Dairy-McKay Sub-Basin Restoration Action Plan

Tualatin River Watershed Council

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Prepared for:

Tualatin River Watershed Council

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Acronyms

Cascade – Cascade Environmental Group, LLC

cfs – Cubic feet per second

CWS – Clean Water Services

dbh – Tree diameter at breast height

DPS – Distinct Population Segment

EIS – Environmental Impact Statement

ESA – Endangered Species Act

GIS – Geographical Information System

GLO – General Land Office

I.P. – Intrinsic Potential

JWC – Joint Water Commission

NEPA – National Environmental Policy Act

NMFS – National Marine Fisheries Service

NorWeST – Northwest Stream Temperature

O&C lands – Oregon and California Railroad Lands

ODFW – Oregon Department of Fish and Wildlife

RBA – Rapid Bio-Assessment

RM – River Mile

SWCD – Soil and Water Conservation District

TAC – Technical Advisory Committee

TRWC – Tualatin River Watershed Council

Tribes – Pacific Northwest Indian Tribes

TVID – Tualatin Valley Irrigation District

DEQ – Department of Environmental Quality

TMDL – total maximum daily load

UWR – Upper Willamette River

USGS – United States Geological Survey

Dairy-McKay Sub-Basin

Restoration Action Plan

Contents

1. Introduction

The Dairy-McKay Creeks Subbasin (Dairy-McKay Sub-Basin), a tributary to the Tualatin River, is identified by the Tualatin River Watershed Council (TRWC) as a high-priority area for coho salmon, Upper Willamette River winter steelhead, Pacific lamprey, and cutthroat trout spawning and rearing.

TRWC and its partners have been active in studies and restoration projects throughout the Tualatin River Basin. This restoration work, which improves watershed health and habitat for fish and wildlife, includes wetland, riparian and upland enhancement; large wood placement; replacement of fish passage barriers; stream flow augmentation; and other actions.

The Restoration Action Plan (Action Plan) builds on TRWC's and its partner organizations' past restoration accomplishments by providing a strategic framework and systematic approach to restoration throughout the Dairy-McKay Sub-Basin. The Restoration Action Plan evaluates the factors limiting focal fish populations and water quality and identifies strategies and activities that will address watershed health issues over time.

The Tualatin River Watershed Council

The TRWC links land, water and people. We bring together all interests in the basin to promote and improve watershed health. We work together through cooperation, collaboration and communication. All of our actions affect the health of our watershed. We need your help in improving our watershed's health!

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2. Geographic Hierarchy: Diary-McKay Sub-Basin, Watersheds, and Sub-Watersheds

The Dairy-McKay Sub-Basin is divided into four watersheds and eight sub-watersheds as follows:

West Fork Dairy Creek Watershed

- Upper West Fork Dairy Creek Sub-Watershed
- Middle West Fork Diary Creek Sub-Watershed
- Lower West Fork Dairy Creek Sub-Watershed

East Fork Dairy Creek Watershed

- Upper East Fork Dairy Creek Sub-Watershed
- Lower East Fork Dairy Creek Sub-Watershed

McKay Creek Watershed

- Upper McKay Creek Sub-Watershed
- Lower McKay Creek Sub-Watershed

Council Creek-Diary Creek Watershed

- Council Creek-Diary Creek Sub-Watershed

The map (**Error! Reference source not found.**) on the following page shows the Dairy-McKay Sub-Basin, w atersheds, and sub-watersheds. Table 1 outlines watershed and sub-watershed acreages and mainstem channel length.

Table 1. Dairy-McKay Subbasin watershed and sub-watershed acreages and mainstem channel lengths. Source: GIS analysis and Hawksworth 1999

Diary-McKay Sub-Basin Watershed	Sub-Watershed	Total Acres	Mainstem Channel Length (miles)
West Fork Dairy	Upper West Fork Dairy Creek	21,196	
	Middle West Fork Dairy Creek	17,126	
	Lower West Fork Dairy Creek	12,620	
	Watershed Total:	**50,942**	**25.6**
East Fork Dairy	Upper East Fork Dairy Creek	20,722	
	Lower East Fork Dairy Creek	20,374	
	Watershed Total:	**41,096**	**22.9**
McKay	Upper McKay Creek	23,750	
	Lower McKay Creek	19,024	
	Watershed Total:	**42,774**	**24.2**
Council Creek-Dairy Creek	Council Creek-Dairy Creek	13,083	
	Watershed Total:	**13,083**	**10.7**

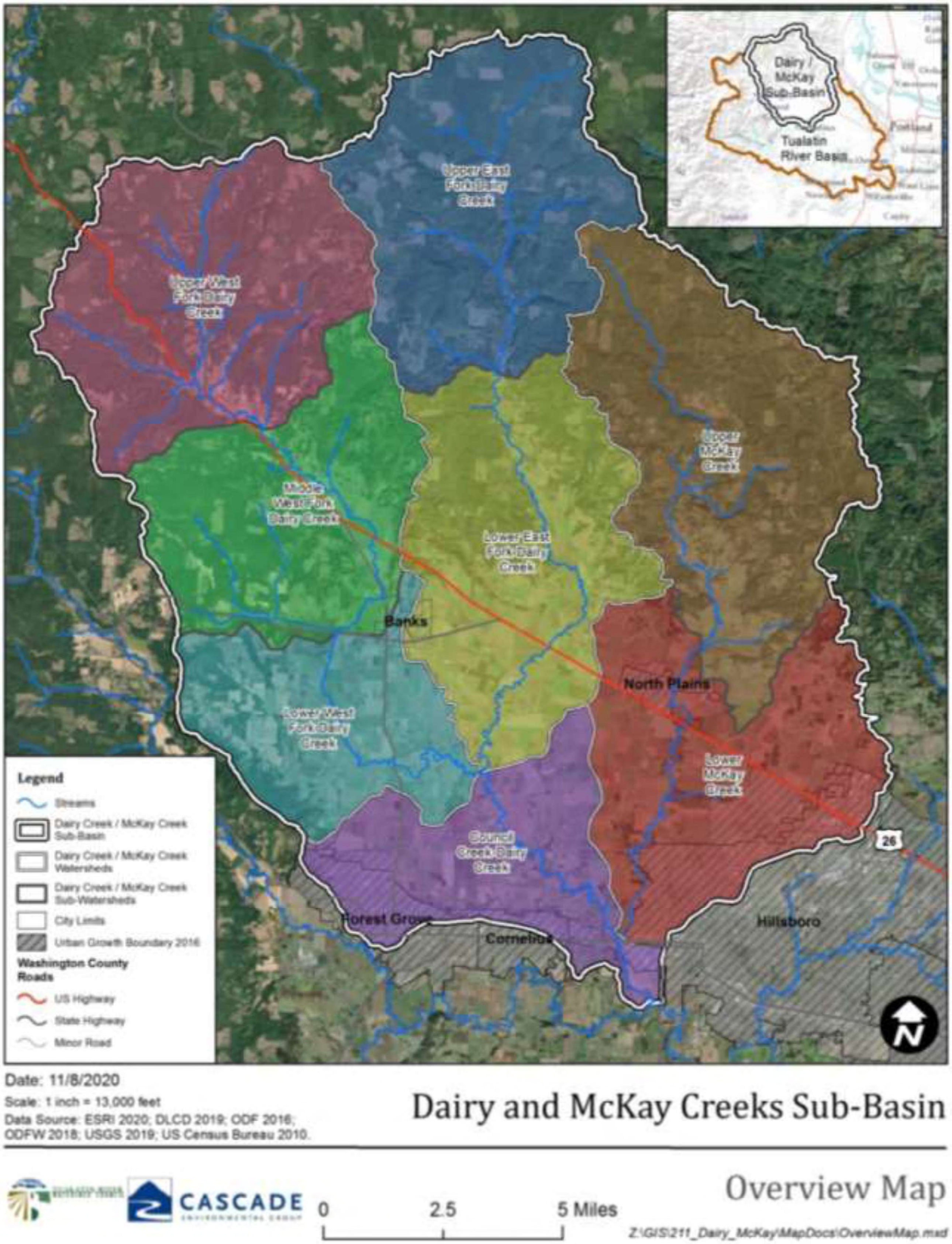

Figure 1. Dairy-McKay Action Plan geographic framework: Sub-Basin, watersheds, and sub-watersheds

3. Dairy-McKay Sub-Basin Overview

The Dairy-McKay Sub-Basin covers approximately 147,895 acres draining the eastern side of the Coast Range Mountains. Elevations range from 2,265 feet above sea level at Longs Peak in the headwaters of Upper East Fork Dairy Creek to approximately 115 feet at Dairy Creek's confluence with the Tualatin River near the City of Hillsboro (TRWC 2012). The sub-basin is bordered to the west by the Coast Range, north and east by the Tualatin Mountains, and south by the Chehalem Mountains. The Dairy-McKay system is the largest sub-basin contributing to the Tualatin River, encompassing nearly one-third of the entire Tualatin River Basin.

Table 2 and **Error! Reference source not found.** illustrate the Dairy-McKay Sub-Basin's land ownership patterns and acreages. Nearly 93 percent of the Dairy-McKay Sub-Basin is privately owned. The upper sub-basin is characterized by forest land uses, while the lower portions are primarily in agricultural, rural residential and urban land uses. There are five incorporated communities with at least a part of their Urban Growth Boundary (UGB) within the sub-basin. The communities and the 2020 population estimate (PSU 2020) are as follows: Forest Grove (25,435), Cornelius (12,635), Hillsboro (104,670), Banks (1,980), and North Plains (3,360). In total, these communities' UGBs cover 10,204 acres (~16 square miles) concentrated in the lower portions of Dairy and McKay Creeks (Figure 2).

The sub-basin's public lands are managed by the federal Bureau of Land Management (BLM), Metro, the State of Oregon, and local jurisdictions. Approximately 6,331 acres of mostly forest lands within three sub-watersheds – Upper East Fork Dairy, Lower East Fork Dairy, and Upper McKay – are managed by the BLM. Most of the BLM-managed areas are Oregon and California Railroad (O&C) lands. Due to this legacy, these lands are distributed in a checkerboard pattern across the landscape rather than a single block. Metro's Killin Wetlands Natural Area is near the town of Banks. The Natural Area, which encompasses nearly 600 acres within the Middle West Fork Dairy Creek Sub-Watershed, provides a rare example of a peat wetland in Oregon and supports significant wildlife populations.

Table 2. Dairy-McKay Sub-Basin land ownership

Sub-Watershed	Federal	State	Private Lands	Local	Metro	Total
Upper West Fork Dairy Creek		2,253	18,796	147		**21,196**
Middle West Fork Dairy Creek			16,342	189	595	**17,126**
Lower West Fork Dairy Creek			12,620			**12,620**
Upper East Fork Dairy Creek	2,867	83	17,684	88		**20,722**
Lower East Fork Dairy Creek	1,021	87	19,262	4		**20,374**
Upper McKay Creek	2,443		21,307			**23,750**
Lower McKay Creek			19,024			**19,024**
Council Creek-Dairy Creek			13,083			**13,083**
Total	**6,331**	**2,423**	**138,118**	**428**	**595**	**147,895**

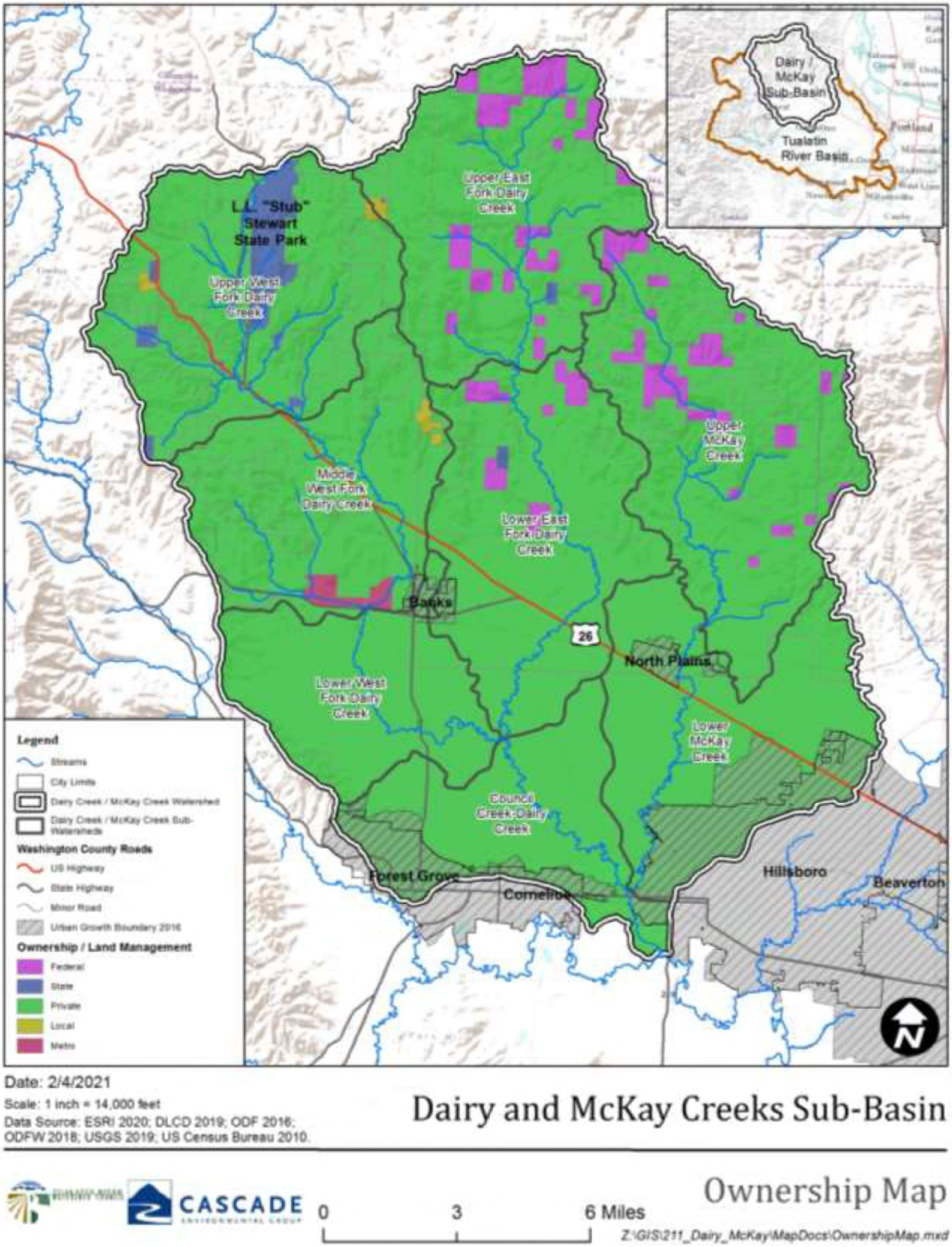

Figure 2. Dairy-McKay Sub-Basin land ownership and land use

Set on a forested hillside, Stub Stewart State Park covers approximately 1,600 acres within the Upper West Fork Dairy Creek Sub-Watershed. The Park offers a variety of camping opportunities and nearly 30 miles of trails. The State of Oregon manages over 800 acres of forest properties within three sub-watersheds. Washington County and city government properties cover a relatively small area (428 acres).

Climate and Hydrology

Western Oregon's climate drives the Dairy-McKay Sub-basin's streamflow and water temperature patterns. Summers (i.e., June-September) and early fall typically have moderate temperatures, with occasional heat waves where temperatures exceed 90^0 F and little rainfall. Conversely, about 75 percent of the annual precipitation falls during the cool months between October and May (Jung and Chang 2012). Due to this seasonal variability in precipitation, streamflow is always higher in winter and lower in summer. In 2019, for example, East Fork Dairy Creek's highest streamflow was in February (monthly mean = 161.0 cfs) and the lowest flow was in August (monthly mean = 9.6 cfs; Bonn 2019)

Stream flows are primarily derived from rainfall. Because the sub-basin's relatively low elevations do not sustain persistent snowpack, streamflow from snowmelt is minimal. The rainfall amounts range from 110 inches on the eastern slopes of the Coast Range to 37 inches in the lowest portions of the sub-basin (Bonn 2019). Rain events mostly drive flooding. The system is "flashy," characterized by a quick flood response from large rain events and a rapid return to lower flows as rainfall decreases.

In contrast, the higher elevation Cascade Mountains sustain a persistent snowpack which helps maintain higher stream flows (and lower water temperatures) into late fall and summer months. Generally, flooding in the Dairy-McKay Sub-Basin is limited to low-lying areas during storms in exceptionally rainy winters (Hawksworth 1999). The effect of droughts on stream flows has been minimized due to water storage behind Scoggins Dam. Flow augmentation and agricultural irrigation water from the reservoir help sustain summer flows. More information on stream flows and impacts on fish populations is presented in Section 6.

