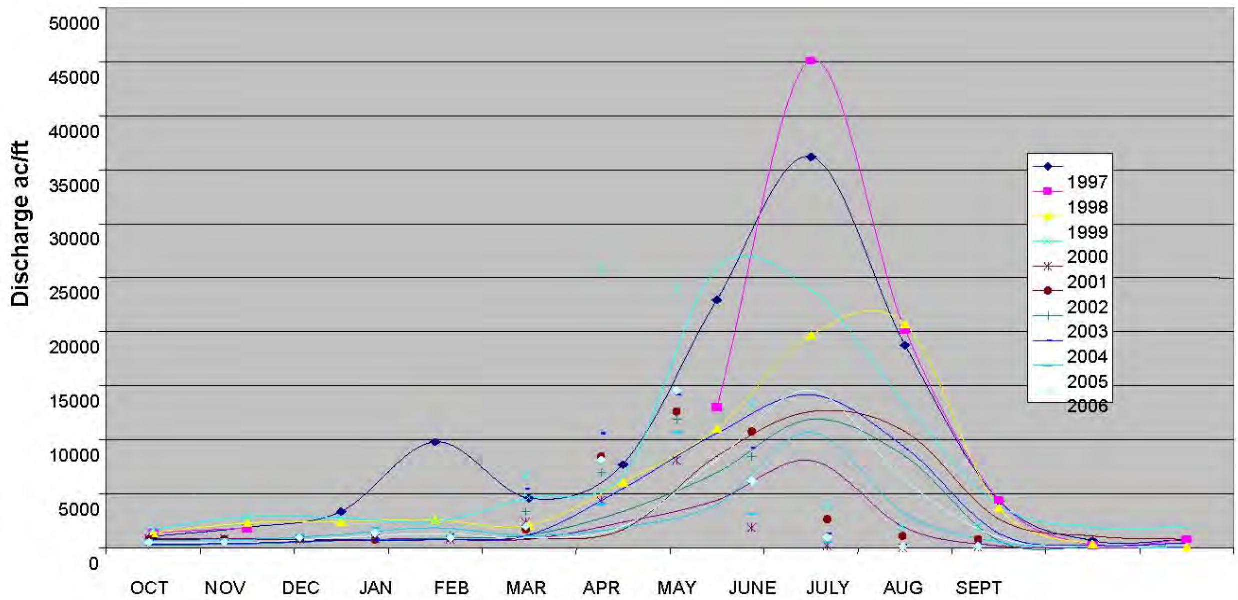

Figure 22. Catherine Creek monthly discharge at 10th Street Bridge in Union for water years 1997 to 2006 (Miles nd).

USWCD collected sets of grab samples at three sites on Catherine Creek over 30-day periods in August from 2004 through 2006 (Miles nd). In 2001, grab samples were collected at 2 sites (USWCD nd). Sites were chosen to provide representative data on long-term nutrient loading patterns in relation to land uses, point sources, and NPSs. The site at RM 43 in reach 4 was selected to represent a transition between forestry and grazing land uses upstream and urban land uses downstream. This site is also located near the upper boundary of the ODEQ Section 303(d) list for most parameters (the CCACF at RM 42.5). It was also important that this site and RM 38 in reach 3 bracketed the section of Catherine Creek that received any discharge from the town of Union WWTP. Previous monitoring showed extreme and varied concentrations at RM 38 when compared to values at RM 43.

At RM 43 in reach 4, DIN 30-day means were 16 μg/L as N for 2004, <10 μg/L for 2005, and 26 μg/L for 2006 as shown in Figure 17. All of these values were less than the loading capacity of 33 μg/L (26 μg/L?) as N for this reach (Miles nd). In 2001, the 30-day median was 20 μg/L as N, which was less than the loading capacity of 32 μg/L (26 μg/L?) as N that DEQ has set for this reach (USWCD nd). Figure 18 shows the 30-day mean of orthophosphate observations at RM 38. Levels were 29 μg/L as P for 2001 (USWCD nd), 15 μg/L as P for 2004, 16 μg/L for 2005, and 17 μg/L for 2006, all of which violated the loading capacity of 6 μg/L set for this reach (Miles nd).

Similar results were found in previous monitoring conducted in 1999. In grab samples collected from June through October, DIN ranged from < 10 to 30 μg/L as N while orthophosphate ranged from 12 to 28 μg/L as P (USWCD nd).

Ammonia toxicity measured at RM 43 in 1999 (Figure 21) and 2001 did not exceed chronic standards (i.e., at 25 ^{o}C and at pH 9.0, a 4-day average ammonia concentration may not exceed 0.0822 mg/L as N more than once every 3 years) or the total ammonia acute standard (0.59 mg/L as N) (USWCD nd). Bacteria counts at RM 43 violated the state acute standard in 2001 and 2005 (Figure 19).