Geology and Geomorphology

The Dairy-McKay Sub-Basin has distinct upland and lowland areas, each with markedly different ecological and geological characteristics (Sobieszczyk et al. 2018). Highly erodible sedimentary and volcanic rocks broadly characterize the geology in the mountainous uplands in the northern part of the sub-basin. Missoula flood deposits and other local flood deposits characterize the southern portion of the sub-basin within the Tualatin Plain's lowlands (**Error! Reference source not found.**). The upland portions of the w atersheds have steeper terrain and higher gradient stream channels. Channel gradients progressively decrease as the streams transition into alluvial valleys and enter the broad and relatively flat Tualatin Plain.

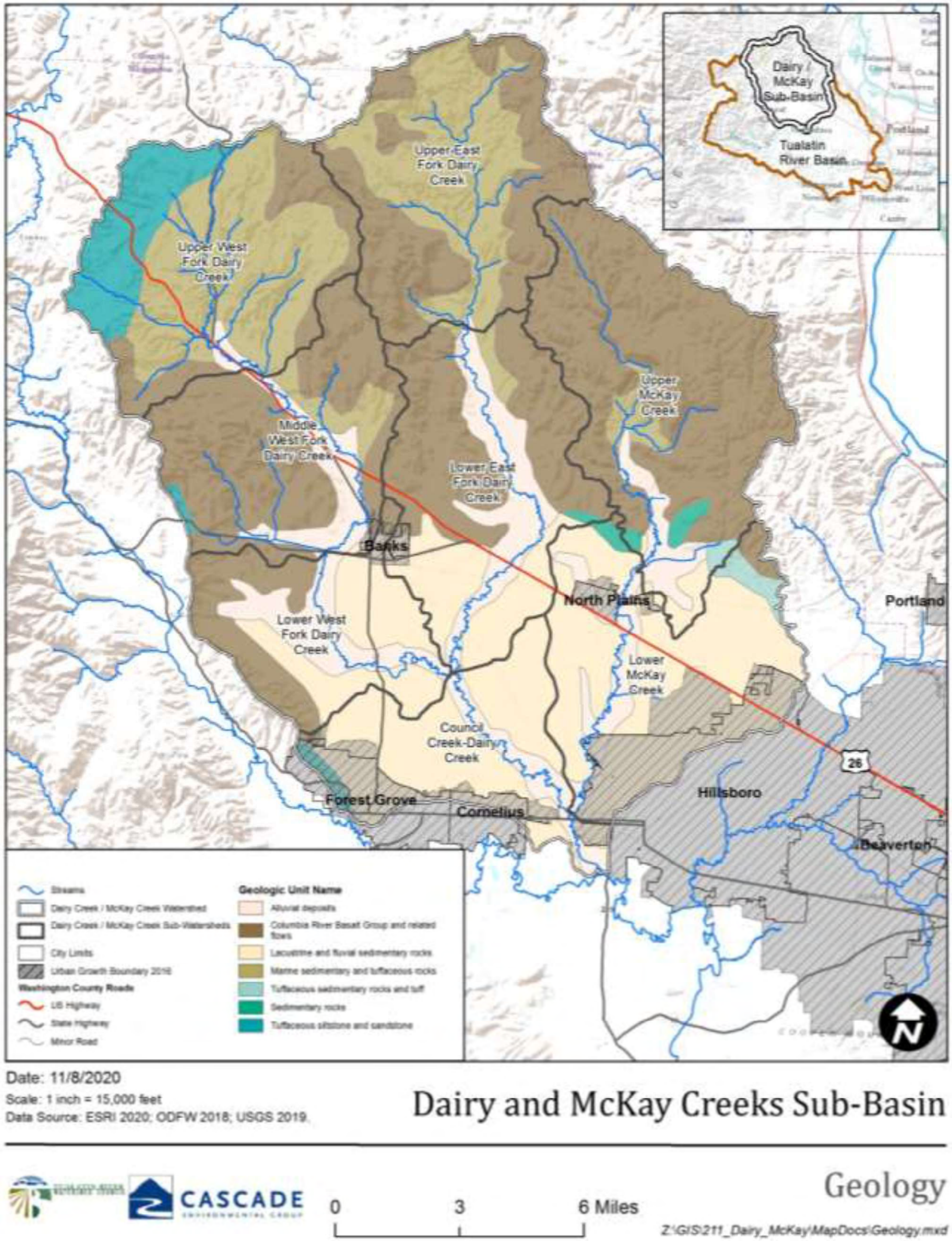

Figure 3. Dairy-McKay Sub-Basin geology

In the mountainous portions of the watersheds, tributaries to the mainstem West Fork Dairy, East Fork Dairy, and McKay Creeks have relatively high gradients. Typical channel gradients for contributing tributary streams draining the mountainous areas average 3-10 percent. These high gradient streams have a substantial capacity to carry sediments, and erosion and sediment transport are dominant processes.

In the Tualatin Plain, low gradient streams with broad floodplains are the dominant channel form. These streams generally have a high sinuosity and are characterized by depositional processes. Streambank erosion is an essential erosional process in these reaches (Hawksworth 1999). The relatively flat topography and fine-grained soils create areas of poor drainage. Historically, extensive wetlands occupied many of these poorly-drained areas (Hawksworth 1999).

Gravel channels are limited mainly to the upper portions of the tributaries. Because the upland sedimentary and volcanic rocks tend to disintegrate into sand and silt during downstream transport, sandy and silty substrates characterize the channels in the lower portion of the sub-basin (O'Connor et al. 2014). A recent study that modeled stream substrate transport and characteristics confirmed that gravel substrates are confined to the upper tributaries draining the sub-watershed mountainous areas (Figure 4; TerrainWorks 2020). Salmonids (e.g., coho salmon and cutthroat trout) and Pacific lamprey require gravels and other course substrates for successful spawning (Riebe et al. 2014). The distribution of substrates in the watershed – fine material in the lowlands and coarser materials in the upland drainages – means that salmonid and Pacific lamprey spawning is limited to the upper portions of the sub-basin.

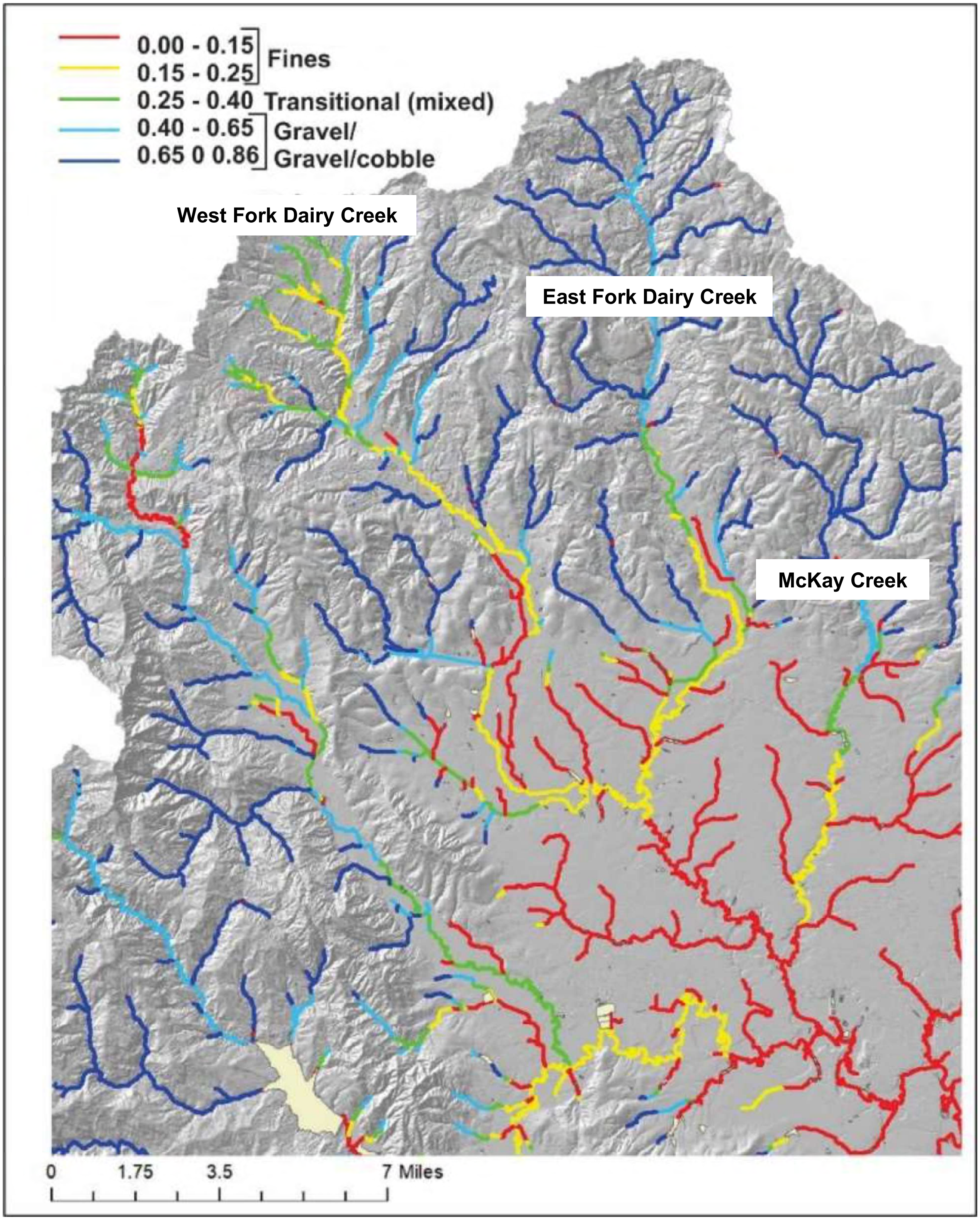

Figure 4. Model predicted channel bed substrate in the upper Tualatin River Basin. Source: TerrainWorks 2020

4. Development of the Action Plan

In 2019, TRWC contracted with Cascade Environmental Group (Cascade) to create a Restoration Action Plan for the Dairy-McKay Sub-Basin. Cascade reviewed reports, studies, and other scientific literature that focused on conditions in the Dairy-McKay Sub-Basin as part of the Action Plan development. The purpose of the review was to evaluate what is known about the sub-basin's conditions and the factors that influence watershed health, with a specific focus on the ***limiting factors*** and ***threats*** that are affecting focal fish populations.

TRWC staff and the TAC provided input and review throughout the development of the Action Plan. Cascade worked with the TAC to incorporate the Information Gap Analysis recommendations and develop a restoration strategy for the Dairy-McKay Sub-Basin, identifying actions that would enhance habitat for the focal fish populations and improve watershed health.

Fish Population Limiting Factors and Threats

Limiting Factors: The biological and physical conditions – e.g., high water temperatures – that limit a fish species' viability for one or more of the species' freshwater life history stages (e.g., adult migration, spawning and egg incubation, early fry rearing, summer rearing, winter rearing, etc.).

Threats: Threats are human activities or natural processes that create the limiting factors. For example, land uses that remove vegetation along the banks of a stream (a threat) can cause higher water temperatures (limiting factor), because the stream is no longer shaded.

From: ODFW and National Marine Fisheries Service (NMFS) 2011

Information Gap Analysis

The ***Dairy-McKay Sub-Basin Information Gap Analysis*** summarizes available information on the focal fish populations, fish passage barriers, stream and riparian habitat, water quality, and other watershed characteristics (Appendix 1). More than 50 documents and data sets were reviewed, focusing on information describing watershed and habitat characteristics, showing trends over time, and having relevance to Dairy-McKay Sub-Basin restoration action planning. The Information Gap Analysis identified the information and data that should be addressed to fully assess watershed conditions and provide the required information for the development of the Action Plan.

Information Gap Analysis Findings

Compared to most Oregon watersheds, the Diary-McKay Subbasin is relatively rich in data and information sources. There is information characterizing water quality parameters, hydrology, fish population extent and density, land uses, and other data helpful in understanding the factors constraining fish populations and watershed health. The key information gap is the lack of current and geographically extensive data describing stream habitat characteristics: Channel gradient, the abundance and depth of pools and riffles, quantities of large wood, substrate composition, etc. These habitat features directly affect fish population densities (e.g., the number of juvenile fish in a pool) and distribution. The Oregon Department of Fish and Wildlife's (ODFW) aquatic habitat inventory methodology, which has been implemented in watersheds throughout Oregon, is designed to provide quantitative information on stream habitat characteristics. Only two streams in the Dairy-McKay Sub-basin have completed ODFW aquatic habitat inventories: Upper McKay Creek (2004) and Murtaugh Creek, a tributary to upper East Fork Diary Creek (1990). Unfortunately, the completed aquatic habitat inventories are not current, nor do the data encompass streams throughout the Dairy-McKay Sub-Basin.

NetMap: Characterizing Streams and Riparian Areas throughout the Dairy-McKay Sub-Basin

TRWC contracted with the consulting firm Terrainworks to create a NetMap "virtual watershed" for the entire Tualatin River Basin, including Dairy-Mckay Sub-Basin. NetMap processes digital elevation data derived from recent high-resolution LiDAR imagery to create models of topographic surfaces and other information on channel and watershed attributes such as stream channel locations, floodplain surfaces, riparian zones, and other features.

NetMap's data and mapping tools help address the critical Dairy-McKay Sub-basin key data gap – the lack of spatially extensive and current information on stream and riparian habitat conditions. Table 3 outlines the selected NetMap outputs for characterizing Diary-McKay Sub-Basin's stream, riparian, and watershed conditions. The Action Plan's watershed characterization did not utilize all of NetMap's features. For example, we did not apply NetMap capabilities for characterizing sediment sources from roads and land use activities. TRWC will build on the Diary-McKay NetMap analysis and explore other features for characterizing stream and watershed conditions throughout the Tualatin River Basin.

Table 3. Description of key NetMap model outputs applied to characterize the Dairy-McKay Sub-Basin

NetMap Output	Description
Intrinsic Potential (I.P.) for winter steelhead and coho	A relative ranking of fish potential habitat quality for anadromous fish using species-specific preferences based on valley form (constrained or unconstrained channels), channel gradient, and relative streamflow patterns based on watershed size
Average annual probability of large wood inputs by tree size	A measure of single-year large wood recruitment potential from mortality for each stream reach in terms of the number of pieces per year per reach length (approximately 100 meters), by average piece diameter class. The model uses vegetation data on tree height and stand density using a range of diameter classes; Landscape Ecology, Modeling, Mapping, and Analysis (LEMMA 2021) data, derived from satellite imagery, is used to characterize riparian conditions
Relative stream thermal energy sensitivity – Optimized shade	A sensitivity analysis of the thermal load changes (with and without vegetation) determines where the most thermally at-risk streams are located in a watershed. Thermal loading (watt-hours/m2) to streams governed by 1) channel width and orientation, 2) topographic shading, 3) vegetation shading, and 4) location within the watershed. Parameters include: 1) solar radiation-vegetated; 2) solar

NetMap Output	Description
effectiveness	radiation-bare earth; and 3) solar radiation difference: vegetated minus bare earth
Bankfull channel width and height	A measure of bankfull channel width and depth. Both are modeled as a power function of mean annual flow, drainage area and/or precipitation, and channel/floodplain surfaces
Floodplain surfaces	Floodplain and valley surface elevations relative to the channel, using increments of bankfull channel depths or in absolute elevation – delineates areas potentially prone to flooding (at varying levels and magnitudes), identifies channel floodplain interactions including channel migration areas and avulsion potential, and terraces of varying elevations
Tributary temperature relative to the mainstem	This tool uses the downstream aggregated Current Shade-Thermal Energy parameter. It compares the aggregate values at tributary confluences to the aggregate values in mainstem channels (e.g., tributary value - mainstem value) to identify potential tributary sources of cooler water (and also potential sources of warmer tributary water). To provide an index of cool water potential to a mainstem, the result is multiplied by the ratio of the tributary drainage area to mainstem drainage area to provide an index of the relative magnitude of the cooler or warmer water conditions in the mainstem channel

Fish Distribution and Abundance: The Rapid BioAssessment and other Studies

Information on the distribution and abundance of the focal fish populations is central to understanding the factors limiting fish populations. To address this essential data need, TRWC contracted with Bio-Surveys, LLC to conduct snorkel surveys to determine the distribution and abundance of juvenile salmonids in the Dairy-McKay Sub-Basin in the summer of 2013. The surveys were repeated for s elected areas in the summer of 2014.

The Rapid Bio-Assessment (RBA) surveyed Dairy and McKay Creeks and key tributaries to assess the relative distribution and abundance of the focal salmonid species[1].

[1] The RBA observations noted salmon, steelhead, and cutthroat trout species presence and abundance; Pacific lamprey were not a focus of the observations. Other sources provided information on Pacific lamprey presence and abundance.

The areas where the RBA survey was conducted provide very high-resolution information on fish presence and distribution. The survey sampled every 5th pool (20 percent sample), ending at the upper extent of anadromous fish distribution. The survey provides detailed, spatially extensive, and current information on fish species distribution and abundance. The RBA data is specific to each stream and can be mapped at a very high resolution (i.e., individual pools).

The RBA provided insights into the factors affecting fish populations and key areas (***Anchor Habitats***) necessary to sustain the populations (Bio-Surveys, LLC 2003).