The DIN levels did not exceed ODEQ standards in any of the years USWCD sampled at RM 43. Orthophosphate levels did exceed standards, although results were less varied and generally lower than levels detected downstream. Exceedences in orthophosphate still suggested that the predominant land uses of forestry and grazing upstream of this site had not achieved the 60 percent reductions of NPS loads called for in the TMDL (ODEQ 2000) in order to meet water quality standards for pH and DO. The low DIN levels while orthophosphate levels remained high could be the result of algal growth being nitrogen limited in this reach (Miles nd).

Bach (1995) reported that there were no violations of either pH or DO standards for a sampling site in reach 4 (approximately RM 41.5) based on ODEQ data since 1989.

5.4 Flow and Riparian Conditions

Flow and habitat modification are parameters included on Oregon's 1998 Section 303(d) list for violating water quality standards on Catherine Creek. Flow modification is not the direct result of a pollutant load, although decreased flow does affect beneficial uses (ODEQ 2000). Loading capacities and allocations are not established; however, improved flow is necessary to adequately address water quality standards and habitat below the town of Union on Catherine Creek. Improving in-stream flow is an identified goal in the TMDL and is identified as a high priority in the Water Quality Management Plan (ODEQ 2000). Habitat modification is also not the direct result of a pollutant although it does affect beneficial uses. Because a pollutant is not the cause, the concept of establishing a loading capacity and allocations does not apply. There is the expectation, however, that the improvements to riparian vegetation that will be necessary to meet temperature surrogates will also lead to improvements in habitat.

Annual stream discharge patterns at 10 historic USGS gauge sites in the Grande Ronde Basin all show peak flows occurring in the spring (April to June) and declining flows through summer and early fall (Huntington 1994). Discharge at most sites remains low through winter, before rising again in spring. Peak discharge and flow volume patterns in Catherine Creek are collected by the OWRD at a flow gauging station near the 10th Street

Bridge in Union (Miles nd). Figure 23 shows a hydrograph of monthly Catherine Creek discharge at RM 39 before it enters the valley for the water years 1997 through 2006.

Water quality standard violations occur from June to September when flows in Catherine Creek are lowest. Water withdrawals for irrigation reduce flows starting in June, with flow reduced by about 20 percent (Nowak 2004). In mid-July, flow reduction is about 50 percent and by the 3rd week in July through the end of September, flow is reduced by 90 to 95 percent. Between mid-July and late September, irrigation demand often exceeds the water supply in Catherine Creek, reducing summer flows that are already naturally very low late season. This results in insufficient flows to support anadromous fish migration and to meet water quality standards (Huntington 1994; ODEQ 2000; Reclamation 2002).

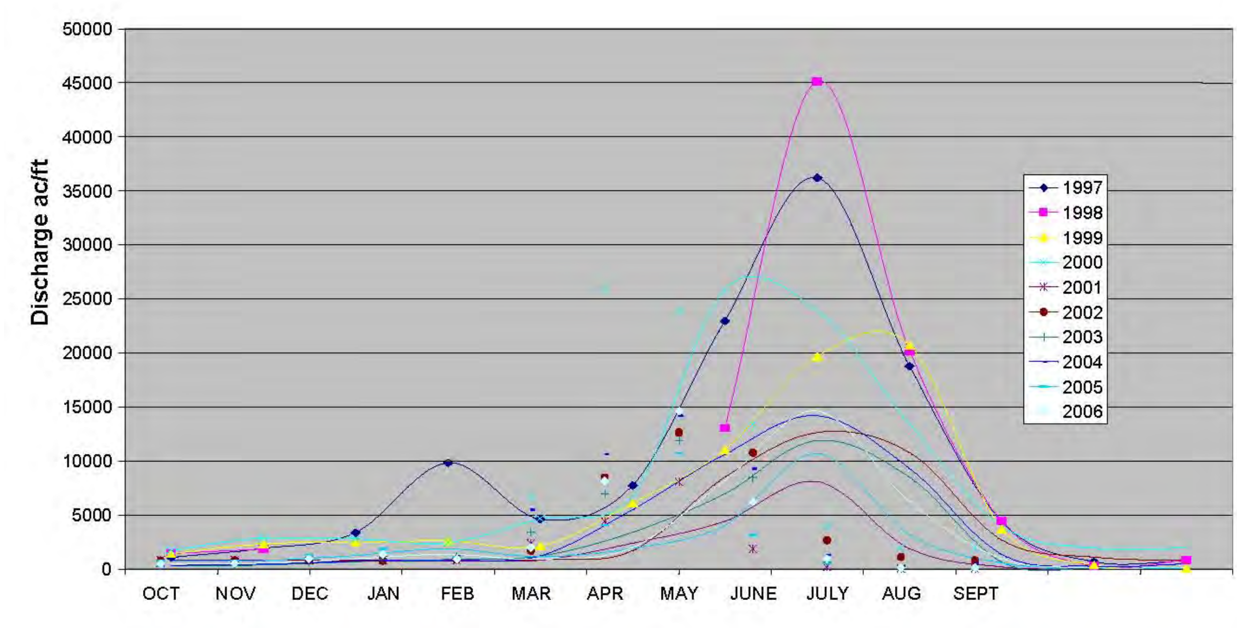

Figure 23. Catherine Creek monthly discharge at 10th Street Bridge in Union for water years 1997 to 2006 (Miles nd; USWCD nd).