The RBA report evaluates some of the factors that are limiting fish populations and distribution. The RBA was completed during the summer months when stream flows are low and water temperatures are the highest, which provides insights into how water temperature regimes have influenced fish distributions. The report describes stream reaches that fish have moved out of to escape high water temperatures and streams that fish reside in because they provide cool water (i.e., thermal refugia). The RBA report also includes high-resolution information on barriers to fish movement (e.g., dams and culverts) and the different salmonid species' habitat types.

Fish Population Anchor Habitats

Anchor Habitats: Stream habitats that provide all of the essential habitat features necessary to support the focal fish species' freshwater life history stages: Egg incubation, summer habitat, and winter high flow refugia. The habitat supports all key stream functions – deposition of gravels, the accumulation of large wood, complex pools, floodplain interaction, and good water temperatures.

Adapted From: Bio-Surveys, LLC 2003

The RBA did not collect information on Pacific lamprey distribution or abundance. Fortunately, a group of scientists with Pacific Northwest Indian Tribes (Tribes), Oregon State University, and other institutions studied Pacific lamprey adult migration, spawning, and juvenile rearing in Willamette River tributaries, including the Tualatin River. A 2013 survey as part of this study provides recent information on juvenile Pacific lamprey's presence in the sub-basin.

Because the RBA information covers a substantial portion of Dairy and McKay Creeks and tributaries, it provides a geographic framework for synthesizing information from other sources, including fish passage barrier inventories. This synthesis offers additional insights into the factors that limit focal fish populations' distribution and abundance. For the Action Plan, the RBA data was compared to NetMap information on channel and floodplain characteristics and other information such as water temperature data to understand how habitat and water temperature characteristics influence salmonid abundance. The RBA also identifies habitat "hot spots"– areas where there are large numbers of fish, presumably because of the presence of high-quality adult spawning and juvenile rearing habitat.

Watershed Health

In addition to habitat and other factors limiting focal fish populations, the Action Plan considers other watershed factors that contribute to the overall health of the Dairy-McKay Sub-Basin. Good water quality (including water temperatures, sediment, and other factors) and quality in-stream habitat are essential for thriving fish and healthy amphibian populations and clean drinking water. Similarly, riparian areas, consisting of streamside vegetation and active floodplains, are necessary for healthy fish populations and wildlife. The width and length of these riparian corridors provide avenues for wildlife to travel between different parts of the landscape. Healthy riparian vegetation provides habitat for a variety of wildlife species. Riparian areas and associated wetland areas are critical habitats for many species, including amphibians such as red-legged frogs.

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5. Upper Willamette River and Tualatin River Basin Context

Overview

The Dairy-McKay Sub-Basin's streams have relatively good indicators of watershed health. In comparison to more urbanized sub-basins in the Tualatin River Basin, the Dairy-McKay Sub-Basin has fewer introduced nonnative fish species and great diversity and numbers of native fish, including winter steelhead and coho salmon (Leader and Hughes 2001). In a study of Tualatin Basin aquatic insects and fish, the Middle East Fork and Upper West Fork of Dairy Creek were identified as one of the least-impaired stream reaches, with higher average fish Index of Biological Integrity (IBI) scores than streams within UGBs (Cole et al. 2006)

Upper Dairy Creek and other streams in the sub-basin have diverse aquatic macroinvertebrate communities well represented by mayflies, stoneflies, caddisflies, and other more environmentally sensitive species (Cole 2000 and Cole 2002). Dairy-McKay Sub-Basin sampling sites were among the sites used as a reference against which other more impacted Tualatin River Basin sites were compared.

In a recent Tualatin River Basin Study, the U.S. Geological Survey (USGS) evaluated 13 metrics characterizing stream ecosystem stressors. The metrics are organized into four groups: hydrologic, water quality, physical habitat, and biological conditions (Sobieszczyk et al. 2018). McKay Creek ranked the highest for these metrics compared to the three other Tualatin River Basin streams evaluated: Beaverton, Fanno, and Chicken Creeks.

Tualatin River Fish Populations: Status and Trends

This section describes the status and trends for the focal fish species – winter steelhead, coho salmon, Pacific lamprey, and cutthroat trout. The focus is on characterizing their population status in the Willamette Tualatin River Basin. Later sections will describe the focal fish species' distribution and abundance for the Dairy-McKay Sub-Basin.

The Tualatin River enters the Willamette River above Willamette Falls. Historically, the Falls, which are nearly 40 feet in height, was an obstacle to fish migrating up the river and created a division between the lower and upper Willamette Basin. Spring Chinook salmon and winter steelhead, strong swimming fish with great ability to jump, could ascend the falls. While not strong swimmers, Pacific lamprey were also able to pass over the falls because they could attach to the rock walls with their oral discs and then ascend slowly while attached. Coho salmon could not make it over the falls because they are weak swimmers.

Spring Chinook salmon are not a focal species for this Action Plan. Chinook salmon juveniles rear in the lower Tualatin River but historically did not have a large spawning population in the Tualatin River Basin (Myers et al. 2006). Spring Chinook salmon prefer to spawn in colder tributaries originating from the Cascade Mountains.

It is difficult to overstate the cultural importance of winter steelhead, salmon, and Pacific lamprey to the Tribes. Tribal dependence on these fish as a food source pre-dates recorded history. It is estimated that, before the arrival of Europeans, more than a million spring Chinook salmon and steelhead returned annually to spawn in the Upper Willamette River Basin (ODFW and NMFS 2011). The limited available information on Pacific lamprey abundance trends comes from Willamette Falls harvest data. Harvest at Willamette Falls, which is primarily conducted by the Tribes, ranged from over 500,000 in the 1940s to less than 50,000 by the 1990s, although harvest counts are a poor index of Pacific lamprey abundance because they are influenced by regulations and harvest effort (Kostow 2002).

The construction of a fish ladder at Willamette Falls in the early 1900s provided fish passage for both the historical fish runs – spring Chinook salmon, winter steelhead, and Pacific lamprey – as well as coho salmon, which were not historically present in the upper basin before the ladders. Over the last two centuries, the combined effects of fish harvest, hatchery fish interactions, flood control, hydropower operations, and habitat alterations have led to drastic declines in the upper Willamette Basin's anadromous fish populations.

The declining abundance has resulted in Willamette River anadromous fish populations' listing under state and federal sensitive species designations. Willamette River spring Chinook and winter steelhead are listed under the federal ESA. The federal listing also includes recognizing streams occupied by winter steelhead as critical habitat if they contain physical or biological features essential to the species' conservation. The upper Tualatin River and Gales Creek are listed as critical habitat for the upper Willamette steelhead population (Federal Register 2005). Winter steelhead are present in the Dairy-McKay Subbasin, but the sub-basin's streams are not listed as critical habitat. Pacific lamprey populations are listed on the federal and State of Oregon sensitive species listings.

The lower Columbia River coho salmon population is listed as threatened under the ESA. This listing extends for coho salmon up to the Willamette Falls (e.g., including the Clackamas River). Still, it does not include the upper Willamette Basin coho salmon, including the Tualatin River runs, because this population was not historically native to the upper basin.

Coastal cutthroat trout are the predominant resident salmonid throughout the upper Willamette Basin. Cutthroat trout are also sensitive to habitat degradation, and populations are declining. The lower Columbia coastal cutthroat trout population is listed under Oregon's sensitive species listing, but the Willamette Basin population is not. Some local cutthroat populations have declined in the Willamette Basin, particularly in urban and other developed areas. A study of cutthroat trout populations in the Tualatin River Basin found that cutthroat trout populations were lowest in the urban areas and more robust in areas where there is better quality habitat (Leader and Hughes 2001). Table 4 describes the life history and status of Willamette River Basin and Tualatin River Basin winter steelhead, coho salmon, cutthroat trout, and Pacific lamprey populations.

Table 4. Dairy-McKay Sub-Basin focal fish species' life history overview and Willamette Basin and Tualatin River Basin population status

Focal Fish Species	Life History Overview	Willamette Basin and Tualatin River Basin Population Status
Winter Steelhead (*Oncorhynchus mykis*)	Upper Willamette River winter steelhead's run timing is a legacy of the fact that flow conditions allowed steelhead to ascend Willamette Falls only during the late winter and spring before construction of a fish ladder at Willamette Falls. As a result, the majority of the winter steelhead run return to freshwater in January through April passes Willamette Falls from mid-February to mid-May. Steelhead spawn in late March through June, with peak spawning in late April and early May. Compared to spring Chinook, steelhead typically migrates further upstream and can spawn in smaller, higher gradient (up to 8% gradient) streams [ODFW and The National Marine Fisheries Service (NMFS) 2011]. Steelhead eggs may incubate in the gravel for up to 50 days before hatching and an additional two to three weeks before emerging. Following emergence, steelhead fry will often seek refuge from fast currents by inhabiting stream margins and pool backwater habitats. As they begin to mature and grow larger, juveniles typically inhabit deeper water habitats of pools, riffles, and runs. Juvenile steelhead rear in headwater tributaries and upper portions of streams for one to four years (most often two years), then as smoltification proceeds in April through May, migrate quickly downstream through the mainstem Willamette River and Columbia River estuary and into the ocean.	NMFS designated critical habitat for Upper Willamette winter steelhead, including the upper Tualatin River and the Gales Creek system, in 2005. Streams within the Dairy-McKay Subbasin were not designated critical habitat. The steelhead population includes all historically independent winter-run steelhead populations in Willamette River tributaries upstream from Willamette Falls to the Calapooia River (inclusive). Winter steelhead have been reported spawning in the west-side tributaries to the Willamette River above Willamette Falls. ODFW recognizes the Tualatin, Yamhill, Rickreall, and Luckiamute west-side tributaries as part of the Upper Willamette River winter steelhead population. However, these tributaries were not considered to have constituted independent populations historically and are not part of the Upper Willamette River steelhead Distinct Population Segment (DPS). Under current or future conditions, steelhead production from west-side tributaries may help buffer or compensate for independent populations not meeting recovery goals (ODFW and NMFS 2011). In future ESA assessments, ODFW proposes exploring with NMFS the possible inclusion of these production areas within the DPS. ODFW currently uses February 15 to discriminate between native and nonnative (Big Creek Hatchery) winter steelhead ascending Willamette Falls (Myers et al. 2006).

Focal Fish Species	Life History Overview	Willamette Basin and Tualatin River Basin Population Status
Coho salmon (*O. kisutch*)	Coho salmon enter the upper Willamette Basin in November through January. Duration of coho salmon egg incubation and fry emergence is greatly affected by water temperature but generally takes between two and three months. Emergence primarily occurs from February through April and peaks in March. Following emergence, juvenile coho salmon typically seek stream margin habitats and backwater pools for initial rearing. As they continue to grow in size, juveniles seek low-gradient, low-velocity pool and off-channel habitats for summer and winter rearing. Juvenile coho favor beaver ponds and slack water habitats with complex large woody debris for protection from winter freshets. Juvenile coho typically migrates to the ocean at about 12 to 14 months of age. The timing of juvenile coho outmigration is usually late March through June, peaking in April and May. Coho salmon in the Lower Columbia River generally rear in the ocean for two summers and return as three-year-olds. The primary exception is "jacks," sexually mature males that return to fresh water after spending one summer in the ocean (Myers et al. 2006).	Coho populations are not native to the upper Willamette Basin but have successfully colonized tributary systems, including the Tualatin River, Diary Creek, and McKay Creek. The population is now self-sustaining.
Coastal cutthroat trout (*O. clarki clarki*)	Coastal cutthroat trout spawning periods vary from late winter to summer, depending on life-history type. Female cutthroat trout commonly lay between 200 to 4,000 eggs in gravel redds. Eggs typically hatch within four to eight weeks, depending on water temperature, and fry spend one to two weeks in the gravel before emerging. Resident cutthroat trout remain for the most part in their natal streams as juveniles and adults. Some cutthroat trout will migrate into the river to reside after a year in their natal stream (fluvial population).	Cutthroat trout appear to be the predominant resident salmonid throughout the Willamette Basin.
Pacific lamprey (*Entosphenus tridentatus*)	After hatching, Pacific lamprey spend about 4-7 years rearing in freshwater as filter-feeding larvae (ammocoetes) prior to metamorphosing and migrating to the ocean (Schultz et al. 2014). Because freshwater rearing consists of a relatively high fraction of the Pacific lamprey's life cycle, this stage is generally viewed as critical for the viability of the species. Following the rearing period, lampreyammocoetes undergo a physiological and morphological transformation into macrophthalmia, and subsequently	The Willamette River appears to have one of the highest returns of lamprey of any of the Columbia River tributaries. It supports one of the only remaining traditional tribal harvest locations in the Columbia River Basin. Pacific Lamprey populations are declining throughout the Columbia River Basin. Willamette River lamprey populations are also declining: estimated

Focal Fish Species	Life History Overview	Willamette Basin and Tualatin River Basin Population Status
	outmigrate to the ocean. The parasitic marine phase lasts less than 3.5 years, after which they return to freshwater. Pacific lamprey enter freshwater in the late spring and summer and hold 8-12 months in the Willamette River or larger tributaries before making a final migration to their ultimate spawning areas. Spawning occurs from March to July; timing varies with water temperature and location. Both sexes participate in redd construction, and individual lamprey typically build multiple redds. Pacific lamprey are gregarious spawners, and researchers have observed up to 12 adults within an individual redd (Schultz et al. 2014).	harvest in the Willamette River declined from ~250,000 pounds in 1943 to less than 12,000 since 2001 (Schultz et al. 2014). Recent population estimates at Willamette Falls ranged from 63,517 to 245,325 between 2010 and 2012, respectively (Schultz et al. 2014). Pacific lamprey populations are listed as "vulnerable" on the Oregon State Sensitive Species list.

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6. Factors Limiting Watershed Health and Fish Populations

The scientific evidence is well established that to survive and successfully reproduce the next generation, winter steelhead, coho salmon, cutthroat trout, and Pacific lamprey require clean water, specific ranges of water temperatures, and critical stream habitat characteristics, including good graveles, connection to floodplains, large wood, pools, and other features. Less is known about the factors that limit Pacific lamprey. Still, a growing number of research studies are providing clues into the habitat, water quality, and other problems that affect Pacific lamprey populations.

In general, the factors limiting focal fish populations can be categorized into four categories: 1) Fish passage barriers, 2) Impaired aquatic habitat, 3) impaired riparian and floodplain habitat and vegetation, and 4) degraded water quality and quantity.

Fish Passage Barriers

Fish passage barriers include obstacles that block or slow migration for adults seeking spawning areas or attempting to access different habitats or cool water areas. Barriers can also affect juveniles by slowing or blocking passage into tributaries that contain cooler water during the summer and refuge from high flows during the winter and spring. Dams that span a stream channel and road crossing culverts are examples of fish passage barriers that can totally or partially block adult or juvenile fish access.

Winter steelhead, coho salmon, and cutthroat trout have similar fish passage requirements. Culverts and dams commonly block or impede fish passage by creating an obstacle that fish must jump through or over. While some adult steelhead can jump to heights of over four feet, most fish cannot. In addition, water can move through culverts or other obstacles at very high velocities, which can exceed a fish's swimming ability. The velocity of water flowing through a culvert is determined by a number of factors, but the primary factor is the gradient of the culvert. A very steep culvert (high gradient) will increase velocities more than a very flat culvert.

Fish passage is a concern for adult and juvenile winter steelhead, coho salmon, and cutthroat trout. Most criteria for fish passage are designed to accommodate juveniles since they are the most vulnerable life stage and are the weakest swimmers, and can a 6-inch drop can prevent fish access.

For example, guidelines for fish passage developed by ODFW specify that culverts need to be installed at a gradient of less than 0.5 percent and have no more than a 6-inch drop at the outlet.

Many fish ladders and road crossings designed to pass salmon and winter steelhead may impede or block passage by Pacific lamprey due to considerable differences in behavior and swimming ability between salmonids and Pacific lamprey. For example, Pacific lamprey cannot effectively navigate culverts with excessively high-water velocities, vertical drops, or sharp angles (Stillwater Sciences 2014). When confronted with high velocities, Pacific lamprey will use their oral discs to attach to substrate and rest before continuing upstream. Their ability to adhere to the substrate within a road crossing culvert is crucial to whether they can pass through the culvert. Pacific lamprey cannot jump, so even a culvert with less than a 6-inch drop at the outlet can block movement upstream. Pacific lamprey can ascend vertical walls at waterfalls if the water velocities are not extreme and there is sufficient variation in the surface to allow the oral disk to attach. Water diversion and other dams present a significant passage problem for Pacific lamprey because the surface is often too smooth for oral disk attachment. They cannot pass over the right angles, which often present at the lip of the dam.

Fish Passage Barrier Evaluation

A list of potential Dairy-McKay Sub-Basin fish passage barriers was compiled from existing inventories, including the following datasets: Washington County Fish Passage Barriers (2020), ODFW Fish Passage Barriers (2018), TRWC Private Lands Barrier Study (2016), and the Rapid Bio-Assessment (RBA) survey (2013 and 2014). The barriers were mapped, and each barrier was cross-referenced with other sources to remove duplicates. Field notes were compiled from each of barrier inventories, and barriers identified in the RBA were reviewed closely for information on barriers and passage status for juvenile and adult fish. Information to determine the fish passage status, including evaluating if they are partial or complete barriers to juvenile and adult fish, was not available for all barriers. For that reason, some of the identified passage barriers should be considered potential barriers until further information is collected. Table 5 summarizes the number of known and potential fish passage barriers for the Dairy-McKay Creek Sub-Basin's watersheds.