There appears to be potential for installing wells to meet irrigation demands during critical periods, although there must be sources for supplemental recharge to replenish the aquifer (Reclamation 2002). More studies are needed to explore this alternative. The GRMWP is conducting preliminary feasibility studies at Hall Ranch in reach 6 (Kuchenbecker 2011). The potential for removing water from Catherine Creek during high flows, injecting that water into an aquifer for storage, and pumping the water back into the creek during low flows will be examined. The capacity of the aquifer to store additional water must be determined. If feasible, this project would not be implemented for some time due to the time and cost involved.

Riparian habitat degradation is considered a major problem in the subbasin (Nowak 2004). Improving the riparian condition of Catherine Creek will lead to improvements in water quality in general ((Nowak 2004; GRWQC 2000; Huntington 1994).

The Grande Ronde Valley bottom (i.e., reaches 1 and 2) has riparian vegetation types composed primarily of annual grasses (ODEQ 2000). However, in some cases where crop cultivation extends to the active channel or where grazing pressure is high, little if any riparian vegetation exists within the Valley bottom (Figure 24). In the upper reaches of Catherine Creek, black cottonwood/mixed conifer and alder communities were identified as the top 2 vegetation communities in providing shade for the creek (Kaufmann et al. 1985).

Riparian vegetation is especially sparse and provides little shade cover in lower Catherine Creek (Favrot et al. 2010). Low shade levels result from a combination of lack of streambank vegetation and/or wide stream channels (ODEQ 2000). Often, low shade levels result from lack of tall streambank vegetation. In many areas that do have tall streambank vegetation but low shade levels, channel widths are too great to effectively shade. Temperature monitoring of stream reaches on Catherine Creek within riparian fencing projects demonstrated that the improved vegetation vigor and density reduced thermal loading of the stream, which suggested a correlation of stream temperature to riparian vegetation's ability to shade the stream (Miles nd).

Figure 24. Grande Ronde River downstream of the Catherine Creek confluence, August 1999. (ODEQ 2000)

Huntington (1993) found that fish habitat conditions related to stream shading in Catherine Creek varied among three major channel types. On average, high gradient channels frequently had high levels of stream shading (mean=74 percent shade). Unconstrained low gradient reaches generally had low levels of stream shading (mean=50 percent). Constrained low gradient channels surveyed had high levels of shading (mean=69 percent). Huntington (1993) also developed reference conditions (RC) based on salmonid habitat requirements, which were used to compare existing habitat conditions. Habitat quality concerning shading along streams surveyed in the Catherine Creek subbasin was frequently below RC levels. Stream shade was below RC levels along 56 percent of miles surveyed.

Favrot et al. (2010) found that early migrant Chinook salmon occupying the high gradient reaches of Catherine Creek most frequently used boulders as cover; fine woody debris was most commonly used as cover in the low gradient reaches, despite cover not being readily available in any of the reaches. Clusters of tumbleweed (*Sisymbrium altissimum*) and American waterweed (*Elodea canadensis*) were commonly available and heavily used as cover in the low gradient reaches, but were not available at higher gradients. The riparian zone of both the high and low gradient reaches used by early migrants was primarily devoted to agriculture, indicating that riparian vegetation – which is ultimately the source of numerous types of cover – may be a limiting factor. In addition, reaches associated with agriculture and minimal riparian vegetation exhibited stream entrenchment, bank erosion, and reduced habitat complexity.

Plans were initiated by CRITFC in 2010 and 2011 to develop a map of potential natural vegetation (PNV) in the Catherine Creek basin (McCullough et al. 2011). The PNV map can provide information about the expected plant and tree community types that are likely to affect riparian shading, food web structure, and possibly streambank stability. This information can in turn help inform the range of possible historical or future riparian scenarios that will likely impact spring Chinook salmon populations in Catherine Creek.

6. Discussion

Most water quality problems in the Grande Ronde subbasin derive from past forestry, grazing and mining activities as well as current improperly managed livestock grazing, cumulative effects of timber harvest and road building, water withdrawals for irrigation, agricultural activities, industrial discharge, and urban and rural development (Nowak 2004). The landscape has been drastically altered by human activities since the mid-1800s due to large-scale disturbances to the riparian vegetation (ODEQ 2000). Riparian species size and composition have decreased from historic conditions (USFWS 2002). Hines (ODEQ 2000) determined that riparian populations of black cottonwood (*Populus trichocarpa*) along the Grande Ronde River declined in number, aerial extent, and average size (a loss of 45 percent, 82 percent, and 70 percent, respectively) from 1937 to 1987. Evidence suggested that changes in vegetative cover in the floodplains are a consequence of intense land use practices in the upper Grande Ronde River subbasin, interacting with such natural variations as climate and precipitation.