Table 5. Potential Dairy-McKay Sub-Basin fish passage barriers

Sub-Watershed	Number of potential fish passage barriers
Upper West Fork Dairy Creek	78
Middle West Fork Dairy Creek	77
Lower West Fork Dairy Creek	43
Upper East Fork Dairy Creek	57
Lower East Fork Dairy Creek	77
Upper McKay Creek	52
Lower McKay Creek	56
Council Creek-Dairy Creek	35

After reviewing available data for each barrier, the barriers were listed by status as either a partial barrier or blocked. A partial barrier is that adult fish can swim through or pass upstream, but juveniles are not able to jump high enough to get through the culvert (i.e., greater than 6-inches jump height). Blocked status means that adult fish are not able to pass through. Barriers were also classified as a velocity barrier (e.g., flow velocities through the culvert exceed fish swimming ability or by the height of culvert drop to the summer's (low water) water surface.

The barriers with potential habitat upstream were prioritized for improvement actions based on the following three criteria:

1) The length of winter steelhead habitat above the barrier,

2) Quality of habitat above the barrier based on winter steelhead intrinsic potential (I.P.) scores, and

3) The presence of cool water temperatures above the barrier – i.e., fish accessible thermal refugia.

See **Appendix 2** for detailed information on the barrier prioritization criteria.

Table 6 and Figure 5 show the priority fish passage barriers. The Dairy-McKay Sub-Basin has relatively good fish habitat connectivity. The fish passage barriers are present in tributary streams and not the mainstem portions of Diary or McKay Creeks. Therefore, most fish habitat is accessible, and there are not extensive areas with high-quality habitat inaccessible to fish.

The highest priority culvert removal projects for restoring aquatic connectivity are in the Upper West Fork Dairy Creek Sub-Watershed. In addition to Upper West Fork Dairy Creek, there are opportunities to address barriers in the Upper East Fork Dairy Sub-Watershed. Most of the barriers affect both the anadromous fish species and resident cutthroat trout. There are two barriers in the Upper McKay Sub-Watershed in an area not accessible to coho salmon and winter steelhead because the habitat is above McKay Falls, a natural fish passage barrier. Habitat above the falls is occupied by cutthroat trout, and Pacific lamprey may navigate the falls to access upstream habitats, but this needs to be confirmed. Addressing the Upper McKay Creek barriers may be an opportunity to improve habitat connectivity for an isolated cutthroat trout population and also benefit Pacific lamprey. See **Appendix 2** for more information on priority barrier status and characteristics.

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Table 6. Dairy-McKay Sub-Basin fish passage barrier action priorities

ID#	Stream Name	Barrier Type	Description	Fish Passage Status	Status (drop to pool in feet)	Priority
UWFD_2	Mendenhall	Culvert	Round	Partial	Juvenile – 2.0 drop	HIGH
UWFD_3	Burgholzer	Culvert	Round	Partial	Juvenile – 1.3 drop	HIGH
UWFD_1	Mendenhall	Culvert	Round	Partial	Velocity	HIGH
UWFD_8	Upper WF Dairy Main	Debris mix	Concrete/ debris	Blocked	Blocked Adult	HIGH
MWFD_1	Sadd – Canyon Creek	Culvert	Round	Partial	Velocity	HIGH
UMCK_1	EF McKay	Culvert	Round	Unknown	Confirm if removed	HIGH
UWFD_6	Paisley - Burgholzer	Culvert	Round	Partial	Juvenile – 0.5 drop	HIGH
UWFD_7	Trib A	Culvert	Round	Partial	Juvenile – 1.3 drop	HIGH
MWFD_2	Sadd – Canyon Creek	Culvert	Round	Partial	Velocity Juvenile	MODERATE
MWFD_3	Sadd – Canyon Creek	Culvert	Round	Partial	Velocity	MODERATE
MWFD_4	Sadd – Canyon Creek	Culvert	Round	Partial	Velocity	MODERATE
UEFD_2	Campbell	Culvert	Round	Partial	Juvenile – 2.5 drop	MODERATE
UWFD_4	Burgholzer	Culvert	Round	Partial	Juvenile – 0.8 drop	MODERATE
MWFD_5	Sadd – Canyon Creek	Culvert	Round	Culvert	Round	MODERATE

ID#	Stream Name	Barrier Type	Description	Fish Passage Status	Status (drop to pool in feet)	Priority
UEFD_3	Upper EF Dairy Main	Culvert	Round	Blocked	Blocked – 3.6 drop	MODERATE
UWFD_5	Burgholzer	Culvert	Round	Partial	Velocity	MODERATE
MWFD_6	Kuder	Culvert	Open Box	Partial	Juvenile – 0.5 drop	MODERATE
MWFD_7	Kuder	Culvert	Open Box	Partial	Juvenile – 0.75 drop	MODERATE
UEFD_1	Denny	Culvert	Unknown	Blocked	Blocked	MODERATE
Additional Priorities for Upper McKay Creek Cutthroat Trout Isolated above Falls						
UMCK_2	Upper Mckay Main	Culvert	Round	Partial	2.0 drop	
UMCK_3	Upper McKay Main	Culvert	Round	Partial	2.3 drop	

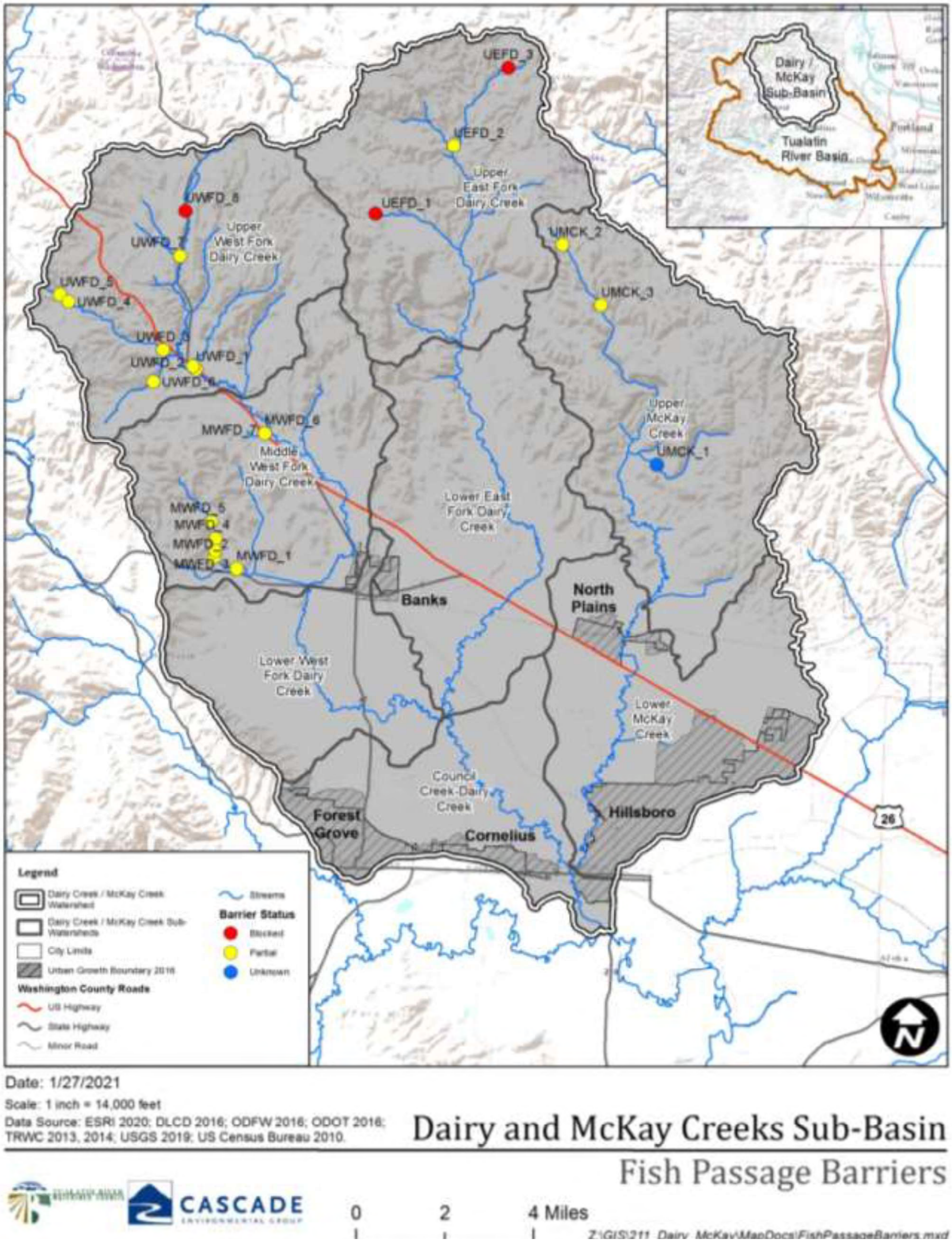


Figure 5. Dairy-McKay Sub-Basin priority fish passage barriers

Aquatic Habitat and Fish Populations

Stream habitat that does not provide the full range of necessary habitat features over the course of the fish's life cycle can limit fish populations. Key aquatic habitat factors that limit winter steelhead, coho salmon and cutthroat trout populations include pools and riffles with inadequate large wood and cover to allow adult and juvenile fish to feed, rest, and hide from predators; stream channel substrate (gravels, cobbles, etc.) with inadequate quantities or distribution for spawning and egg incubation; and high sediment loads that cover eggs, leading to mortality.

For the most part, Pacific lamprey require habitat qualities similar to trout and salmon habitat requirements, but there are differences due to their specific life cycle needs. Larval Pacific lamprey need low-velocity habitats with fine sediments. Pacific lamprey larvae are most abundant in areas composed of deep, fine sediment that provide suitable burrowing habitat, particularly off-channel habitats (Schultz et al. 2014).

Pacific lamprey are spawning generalists, capable of spawning in a wide diversity of stream sizes, ranging from small streams to larger rivers and underlying geologic types, provided there are no barriers to upstream migration. Similar to trout and salmon, spawning Pacific lamprey deposit their eggs in depressions (redds) that they construct. Pacific lamprey redds are most abundant in stream areas associated with gradient breaks (e.g., pool tailouts and run habitats) composed of gravel and cobble substrates, similar to trout and salmon spawning requirements (Schultz et al. 2014).

Aquatic Habitat and Fish Population Evaluation

Dairy-McKay floodplain habitats historically provided diverse and dynamic habitats for the focal fish species. Juvenile coho, winter steelhead, and cutthroat trout can access side channels, alcoves, and floodplain wetlands to feed and escape flood events. While winter steelhead and cutthroat trout benefit from side channels and other off-channel habitats for feeding and refuge from high flows, these habitats are essential for coho. Access to off-channel habitats is critical for survival during winter high flow events and it the key limiting factor for coho populations across most of their range.

Figure 6. Relative elevations of floodplain surfaces shows the NetMap-derived relative height of streamside floodplain surfaces throughout the Diary-McKay Sub-Basin. The relative floodplain surface height is measured in multiples of stream bankfull height. Bankfull height is the water surface elevation during common high-flow events (e.g., a two-year flood). Bankfull height is the elevation where any additional water from flooding will spill onto the adjacent floodplain surface. The water surface height relative to bankfull height gauges how often the floodplain surface interacts with streamflow. Floodplain areas that are one or fewer multiples of bankfull height will interact more often with floods than floodplain areas that are, for example, five multiples of bankfull height.

Relative floodplain surface elevations are a good indicator of how accessible off-channel habitats (e.g., floodplain wetlands) are to fish. Figure 7 shows the relative elevations of floodplain surfaces and the number of coho observed in pools based on the RBA. The number of coho observed in pools roughly corresponds to areas where the stream can interact with the floodplain, providing fish access to off-channel habitats.

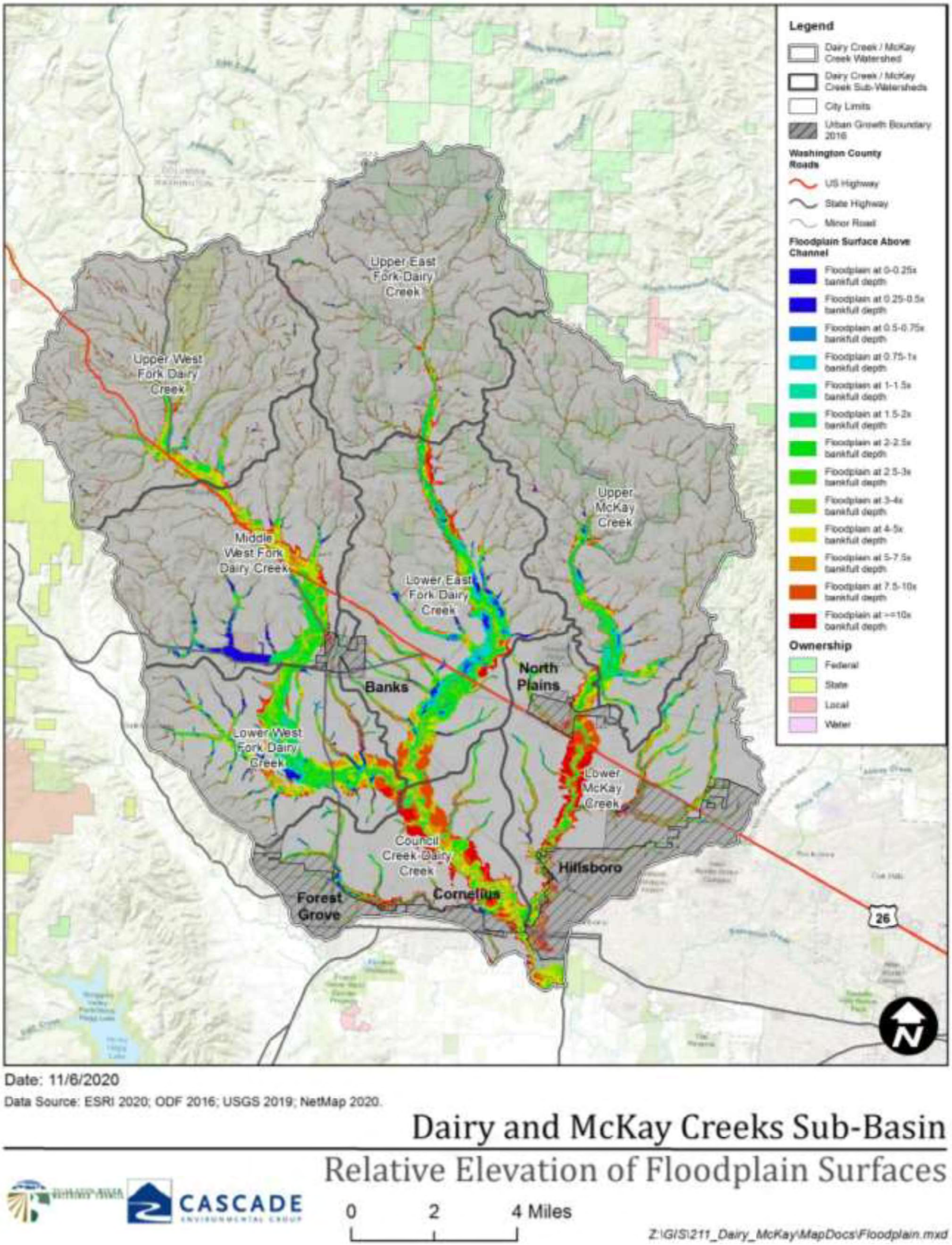


Figure 6. Relative elevations of floodplain surfaces based on multiples of bankfull depth

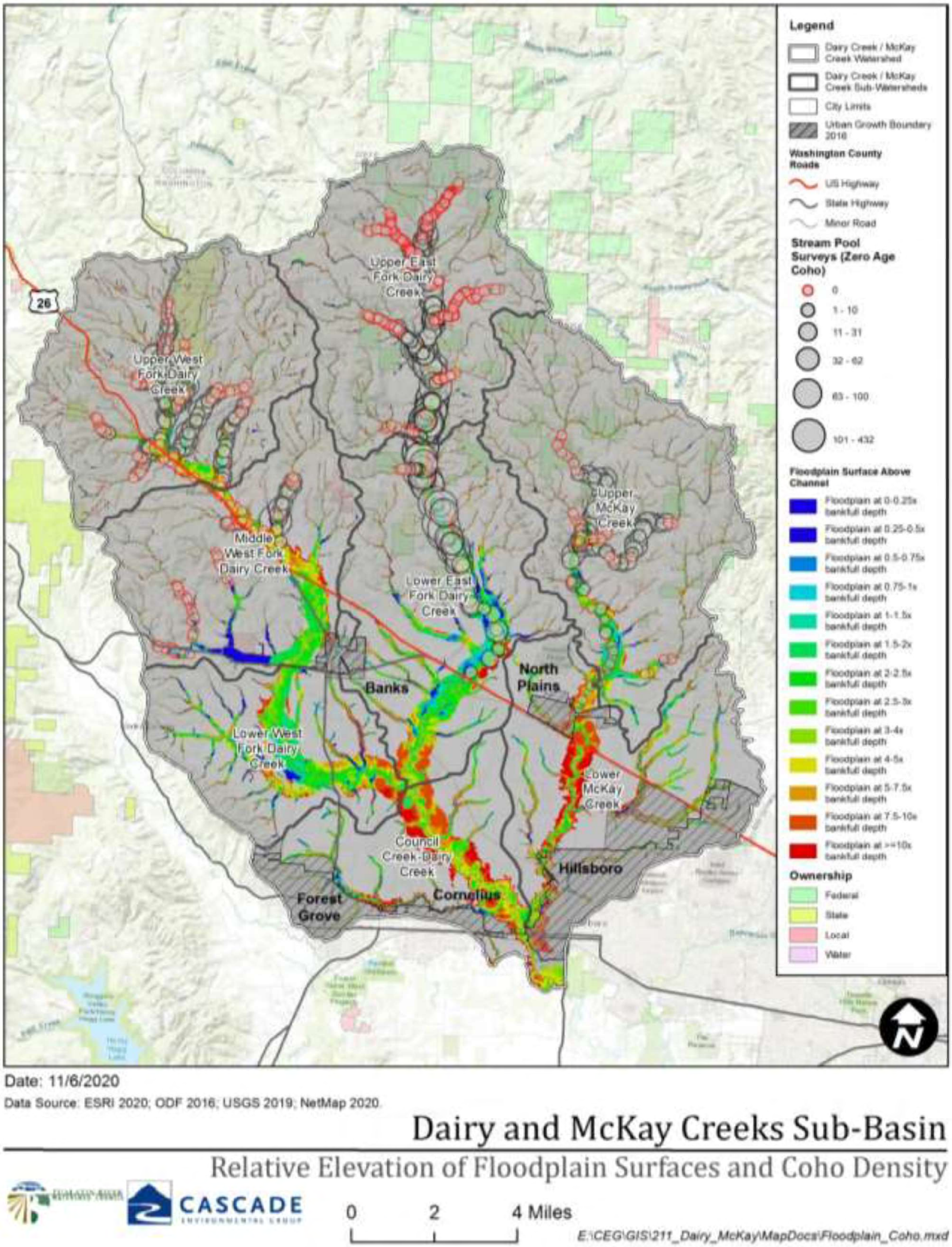


Figure 7. Relative elevations of floodplain surfaces and the number of coho observed in pools

The Dairy-McKay Sub-Basin accounts for the greatest number of juvenile coho, winter steelhead and adult cutthroat in the Tualatin River Basin, based on RBA data (Table 7). Nearby Gales Creek provides substantial fish habitat capacity, but the Dairy-McKay Sub-Basin contains nearly double the number of coho, and substantially more winter steelhead and cutthroat trout. In contrast to juvenile coho, winter steelhead and cutthroat trout were observed at lower numbers but with a similar distribution as coho: Primarily residing in the mainstem, with much lower fish numbers in the tributary streams. The East Fork of Dairy Creek has the largest number of fish observed in the RBA.

Water temperatures appear to constrain fish distribution. The RBA concluded that most of the observed fish are present above Highway 26, roughly the dividing line between the Tualatin Plan and the upper mountainous portions of the sub-basin where water temperatures are cooler. The RBA noted that the highest densities of fish in the Dairy-McKay system were observed in East Fork Dairy Creek. East Fork Dairy Creek side channels, where cool water temperatures were recorded, have the highest densities of winter steelhead and coho in the Diary-McKay system (Table 7; Figure 8). Figure 9 and **Error! Reference source not found.** show Dairy-McKay Sub-Basin winter steelhead and cutthroat trout pool counts, respectively.

Table 7. Estimated numbers of coho salmon, winter steelhead, and cutthroat trout in the Tualatin River Basin streams surveyed in 2013 with the RBA protocol. Source: Bio-Surveys, LLC 2014

Tualatin River Basin Sub-Basin and Watershed	Steelhead	Coho Salmon	Cutthroat Trout
Tualatin River	132	3,938	640
Gales Creek Sub-Basin	650	26,805	4,055
Gales / Tualatin Total	**782**	**30,743**	**4,695**
East Fork Dairy Creek Watershed	1,965	37,124	3,776
McKay Creek Watershed	0	8,855	1,984
WF Dairy Creek Watershed	0	13,369	1,565
Dairy-McKay Sub-Basin Total	**1,965**	**59,348**	**7,325**

Fish access to mainstem Dairy and McKay Creek's off-channel floodplain habitats during the winter and in the summer is a crucial factor in the system's capacity to support coho, winter steelhead, and cutthroat trout. Water temperatures limit summer off-channel fish access. Off-channel features, such as side channels with cool water temperatures, can accommodate very high fish densities.

Floodplain areas and off-channel habitats throughout the Dairy-McKay Subbasin have been modified through channel straightening, levees, wetland modification, removal of large wood, and other land use activities.

Pacific lamprey larvae require floodplain connectivity for juvenile rearing. Lamprey juveniles are found in large numbers in off-channel habitats because these areas provide the deep, fine sediments that provide suitable burrowing habitat. In a survey of Willamette Basin lamprey habitats, mean Pacific lamprey density in off-channel habitats was 10 times greater than in main-channel habitats (Schultz et al. 2014).

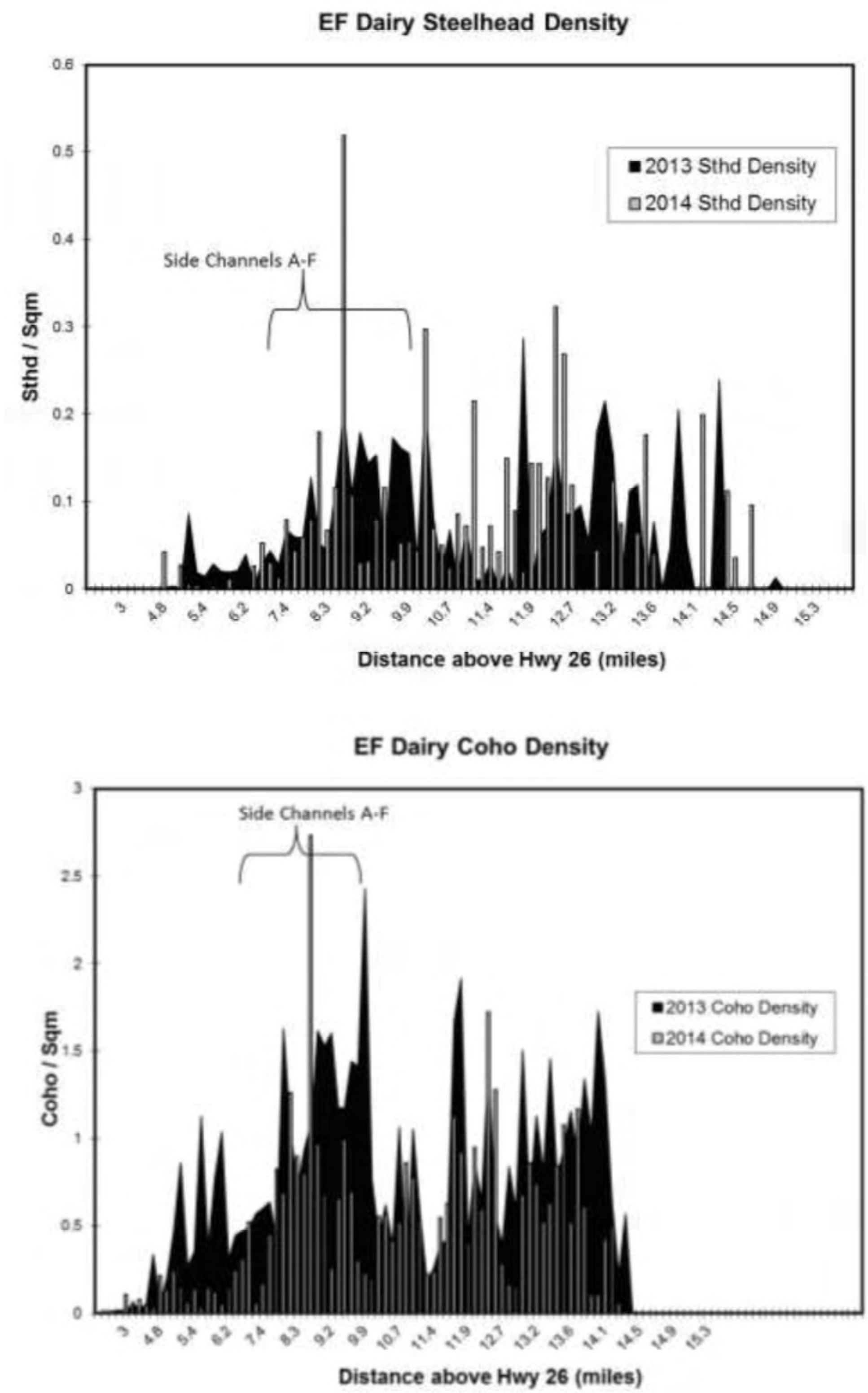
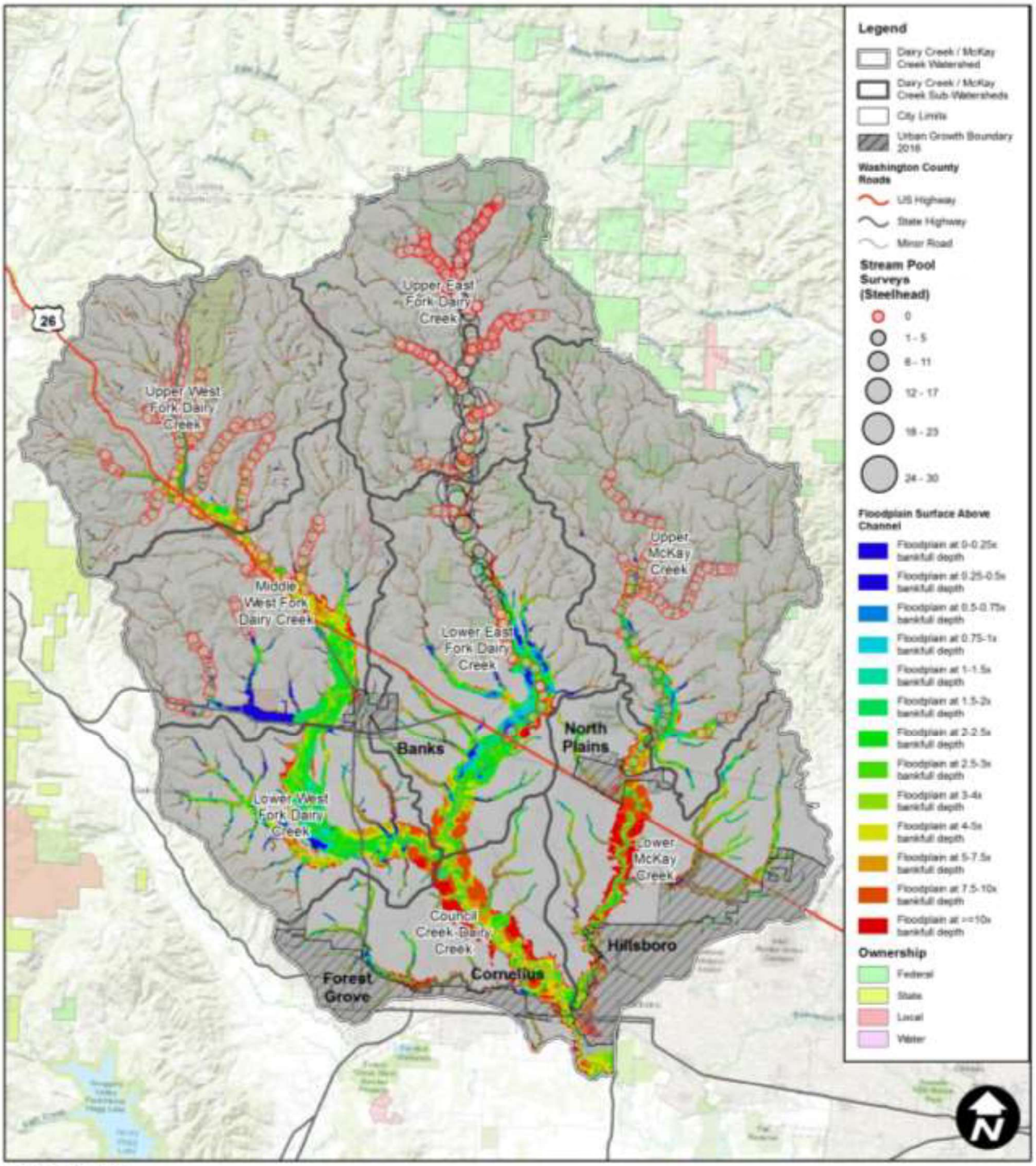


Figure 8. East Fork Dairy-Creek winter steelhead and coho pool and side-channel densities



Date: 11/6/2020

Data Source: ESRI 2020; ODF 2016; USGS 2019; NetMap 2020.

Dairy and McKay Creeks Sub-Basin

Relative Elevation of Floodplain Surfaces and Steelhead Density

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Figure 9. Relative elevation of floodplain surfaces and number of winter steelhead observed in pools

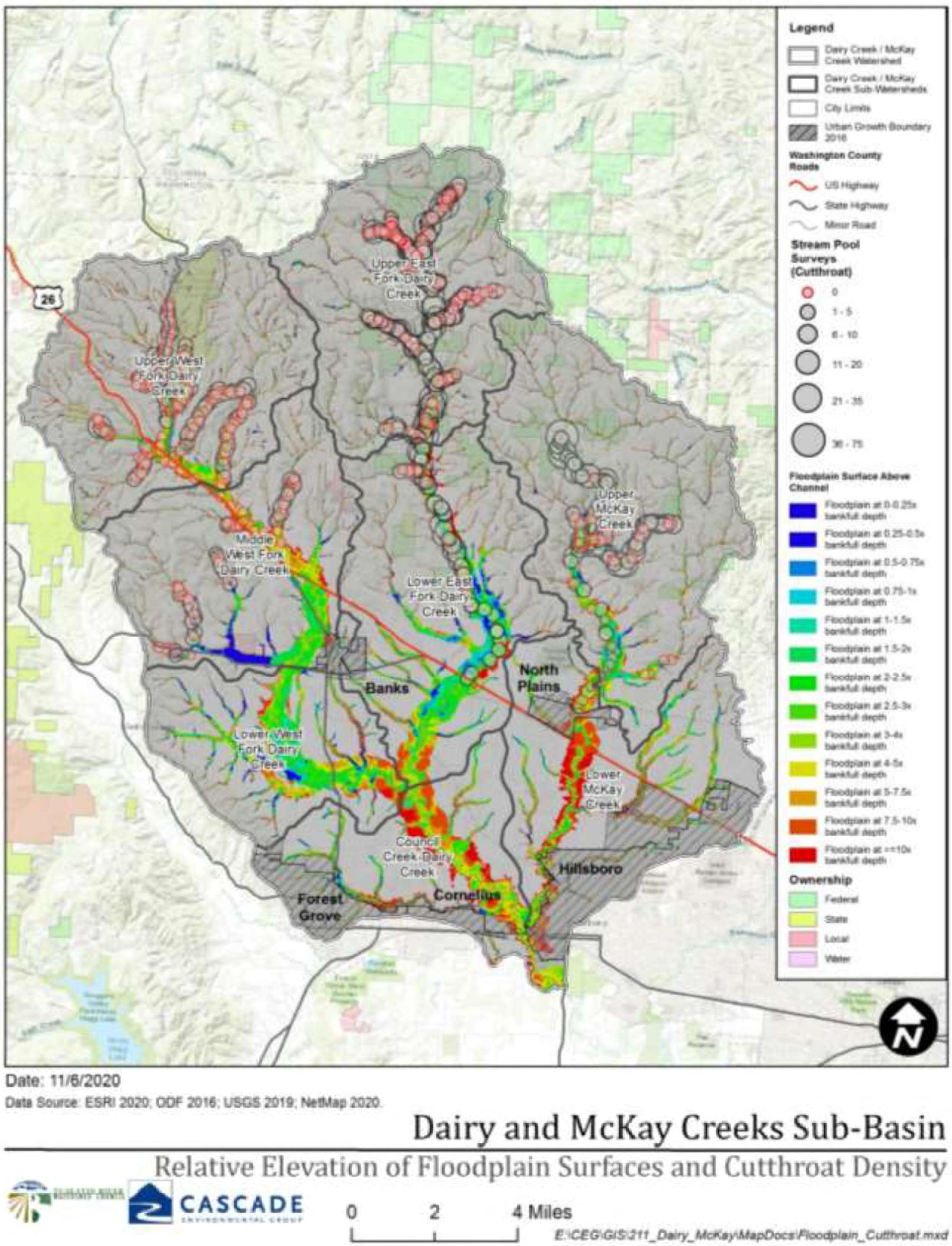


Figure 10. Relative elevation of floodplain surfaces and the numbers cutthroat trout observed in pools

Riparian and Floodplain Vegetation

Riparian area and floodplain vegetation and habitat attributes can limit winter steelhead, coho salmon, cutthroat trout, and Pacific lamprey populations. These attributes include inadequate shade over streams, which contribute to higher temperatures; insufficient supplies of leaf litter and other organic matter necessary to support the food web; and limited large wood inputs from large trees falling into channels.