Much of the literature identifies degraded riparian conditions as one of the primary problems in the Upper Grande Ronde basin and in Catherine Creek (ODEQ 2000; Huntington 1994; Nowak 2004; NOAA Fisheries 2008). As such, many riparian functions have been historically compromised (USFWS 2002). Long-term degradation of riparian areas has reduced shade, which has led to chronic stream temperature problems (Huntington 1994). Solar radiation loading was determined to be the primary source of elevated stream temperatures in the Grande Ronde River (ODEQ 2000). ODEQ (2000) identified the following anthropogenic sources for elevated summertime stream temperatures in the Upper Grande Ronde subbasin:

1. Riparian vegetation disturbance reduces stream surface shading via decreased riparian vegetation height, width and/or density, thus increasing the amount of solar radiation reaching the stream surface,
2. Channel widening (increased width-to-depth ratios) increases the stream surface area exposed to solar radiation,
3. Reduced summertime saturated riparian soils that reduce the overall watershed ability to capture and slowly release stored water, and
4. Reduced summertime base flows may result from instream withdrawals.

Poor riparian vegetation conditions have also contributed to bank erosion and sedimentation. Riparian vegetation reduces streambank erosion by increasing stream bank stability via rooting strength and near-stream roughness (ODEQ 2000). The species composition and condition of the riparian vegetation determine natural streambank roughness. Rough surfaces decrease local flow velocity, which sequentially lowers shear stress acting on the streambank. Sediment sources, both upslope and instream, are elevated in some portions of Catherine Creek. If the stream channel, riparian zone and/or upslope landscape is in a degraded state, the same high flow events that transport sediments out of the stream channel can introduce large quantities of fine sediment into the channel.

Land uses that include urban, agriculture, and livestock grazing have increased the input of nitrogen and phosphorus into the Catherine Creek system. Nutrients often enter water attached to soil particles and fine organic matter that erodes off adjacent land due to reduced bank stability, streambank roughness, and riparian vegetation. At low concentrations of nutrients algal growth is inhibited, but at high nutrient concentrations algal nutrient demands are fully met and growth is limited only by temperature and available light (ODEQ 2000). As temperature increases, the growth rate increases.

Because Catherine Creek experiences elevated temperatures, algal growth rates are high and the stream is more likely to experience pH and DO violations than those with lower temperatures.

In general, reduced flows are also frequently identified as a limiting factor in the Upper Grande Ronde and in Catherine Creek in reaches 1 through 4 (GRMWP 1994; ODEQ 2000; Nowak 2004; NOAA Fisheries 2008). Although flows are naturally low in summer due to the local climate, water withdrawal for irrigation has caused severe water depletions in Catherine Creek. Low summertime streamflows have caused temperatures to increase. Nutrients and bacteria entering the stream are less diluted. These conditions have led to increased algal growth, which in turn affects DO concentrations and pH levels.

Riparian and instream habitat degradation has severely affected spring Chinook salmon production potential in the subbasin (Nowak 2004). The Grande Ronde Basin historically produced large runs of native spring Chinook salmon and summer steelhead (Bach 1995). The runs have declined substantially since the early 1970s. Water withdrawals for irrigated agriculture, human residential development, livestock overgrazing, mining, mountain pine beetle damage, channelization, low streamflows, poor water quality, logging activity, and road construction are major problems affecting salmon production. Significant changes in many salmonid habitat attributes have occurred in Catherine Creek relative to historic conditions (NOAA Fisheries 2008).

Overall changes in water temperatures between historic and existing conditions appear to have had the greatest contribution in reducing spring Chinook productivity (Duncan 1998). Flow and temperature patterns have been altered with much reduced flow caused by irrigation withdrawals in summer and increased temperatures due to low flows and the loss of streamside shade (Duncan 1998; NOAA Fisheries 2008). These factors have significantly influenced adult and juvenile migration opportunity and created heat sinks in what would be prime rearing habitat. Lower flows and warmer water temperatures have likely shifted and reduced variability of adult migration and spawn timing relative to historic timing (NOAA Fisheries 2008). The opportunity for fry and summer parr downstream migration in Catherine Creek has also been reduced. Lower than optimum winter temperatures resulting from the disconnect between streams and moderating groundwater supplies may adversely affect overwintering juvenile fish (Duncan 1998).

A study comparing historic BOF surveys to present day conditions in the Grand Ronde Basin found that fish habitat has changed since l934 (McIntosh et al. 1994). Pool habitat decreased significantly. Substrate conditions shifted toward smaller substrates in managed watersheds with an increase in fine sediments. Shifts in substrate composition suggest altered sediment supplies. Changes in substrate size can signify impacts of sediment inputs and bedload transport in the stream (McIntosh et al. 1994). Given current and past management practices in Catherine Creek, both have likely occurred (McIntosh et al. 1994). These changes can result in channel-widening leading to increased water temperatures and decreased pool volumes (McIntosh et al. 1994). Increases in the sediments have probably led to lower egg survival and the decrease in pool habitat (McIntosh et al. 1994).

The water quality changes that have occurred in Catherine Creek over time and the effects of those changes on salmonids are discussed at reach level below. Relatively similar reaches are grouped.