Riparian and Floodplain Vegetation Evaluation

Historically, riparian and floodplain vegetation in the Dairy-McKay Sub-Basin was characterized by large conifers, deciduous trees, and other native vegetation. Riparian and floodplain vegetation has been modified through streamside timber harvest, clearing vegetation for agriculture and homes, and extensive road-building adjacent to streams. Over the previous 150 years, large Douglas firs and other trees with commercial value have been harvested.

Large wood in streams forms complex and diverse habitats by creating pools, capturing gravels, and providing cover, and these are all important habitat attributes for fish. Historically, there was abundant large wood in channels. Over time large wood was removed from stream channels to reduce local flooding and in the mistaken belief that wood jams restricted fish access. Splash-dams and log drives down stream channels also altered the distribution and quantities of large wood.

Oregon Forest Practices Rules and restoration actions designed to improve riparian vegetation create larger riparian buffers, and improve native vegetation next to streams. While these actions enhance habitats and watershed processes, riparian and floodplain vegetation has not recovered to historical levels. It will take more time for trees to grow large enough to contribute substantial wood pieces to streams.

Figure 11 shows the number of riparian tree pieces NetMap predicts will fall into Dairy-McKay Sub-Basin stream sections (approximately 100 meters) per year. The model output, which is based on interpreting tree size and age from satellite imagery, is for trees at least 25 to 50 cm diameter at breast height (dbh), a relatively small tree. Much of the watershed is now covered by second- and third-growth forests. The small tree size and young age mean relatively few trees are falling into streams. It will take decades for riparian trees to grow and contribute adequate large wood to stream channels. In the meantime, placing large wood in streams can help "jump-start" the creation of complex fish habitats while riparian vegetation recovers.

Figure 12 shows optimized shade effectiveness, a relative measure of how effective riparian shade enhancement reduces solar heating and resulting water temperatures. NetMap evaluated stream thermal load changes (with and without vegetation) to determine where the most thermally at-risk streams are located in the Diary-McKay Sub-Basin. Thermal loading (watt-hours/m^2) to streams is calculated based on channel width and orientation, topographic shading, and existing vegetation shading.

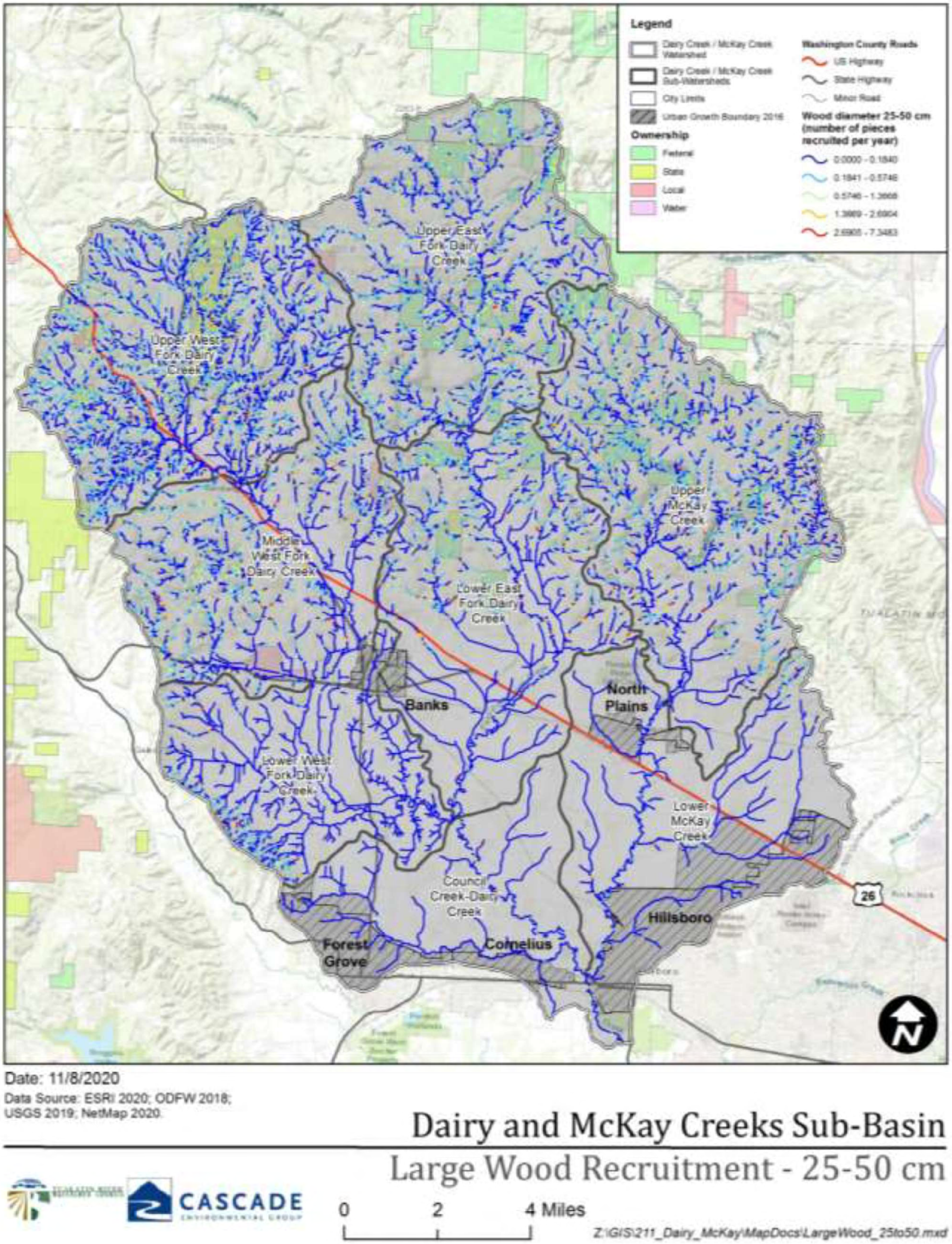


Figure 11. Number of pieces of large wood recruited to stream channels per year for trees at least 25 to 50 cm dbh

Riparian shade patterns in the sub-basin are primarily driven by the size and density of trees along streams. In the mountainous upper sub-basin, where forestry is the primary land use, dense tree stands along streams provide adequate shade. There are few opportunities where the additional shade will substantially reduce thermal loading on the stream. In contrast, in the lower sub-basin, where agricultural, rural residential and urban lands are located, there are fewer riparian trees and narrower buffers shading streams. In this area, enhancing shade along streams will reduce solar exposure and contribute to stream temperature cooling. Lower East Fork Dairy Creek Sub-Watershed, for example, has extensive opportunities to improve riparian shade. Figure 13 shows optimized shade effectiveness for Lower East Fork Diary Creek.

For more detailed information on stream and riparian attributes, see **Appendix 3** for summaries of reach-specific NetMap data.

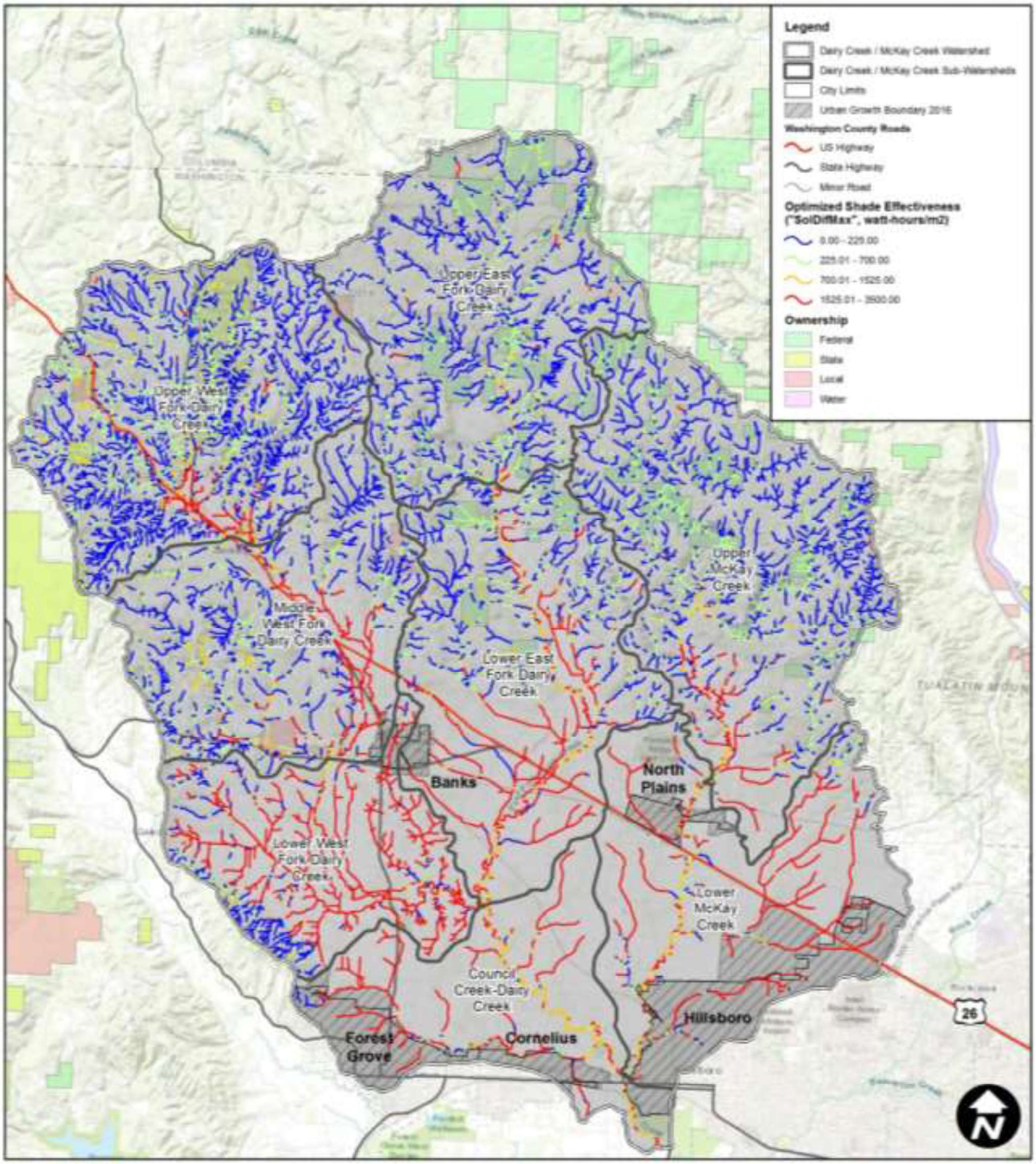
Water Quality and Quantity

Impaired water quality, mainly increased water temperatures, can limit coho salmon, winter steelhead, and cutthroat trout populations. Water temperatures that exceed 18°C (64.4^{0}F) for sustained periods during the summer and early fall can stress fish, leading to a weakened condition, increased susceptibility to disease, and mortality (Richter and Kolmes 2005). Fish will move from warm water areas into cooler water habitats within the stream or tributaries if a culvert or other barrier does not block access. Other water quality problems that can affect fish include inadequate dissolved oxygen levels (caused by high water temperatures or increased nutrients), high levels of pesticides, and the presence of other chemicals (e.g., copper) that affect fish behavior or reproductive success.

Reduced water quantities from water withdrawals or other uses can limit fish populations. Reducing stream flows can increase water temperatures in the summer and early fall because of the reduced volume of water subject to heating. Water diversions can dewater sections of streams, effectively blocking fish movement through the dry channel areas.

Very little is known about Pacific lamprey's water quality requirements, but it is clear that lamprey are sensitive to water temperatures. For example, spawning is generally initiated when water temperatures are in the 10 -15°C range, and seasonal hydrographs are descending (Schultz et al. 2014). It is unknown if Pacific lamprey's tolerance for high water temperatures is similar to trout and salmon.

Upon entry into freshwater, Pacific lamprey do not home into their natal stream as winter steelhead and salmon do. Instead, bile acid chemicals from upstream larval lamprey are attracting pheromones to adult Pacific lamprey, drawing them into the spawning tributary. Environmental pollutants can disrupt other fishes' physiology and behavior, but the extent to which specific chemicals affect Pacific lamprey migration is unknown (Schultz et al. 2014).



Date: 11/8/2020

Data Source: ESRI 2020; ODFW 2018; USGS 2019; NetMap 2020.

Note: SolDifMax field based on LEMMA data, bare earth, and difference between reach value and watershed maximum.

Dairy and McKay Creeks Sub-Basin

Optimized Shade Effectiveness

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Figure 12. Optimized shade effectiveness

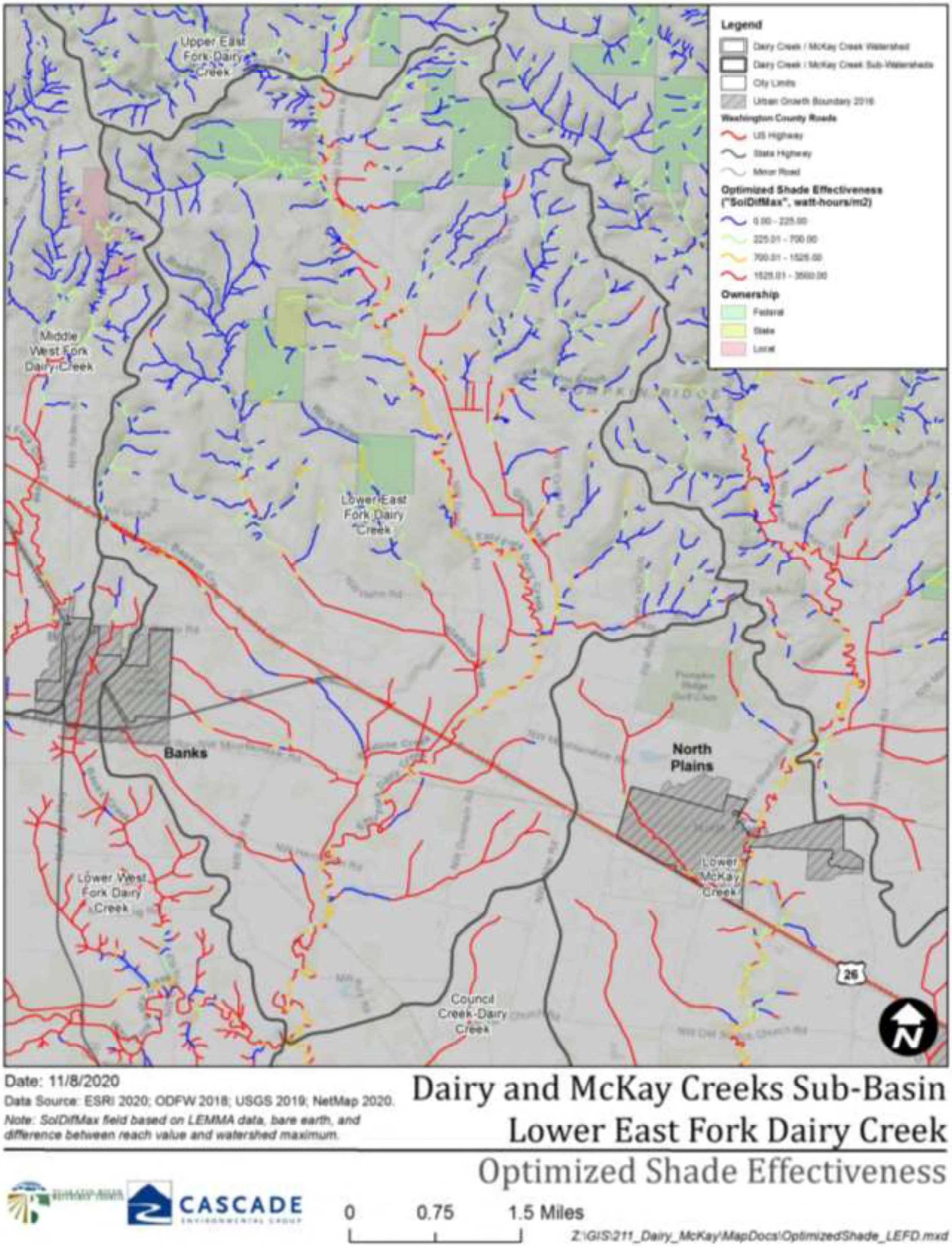

Figure 13. Lower East Fork Dairy Creek optimized shade effectiveness

Water Quality and Quantity Evaluation

The Diary-McKay Sub-Basin's hydrology has been altered through wetland drainage, stream channelization, development, and water diversion for agriculture. Over 90% of water rights are allocated for irrigation (TRWC 2012). Water rights in the watershed are over-allocated during much of the year, and most of the water rights are senior to existing instream rights (TRWC 2012). Flow diversion for irrigation during the summer months exacerbates already high water temperatures. The 18°C (64.4°F) water temperature threshold is exceeded in most years in Dairy and McKay Creeks. For example, East Fork Diary Creek (near Meacham Conner) exceeded the water temperature threshold for 39 days between June 16 and September 8, 2019 (Bonn 2019).

To improve water temperatures and dissolved oxygen levels, Clean Water Services (CWS) partners with the Tualatin Valley Irrigation District (TVID) to deliver water to the Dairy-McKay Sub-basin in the summer and early fall (Bonn 2019). Approximately 1 to 2.5 cfs of water has been added to McKay Creek every year since 2005. Similar measures have been implemented for sites on the East and West Forks of Dairy Creek (Table 8).

Table 8. Dairy-McKay Sub-Basin flow augmentation sites. Source: Bonn 2019

Stream	River Mile (RM)	Year Initiated	Flow Augmentation Range (cfs)
McKay Creek	7.0	2005	0.5 – 3.0
East Fork Dairy Creek	4.9	2010	0.5 – 1.6
West Fork Dairy Creek	5.2	2011	0.4 – 1.0

The flow augmentation program aims to increase base flows in the tributaries and improve water quality, with a specific intention of decreasing stream temperatures and increasing dissolved oxygen concentrations (Bonn 2019). The period of flow restoration begins in mid-June and ends in late October (Stillwater Sciences 2016).

A recent study evaluated the effectiveness of flow augmentation at the McKay and East Fork Dairy Creek sites (Stillwater Sciences 2016). In general, beneficial effects were noted for both temperature and dissolved oxygen in both streams. The proportionately greater discharges added to McKay Creek resulted in proportionately greater benefits relative to East Fork Dairy Creek's observed benefits.

The study collected McKay and Dairy Creek data at two locations: An upstream control and a downstream treatment site. Continuous temperature data were collected and summarized as seven-day average maximum temperatures compared to the fish biological threshold of 18°C (Stillwater Sciences 2016).

Augmentation flows significantly affected water temperature patterns in McKay Creek, with maximum temperatures at the control and treatment locations diverging with the added flow. The difference in stream temperatures continued through the end of August when maximum temperatures at the treatment and control sites fell below 18°C. Temperatures were as much as 3.5°C cooler at the treatment site and exceeded the 18°C biological threshold for 55 fewer days than the control site – 87 vs. 32 days over the 136 days of treatment (Stillwater Science 2016).

Beneficial temperature effects were less pronounced at the East Fork Dairy Creek site. Maximum temperature values were no more than 1.1°C lower at the treatment location than at the control location. The number of days over 18°C was reduced by eight days (Stillwater Sciences 2016).

Flow augmentation had an immediate and beneficial effect on McKay Creek's dissolved oxygen values. Augmentation maintained dissolved oxygen values above the absolute minimum threshold for nearly the entire summer period. In contrast, the control location in McKay Creek had slight but consistently higher dissolved oxygen concentrations than the treatment location (Stillwater Sciences 2016).

East Fork Dairy Creek showed minimal impacts from flow augmentation. The dissolved oxygen levels were already well above the minimum threshold value for both the treatment and control locations, so the minimal effectiveness of flow restoration on dissolved oxygen. had no significant biological consequences (Stillwater Sciences 2016).

The Northwest Stream Temperature (NorWeST) database provides spatially continuous water temperature maps (Isaak et al. 2017). The NorWeST database combines water temperature data from multiple sources to summarize water temperature patterns for streams throughout the Pacific Northwest. Using the framework provided by the National Hydrography Dataset, the NorWeST database hosts continuous temperature recordings from >22,700 stream and river sites. Spatial-stream-network models were fit to a subset of the water temperature data to describe mean August water temperatures. See **Appendix 4** for background on NorWeST data and models.

Figure 14 shows Dairy-McKay Sub-Basin mean August stream temperature patterns derived from the NorWeST database that compiled stream temperature data collected between 1993 and 2011. Most of the stream channels in the lower portion of the sub-basin, and many in the upper sub-basin, show August mean temperatures at or above the 18^{0}C threshold. Mean August water temperatures less than 18^{0}C are primarily within upper portions of the sub-basin. The stream channels with cooler water roughly correspond to the RBA fish distributions, supporting the conclusion that summer water temperature patterns control fish distribution.

Figure 15 shows Dairy-McKay Sub-Basin tributary water temperatures relative to the mainstem water temperatures based on the NetMap model. The model uses the downstream aggregated current shade-thermal energy parameter and compares the aggregate values at tributary confluences to the aggregate values in mainstem channels (e.g., tributary value - mainstem value) to identify potential tributary sources of cooler water (and also potential sources of warmer tributary water). Figure 16 shows confluence water temperatures for the East Fork Dairy Sub-Watershed, which has a large number of tributaries in the sub-basin providing cool water, creating potential thermal refugia areas for fish seeking lower water temperatures.

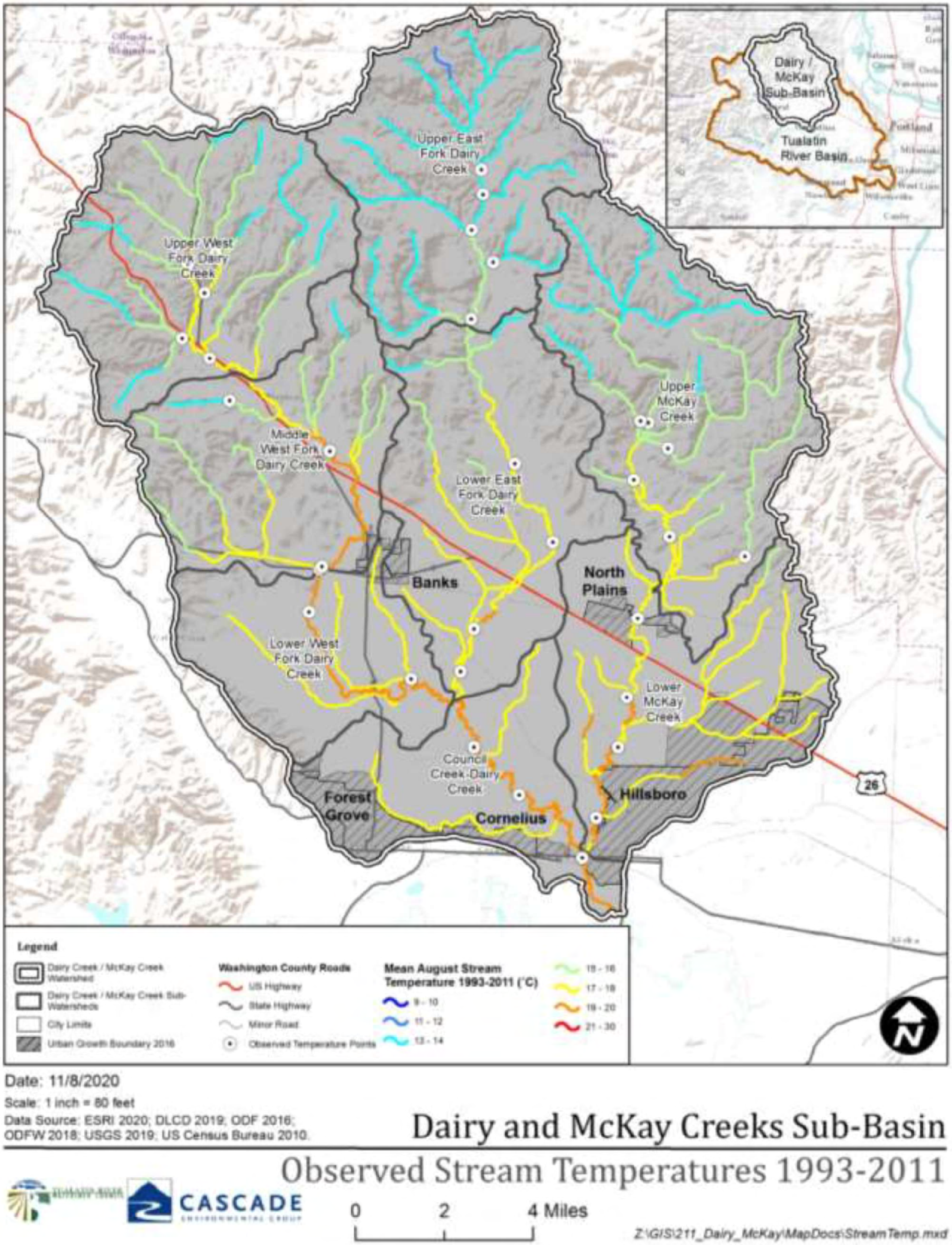

Figure 14. Dairy-McKay Sub-Basin stream temperature patterns, 1993-2011. Source: NorWeST database

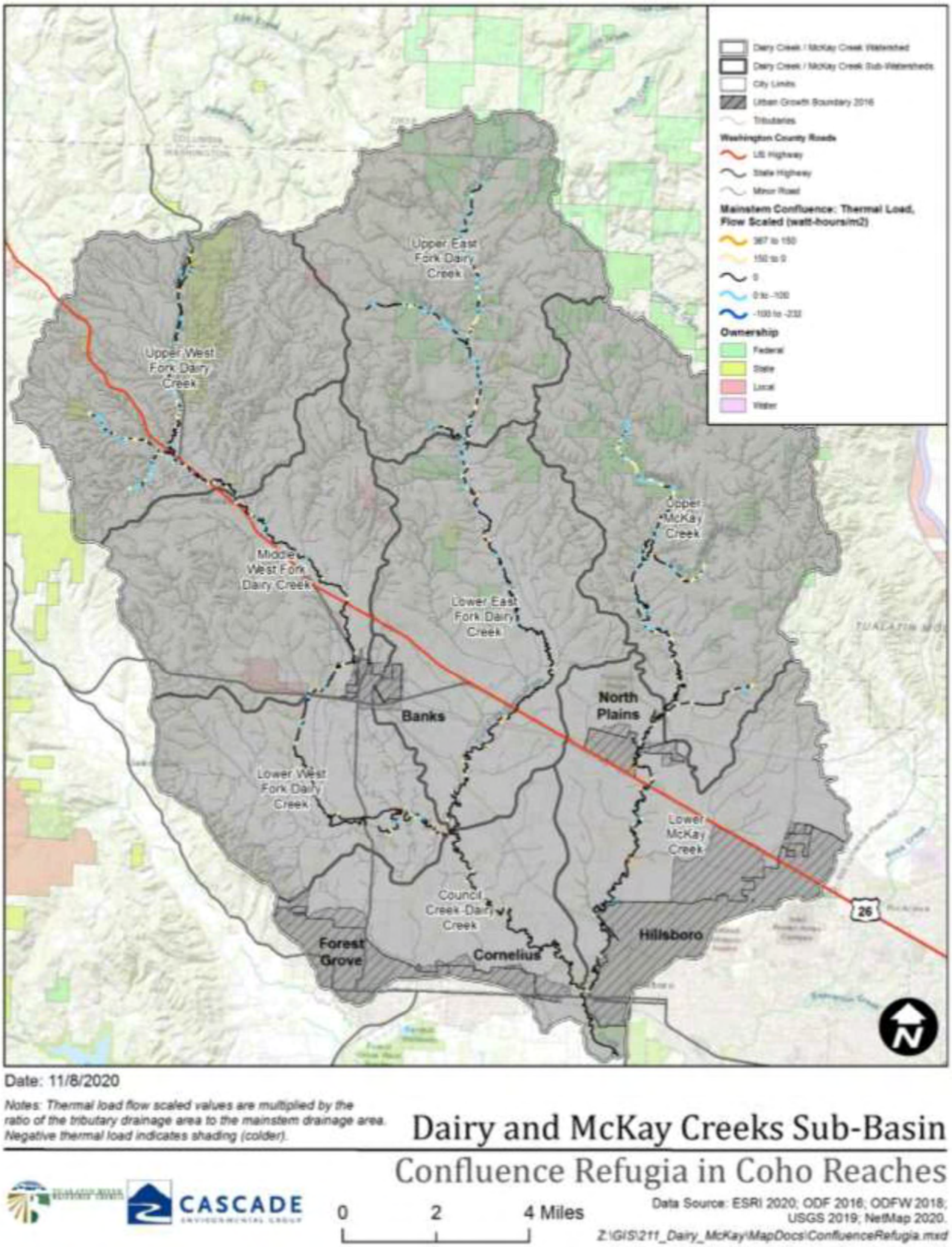

Figure 15. Dairy-McKay Sub-Basin tributary water temperatures relative (warmer or cooler) to the mainstem water temperatures based on the NetMap model.

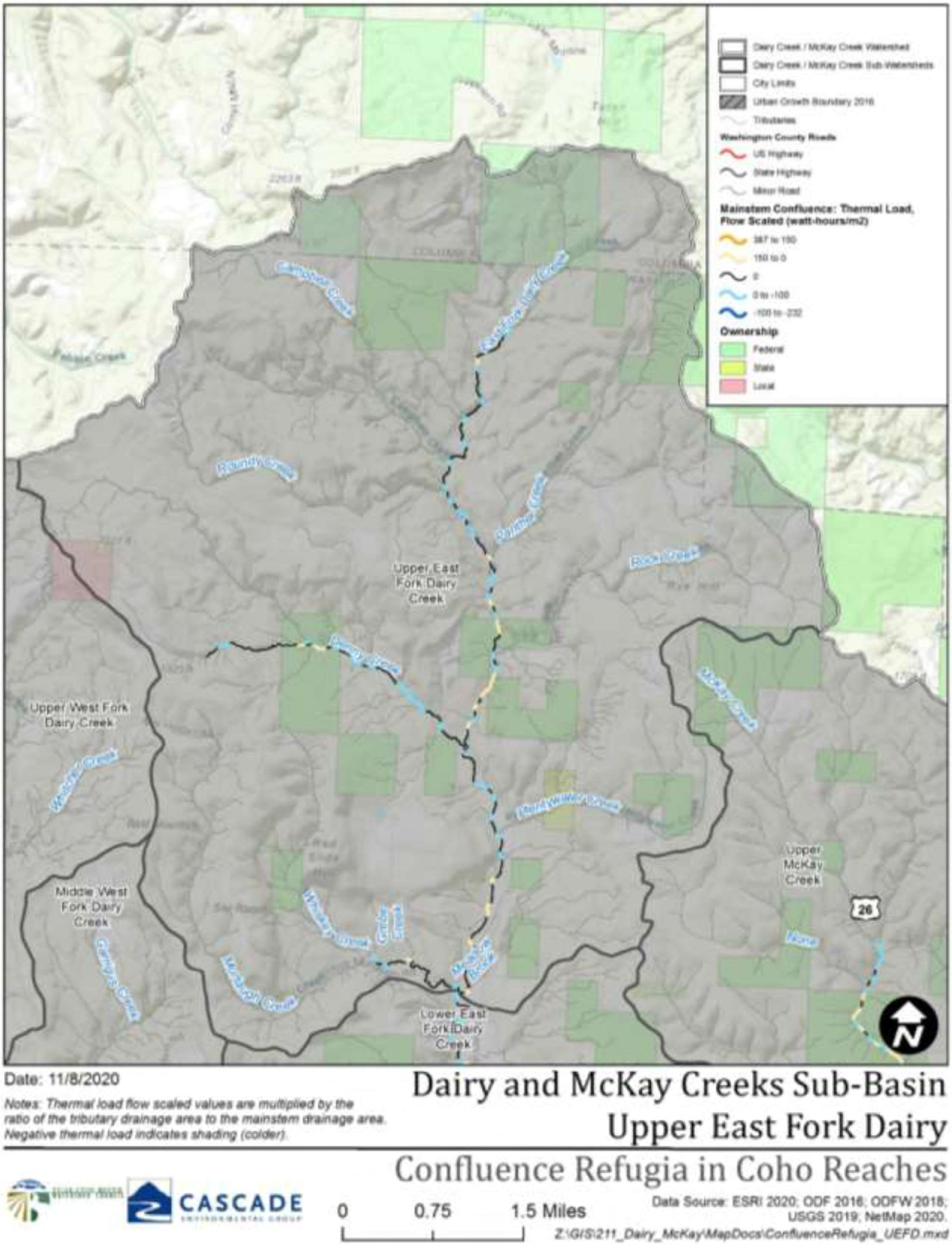

Figure 16. The East Fork Dairy Sub-Watershed has many tributaries in the sub-basin providing cool water, creating potential thermal refugia areas for fish seeking lower water temperatures.

Primary Limiting Factors

Based on the evaluation of the Dairy-McKay Sub-Basin's stream connectivity, aquatic habitat, riparian conditions, and water quality patterns, the key factors limiting focal fish population distribution and survival are as follows:

Stream temperatures: Based on sub-basin temperature patterns and RBA observations, summer stream temperatures limit fish distribution to the areas of the watershed where water temperatures are at or below the biologically relevant threshold of 18^0C. Limited shade over channels and water withdrawals contribute to elevated stream temperatures.