6.1 Reach 1 and 2

Unique features in the Grande Ronde Valley, where reaches 1 and 2 are located, must be considered when evaluating water quality (GRWQC 2000). The valley form is flat and wide, offering an unconstrained area for low velocity channel development with significant sediment deposition. As a result, a large floodplain has developed where soils are much deeper than in other parts of the subbasin. The combination of valley and a channel form with high sinuosity creates the potential for erosion and down cutting when banks are destabilized or streams are artificially straightened. In addition, there are a number of land management activities and pollution sources that are unique to the Valley including population centers with both residential and commercial areas and sewage treatment plants. The land has been highly developed for agriculture and livestock management, which are now the predominant land uses in the valley. The river and most of the tributaries in the valley have been channelized and riparian vegetation altered to some extent. This relatively high level of land development means that there are many more potential sources of pollution in the valley than in the rest of the subbasin.

Historically this portion of the subbasin was wet meadows and emergent wetland (Nowak 2004). In developing this area for agricultural production, many acres of previously flooded valley-bottom land were drained and streams were channelized to prevent flooding and manage water delivery (Bach 1995). The historic Tule Lake, remnants of which can be found in the Ladd Marsh Wildlife Area, covered nearly 20,000 acres of the valley before it was drained for agricultural use (Nowak 2004). These wetland areas served an important function in the hydrology of the area by collecting and filtering water for slow release into the system. Beavers were an integral part of these wetland systems; beaver dams created a succession of wetland types from open water ponds to wet meadows. These wet meadows and emergent wetlands have been lost or degraded by conversion to agriculture, road building, livestock introduction, and removal of beavers. Channelization and conversion to agriculture has also dramatically decreased streamside riparian vegetation. The result of channelization and conversion to agriculture has been a dramatic decrease in riparian area, with subsequent loss of rearing habitat for juvenile salmonids (Bach 1995).

Irrigation diversions and water withdrawals have severely depleted summertime flows in Catherine Creek. Low streamflows strand rearing juvenile fish in dry channel beds and result in elevated water temperatures, which can delay spawning (USFWS 2002). Irrigation, particularly flood irrigation, increases runoff, and subsurface drainage from agricultural fields (Bach 1995). When irrigation water is returned to the stream, it carries sediment and nonpoint pollution from agricultural chemicals and may contribute warmer water to the stream, which degrade water quality.

The use of lower Catherine Creek by salmon as habitat for particular lifestages has been significantly reduced from historic. Adult holding has been eliminated in reaches 1 and 2 due to high temperatures and low flows throughout summer (Huntington 1994). The entire creek below Union is not suitable for spawning and incubation with issues that include sedimentation, loss of pools, and high temperatures. The loss of occupancy in the lower reaches of Catherine Creek has affected the entire Grande Ronde River Basin by reducing the current spawner distribution (NOAA Fisheries 2007). Currently 50 percent of the historic MaSAs in the basin are occupied and none of the MiSAs are occupied. Adult migration to areas above town is eliminated after mid July in most years due to water withdrawal and high temperatures in the lower reaches (Huntington 1994). Reaches 1 and 2 are not suitable for summer rearing after early June due to high water temperatures. Loss of habitat prevents juveniles from migrating from Catherine Creek into the Grande Ronde River prior to early fall.

Juvenile fish may overwinter below Union, but capacity for such use of the stream has been much reduced by channelization and loss of habitat complexity (Huntington 1994). Winter rearing habitat quantity and quality in Grande Ronde River Valley may be important factors limiting spring Chinook salmon smolt production for Catherine Creek (Favrot et al. 2010). Rearing of juvenile spring Chinook salmon and summer steelhead is not confined to the areas in which the adults spawn (Yanke et al. 2008). The majority of juvenile spring Chinook salmon and steelhead move out of natal rearing areas to overwinter in downstream areas of Catherine Creek before migrating toward the ocean as smolts the following spring or later. Favrot et al. (2010) found that a considerably larger proportion of fish occupied reaches downstream of lower Davis Dam during winter compared to fall. These movements of spring Chinook salmon and steelhead show that lower river reaches are used for more than migratory corridors.

6.2 Reach 3

Catherine Creek passes through the town of Union in reach 3, where urban land use has led to modifications to the stream. Catherine Creek is a single channel through town with some dams, fish ladders, and diversions located in this stretch. Urban development closely borders the creek and limits the extent of riparian vegetation. Roads and paved areas also contribute to the reduction of riparian vegetation and to the input of sediment and nutrients into the stream. On the outskirts of town within reach 3, agriculture and grazing are the land uses. Water quality issues within reach 3 are the same as those in the lower reaches of Catherine Creek (Table 3) and include elevated temperatures, algae growth, and nutrient input; high fluctuations in DO and pH levels; and low flows and degraded riparian conditions.

In the 1998 TMDLs, ODEQ (2000) recommended that no effluent be discharged from the Union WWTP during summer months in order to mitigate the impact of the point source discharge on Catherine Creek water quality. ODEQ predicted that the likelihood of standards being met would be improved by the implementation of a summer no discharge period, since there would be less periphyton biomass produced which would reduce the likelihood of excessive diurnal DO and pH variation. The Union WWTP ceased summer discharge in 2001 (Ramondo 2011). Based on summer sampling conducted downstream of the WWTP between 2001 and 2006, there were still excessive nutrient levels and E. coli bacteria counts detected, although ammonia appeared to be reduced to non-toxic levels (Miles nd; USWCD nd). The 60 percent reduction in NPS loads (ODEQ nutrient loading allocations) has not been achieved even with no discharge from Union's wastewater treatment plant. It appears that the urban land use area that the streamflows through is a significant NPS of nutrient and bacteria loading.

With regards to currently available salmonid habitat found in reach 3 as compared to historic conditions, the capacity for adult holding from Union to the State Park (in lower reach 5) has been reduced because of loss of pool habitat and high temperatures (Huntington 1994). The quality and quantity of spawning and incubation habitat from Union upstream to State Park has been reduced due to high temperatures, loss of pools and sedimentation. Catherine Creek just upstream from Union in reach 3 is a potential high gradient overwintering reach but is not consistently occupied by early migrants, which indicates that habitat conditions are not conducive to successful overwintering (Favrot et al. 2010). Specifically, the high gradient channelized segment extending approximately 1.1 mi (1.7 km) upstream of Schwackhammer Fish Ladder at RM 40.6 appears to only be utilized as a migration corridor and is avoided as overwintering habitat.

6.3 Reaches 4 and 5

The predominate land use in reaches 4 and 5 of Catherine Creek is grazing on pasture and rangelands. Effects of overgrazing in the late 1800s and early 1900s remain severe throughout the Grande Ronde basin, especially in riparian areas where livestock tend to gather (Duncan 1998). Even lower levels of grazing today continue to cause watershed problems. Unless properly managed, livestock congregate around stream channels, where water and forage are abundant. This causes severe reductions in the amount and diversity of riparian vegetation, and increases soil compaction and streambank erosion. These changes severely reduce riparian function, with subsequent increases in stream temperature, nutrient-loading, sediment deposition in spawning and rearing areas, and alterations in streamflow patterns (Bach 1995). Rangeland can become infested with noxious weeds and annual grasses due to inadequate forage and grazing management, which causes loss of riparian vegetation and increased sedimentation (NRCS 2005).

The highway is adjacent to Catherine Creek in the lower segments of reach 4 and along all of reach 5, which has contributed to the reduction of riparian vegetation (USFWS 2002). Buffer widths between roads and streams are too narrow to filter out all soil movement before reaching the stream.

With regards to currently available salmonid habitat found in reaches 4 and 5 as compared to historic conditions, the capacity for adult holding from Union to the State Park (in lower reach 5) has been reduced because of loss of pool habitat and high temperatures (Huntington 1994). The quality and quantity of spawning and incubation habitat from Union upstream to State Park has been reduced due to high temperatures, loss of pools and sedimentation. USFWS (2002) recommends revegetation in riparian zones associated with habitat in these reaches to restore shade and canopy, riparian cover, and native vegetation that has been lost.

6.4 Reaches 6 and 7

The majority of stream miles in the upper watershed of Catherine Creek are affected by either grazing, logging, fire, roads, or a combination (USFS 1994 as cited in GRWQC 2000,). Most large conifers in the riparian zone were logged off before 1930 (Hug 1961 as cited in Kaufman et al. 1985). Grazed areas were cleared of brush periodically through the 1950s to increase forage for livestock.

In studies conducted on Hall Ranch at RM 50.1 in reach 6, cattle grazing was found to have significantly impacted structure, composition and standing biomass in some vegetation communities, as well as significantly increasing streambank sloughoff (Kaufman, Krueger, and Vavra 1985). Grazing impacts to the riparian ecosystem included forage removal, trampling, and physical damage of vegetation. While grazing enhanced species richness in some communities, it was halted or slowed in others, especially gravel bars dominated by willows and moist meadows (Kaufman, Krueger, and Vavra 1985). The presence of cattle created drier environments in some communities, decreasing the abundance of mesic plants. Kentucky bluegrass (i.e., dry meadow) communities were the most widespread in this reach. Historically, the dominant communities were probably native bunchgrass, sedge, and rushes. Overgrazing is likely the reason for the change in composition (Kaufman, Krueger, and Vavra 1985).

Effects of overgrazing in the late 1800s and early 1900s remain severe throughout the Grande Ronde basin, especially in riparian areas where livestock congregate (Duncan

1998). Even lower levels of grazing today continue to cause watershed problems. Grazing impacts to riparian vegetation severely reduce riparian function , with subsequent increases in stream temperature, nutrient-loading, sediment deposition in spawning and rearing areas, and alterations in streamflow patterns (MacDonald et al. 1991; Platts 1991; Rhodes et al. 1994 as cited in Bach 1995).

Kaufman, Krueger, and Vavra (1985) reported that beaver almost completely removed young black cottonweed communities (dbh<15 cm) in the upper reaches of Catherine Creek. They altered the riparian ecosystem by removing or thinning overstory, causing changes in community composition and structure. The potential effect of continued beaver browing is a decrease in shade cover and altered run-off and bank physiognomy.

The highway is adjacent to Catherine Creek along reach 6, which has contributed to the reduction of riparian vegetation (USFWS 2002). Buffer widths between roads and streams are too narrow to filter out all soil movement before reaching the stream. The highway veers away from the creek in reach 7. Forest Service roads were identified as a major problem in contributing sediment to South Fork of Catherine Creek upstream of reach 7 (Lovatt 2011).

The upper reaches of Catherine Creek have quality that is low relative to reference conditions for five habitat measures: shade, bank stability, sediment, pool frequency, and woody debris (GRWQC 2000). The most affected reaches, at present, are located in large meadow systems high in the watershed. The Forest Service concluded that this has led to unstable banks, higher width to depth ratios and lower water tables than would naturally occur (GRWQC 2000).

7. Recommendations

The following information relating to water quality in Catherine Creek appears to be limited:

- Nutrient and bacteria data upstream of reach 4.
- Comparisons of nutrients before and after WWTP stopped discharging during summer months.
- Current DO concentrations and pH levels throughout stream.
- Lack of sediment loading and source data for entire stream. (Sediment is on the 303(d) list for North and South Forks of Catherine Creek only but is apparently a problem throughout the stream regarding salmonid habitat).
- The extent, species distribution, and density of riparian vegetation canopy and ground cover; linked to riparian site potential (Bach 1995). CRITFC is planning to create a PNV map of the Catherine Creek basin, which may address this data gap.

- Detailed spatial information on land use: irrigated versus non-irrigated agriculture, types of agriculture, extent of grazing and riparian areas excluded from grazing, road locations and densities, timber harvest activities (Bach 1995) to better identify sources of water quality problems

Recommendations for improving water quality, and consequently Chinook and steelhead habitat, in Catherine Creek are provided by parameter below. Much of the literature agrees that addressing riparian condition and streamflow issues would lead to improvements in most other water quality parameters.

7.1 Temperature

Lack of riparian vegetation and shade, as well as low flows, contribute to increases in temperature. To address these problems, provide riparian shading by planting new shrubs and trees, as well as protecting existing shade. Protect (and possibly increase) flow from springs by enhancing groundwater recharge (limit surface runoff from roads, etc.). Plant and/or protect conifers in riparian area to provide thermal cover in winter, but allow for biodiversity with deciduous vegetation. Increase irrigation efficiency and limit amounts of warm irrigation return flows (WCSRCS 1999).

Improving livestock management and distribution will also help to address temperature problems by minimizing impacts to riparian vegetation. Recommendations for managing livestock in riparian areas include using riparian pastures as part of a rotational grazing scheme, creating off-stream water developments and salting sites to deter cattle away from the stream, herding, and fencing where appropriate to exclude livestock from riparian zones (Upper Grande Ronde River Subbasin Local AWQAC 1999). Whitney (2007) found that in most cases, cooler stream temperatures were clearly associated with minimal impact from grazing and other land uses, while higher temperatures were associated with heavier use. The parameters most responsive to disturbance were temperature, DO, and pH.

Slowing the rate of water warming will push the point at which maximum temperatures occur further downstream, adding many miles of fish habitat (Nowak 2004). Improved riparian vegetation along smaller order streams will dramatically reduce the daily maximum stream temperature in Catherine Creek.

7.2 Sediment

Prevent bank erosion and destruction through livestock by fencing riparian area and providing water corridors or alternate water sources (WCSRCS 1999). Protect water corridors with rock of appropriate size. Avoid excessively high peak flows, and resultant bank erosion, by keeping enough watershed vegetation to slow runoff. Plant in critical areas. Manage weeds, which generally have shallow root systems that do not provide soil stability and can result in increased sedimentation.

Methods for avoiding agricultural field erosion include planting buffer strips, planting perennial crops, and planting wind breaks to control wind erosion (Upper Grande Ronde River Subbasin Local AWQAC 1999). Use conservation tillage. Use sediment traps by providing wetlands, filter strips, or settling ponds for irrigation return flows. Limit sediment-laden irrigation return flows (WCSRCS 1999).

Road design and maintenance should be planned to avoid quick runoff and sediment entrainment. If there is a sediment problem that could not be mitigated by road design, maintenance, or relocation, the road could be revegetated, use could be limited, or the road closed (WCSRCS 1999). Wetlands and/or filter strips could be developed to filter runoff from roads and campgrounds.

7.3 Nutrients

Nutrients often enter water attached to soil particles and fine organic matter that washes off adjacent land; therefore, bank stability and riparian vegetation are important. Follow practices that will limit erosion and sedimentation. Healthy riparian areas with deep-rooted woody vegetation have been shown to intercept significant amounts of nutrients and prevent them from reaching surface waters (GRWQC 2000). Sediment and dissolved nutrients can also be transported via roadside and drainage ditches. Dissolved nutrients move easily into surface waters via shallow groundwater and drain tiles. Fertilizer management, cover crops, soil disturbance, and irrigation management on agricultural fields have an impact on the nutrient load (GRWQC 2000). Soil and foliage testing should be encouraged (Upper Grande Ronde River Subbasin Local AWQAC 1999). Plant buffer strips to filter nutrients.

Whitney (2007) found that in most cases, better water quality was seen in study reaches with minimal impact from grazing and other land use activities, while poorest water quality was seen in study reaches with heavy grazing use. The parameters most responsive to disturbance were temperature, DO, and pH.

Methods for preventing bacteria from entering the stream include managing animal waste, planting buffer zones, installing settling ponds and clean water diversions around livestock concentration areas (Upper Grande Ronde River Subbasin Local AWQAC 1999).

7.4 Flow and Riparian Conditions

Increased late season flow would improve almost all of the 303(d) listed parameters – temperature, habitat modification, pH, algae, nutrients, DO, and bacteria – by providing dilution and increased moisture (GRWQC 2000).

Areas with a large number of irrigated acres have the potential for reduced water use through irrigation efficiency or changes in land use (Bach 1995). Irrigation efficiency can be improved by: pump testing, sizing mainlines properly, using proper nozzle sizes, fixing leaks, installing headgates at diversion points and/or improving the existing structures, converting surface systems to buried mainline, monitoring soil moisture levels, and lining or piping irrigation ditches (Upper Grande Ronde River Subbasin Local AWQAC 1999). Alternative sources of water for irrigation could be used, such as city wastewater or deep wells.

While not the only issue, riparian habitat degradation is the most serious problem in the subbasin (Nowak 2004). Improving riparian conditions will improve temperature, bank stability, sediment, and other water quality factors (Nowak 2004; GRWQC 2000; Huntington 1994).

Riparian restoration is probably the most cost effective way to improve fish habitat throughout the basin and is the only way to reduce high water temperatures (Huntington 1994). Establishment and protection of riparian vegetation would likely increase the contribution of LWD into the stream, thereby elevating habitat complexity and cover availability (Favrot et al. 2010). In addition, riparian vegetation is associated with bank stability and reduced erosion.

To improve riparian conditions, it is important to encourage revegetation and protection of existing vegetation on non-forested riparian areas with woody material (e.g., educate landowners on the value of streamside woody plants) (WCSRCS 1999). Livestock use of riparian areas should be carefully controlled in order to assure health of shrub and woody components (Huntington 1994). Restoration measures related to grazing might include temporary fencing of riparian areas, corridors, changes in grazing seasons and duration, development of offstream watering sites, and planting appropriate native shrubs and trees. Results of a study to evaluate the effectiveness of channel restoration efforts in McCoy Creek, a degraded stream in the Upper Grande Ronde basin with characteristics similar to Catherine Creek, showed livestock exclusion by itself may not result in improved habitat and recovery of sensitive aquatic life (Whitney 2007). In most cases, however, better water quality was seen in study reaches with minimal impact from grazing and other land use activities, while poorest water quality was seen in study reaches with heavy grazing use. Cool groundwater influx and shade were important factors affecting water quality.

Higher in the Catherine Creek watershed, catastrophic fires could destroy vegetative cover and consequently result in sediment input to the river. Prescribed burning in forests can help reduce fuel levels and provide fire breaks to prevent large uncontrollable fires. In riparian areas, fuel rearrangement (placing fuels to protect streambank or placing large woody debris in stream to add to stream structure) may be preferable to burning in order to keep the organic material as part of the ecosystem, preserve shade, and prevent sedimentation (Wallow County SRSC 1999).

If funds are limited, restoration should initially emphasize vegetative recovery along unconstrained low-gradient reaches of streams which have greatest capacity for rapid response, are naturally the most dynamic and productive stream channels, and tend to be the preferred spawning or rearing areas of spring Chinook (Huntington 1994). Whitney (2007) found that restoration of meandering wet meadow channels (i.e., reaches 1 and 2) can improve habitat and benefit sensitive aquatic life in a relatively short period (2 to 5 years). Efforts directed toward increasing survival of early migrants during fall migration and overwintering periods would likely be most efficiently directed toward portions bounded by Union and the mouth of Mill Creek (reach 2). Despite channelization and lack of habitat complexity (e.g., pools and cover), several smaller reaches positioned between Union, Oregon, and the mouth of Pyles Creek (lower section of reach 3) were intensely utilized (Favrot et al. 2010).

Riparian recovery along constrained stream channels should also be a high priority because these reaches provide important habitat by providing a source for woody debris and moderating stream temperatures (Huntington 1994). Management practices that enhance the riparian corridor vegetation of Catherine Creek could improve overwinter carrying capacity of early migrants by increasing habitat complexity (i.e., cover) and bank stability (Favrot et al. 2010). Several reaches within the high gradient overwintering reach (e.g., 1.7 km upstream of Swackhammer Fish Ladder at RM 40.6 in reach 3) were not occupied consistently by the early migrant population, indicating that these reaches do not contain habitat conditions conducive to successful overwintering. Employing habitat restoration techniques within these degraded reaches would likely increase overwintering carrying capacity (Favrot et al. 2010).

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