Access to off-channel habitats: The RBA concluded that the highest juvenile coho salmon and winter steelhead densities were found in East Fork Dairy Creek side channels. Access to side channels, alcoves, beaver ponds, and other off-channel habitats is essential for juvenile fish survival in the summer and the winter. Off-channel areas provide cover, complex habitats, and cool water where juvenile fish can feed and avoid predators in the summer. In the winter and early spring, these habitats provide fish with refuge areas to avoid floods. Off-channel habitat quality and fish access have been impaired by channel straightening, levees, floodplain wetland modification, and other land use activities. The RBA and other assessments have noted that channels in the sub-basin's lower potions are deeply incised. Removal of wood from channels, flood-protection berms, vegetation removal, and other activities have resulted in channels that are now lower than it was historically. In many areas, the entrenched channel does not connect to the floodplain and off-channel features that provide essential fish habitat.

Riparian conditions: Riparian vegetation has been altered through logging, clearing for agriculture and homes, and other activities. Most of the sub-basin's riparian trees are relatively young, and limited tree mortality means that few trees fall into stream channels. As a result, there are few large wood pieces in stream channels to create pools, cover, and complex habitats that are optimal habitats for fish. Riparian shade levels are primarily adequate to protect stream temperatures in the Dairy-McKay Sub-Basin's forested upper portions. However, there are extensive areas with limited shade over streams in the lower sub-basin, which contribute to the sub-basin's higher water temperatures.

Habitat Complexity: There is inadequate large wood in streams to create the necessary cover, create pool habitats, and retain spawning gravels. Studies in Gales Creek that have evaluated fish numbers before and after large wood placement have seen dramatic increases in fish numbers. There are adequate sources of spawning gravels and small cobbles to the stream system in the sub-basin's upper portions. However, limited channel complexity, particularly lack of large wood in the channels, has reduced channel structure and the creation of pool habitats necessary to trap gravels.

Fish passage barriers: The highest densities of juvenile fish are found in mainstem Dairy and McKay Creeks. Fish passage barriers are in the tributaries to the mainstem. Far fewer fish are found in the tributaries. For this reason, providing unblocked fish access into tributaries is not a key limiting factor. On a limited basis, fish passage barriers should be addressed where there is access to cooler water areas and high-quality fish habitat.

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7. Threats to Fish Populations and Watershed Health

Threats are human activities or natural processes that result in creating limiting factors for fish populations. For example, removing the vegetation along the banks of a stream (the threat) can cause higher water temperatures (the limiting factor) because the stream is no longer shaded. The primary human activities driving current and emerging threats in the Dairy-McKay Sub-Basin and the Tualatin River Basin are climate change and human population increase.

Climate Change

Although the precise impacts are challenging to predict, climate change will likely increase the limiting factors affecting the focal fish populations. The University of Washington estimates that average annual air temperatures in western Oregon are projected to rise through the twenty-first century, resulting in warmer and drier summers (Climate Change Impacts Group 2011). Long-term stream temperature patterns suggest that many Pacific Northwest streams are exhibiting warming attributable to climate change (Isaak et al. 2012).

Although the potential ecological responses to climate change are complex and not precisely predictable, the projected regional trajectories of increased winter flooding, decreased summer and fall stream flows, and elevated temperatures in streams are likely to compound already degraded habitat conditions. The effects of degraded and lost habitat quality and complexity could be amplified through climate change (Beechie et al. 2013). With the anticipated changes in precipitation patterns and resulting altered hydrology, particularly during the summer when flows are at their lowest and higher seasonal water temperatures, there will likely be further loss of areas that provide cool water refugia and resting habitat critical to salmonid survival. Degraded riparian habitat conditions may exacerbate altered hydrology and water temperatures by altering other essential ecosystem components, including shading and cover, organic matter inputs and aquatic food production, and nutrient inputs.

Juvenile coho salmon and winter steelhead rear in the Dairy-McKay Sub-Basin over multiple seasons before migrating to the ocean. Coho and steelhead life history patterns expose the fish to adverse conditions exacerbated by climate change (Figure 17). Increased flooding frequency and intensity can limit adult access to preferred spawning areas, and high flows can scour stream substrates impacting embryo survival (Battin et al. 2007). Decreased low flows and increased summer water temperatures reduced habitat capacity for juvenile fish, and sustained extreme water temperatures can lead to fish mortality (Richter and Kolmes 2005).

The NorWeST model forecasts the impact of climate change on water temperature patterns. Mean air temperature values from ten climate models and other key parameters (e.g., watershed precipitation, stream gradient, average discharge, etc.) are used to simulate water temperature patterns in 2040 and 2080. See **Appendix 4** for information on the NorWeST water temperature climate change model.

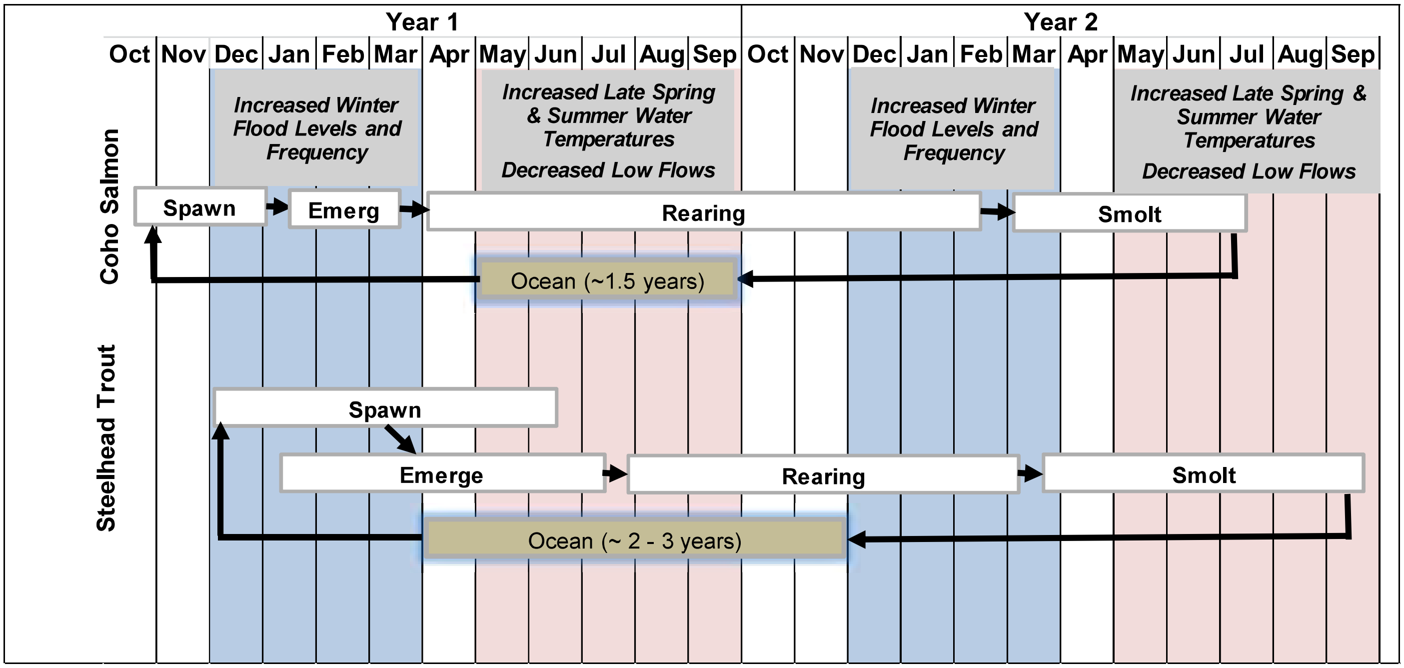

Figure 17. Increased flooding, low base flows, and increased water temperatures from climate change impacts coho and winter steelhead life stages: Spawning, embryo survival, summer and winter rearing, and migration. Source: Adapted from Beechie et al. 2013, and Muck et al. 2003

Figure 18 Figure 19 show predicted Dairy-McKay mean 2040 and 2080 August water temperature patterns from predicted climate change scenarios. As the figures illustrate, under climate change scenarios, high water temperatures (>18^{0}C) will increasingly extend further up Dairy and McKay Creeks and into headwater tributaries, transforming habitats that are now optimal for water temperatures to habitats with sub-optimal or lethal temperatures. By 2080, currently productive mainstem habitats will be too warm, and most fish will reside in the cooler small tributary streams where there is dramatically less habitat diversity and capacity. The loss of mainstem summer juvenile rearing habitat diversity will reduce fish population resilience to environmental changes (Beechie et al. 2013).

Targeted restoration actions will help buffer natural systems against the negative impacts of climate change. For example, an analysis of the future effects of climate change in the City of Portland's Johnson Creek watershed (through 2040) showed that, with the implementation of planned restoration projects, the quality of habitat for winter steelhead and coho and Chinook salmon would be maintained at a high level, even in the face of climate change; without the restoration actions, habitat quality would decline (McConnaha and Runyon 2011).

Table 9 shows restoration actions and the degree to which the restoration activity mitigates the watershed processes and habitats affected by climate change. The targeted watershed processes and habitats are as follows (Beechie et al. 2013): 1) Ameliorates temperature increase, 2) ameliorates base flow decrease, 3) ameliorates peak flow increase, and 4) improves fish population resilience by improving habitat capacity or enhancing access to a diverse array of habitats.

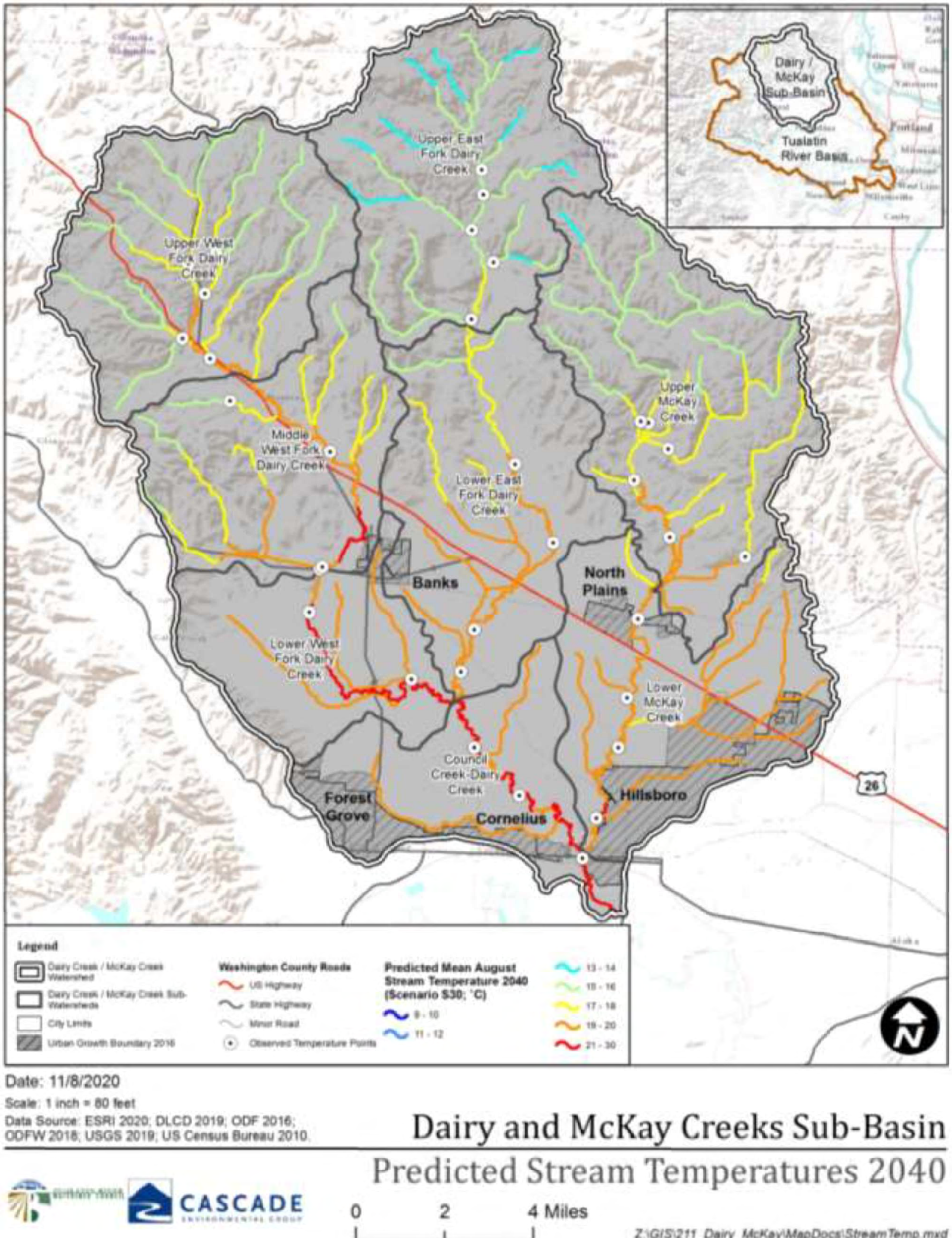

Figure 18. Predicted 2040 Dairy-McKay Sub-Basin Stream temperatures. Source: NorWeST model

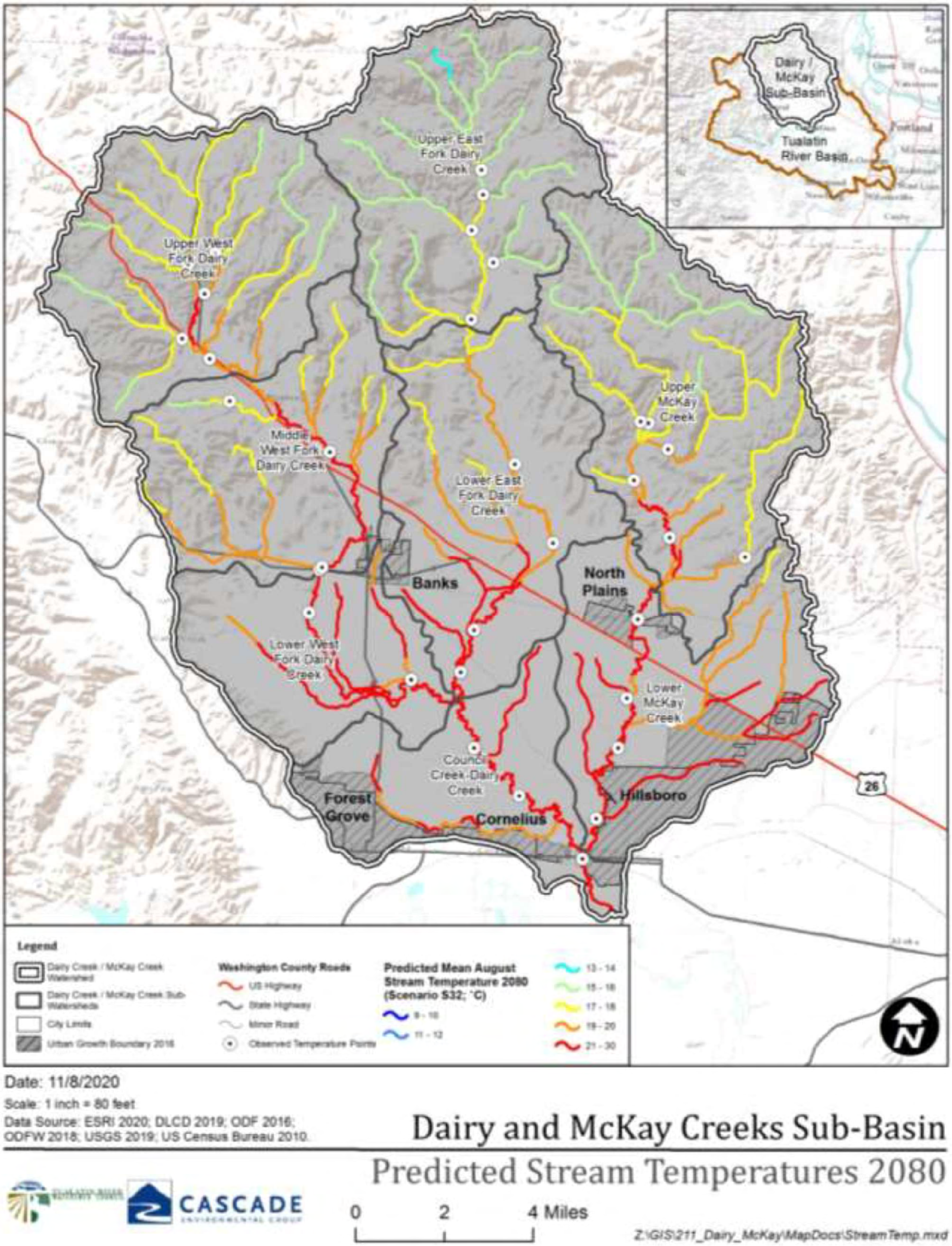

Figure 19. Predicted 2080 Dairy-McKay Sub-Basin Stream temperatures. Source: NorWeST model

Table 9. Restoration actions and the degree to which the activities mitigate for watershed processes modified by climate change.

+ = address process; – = partially addresses process; 0 = does not address process

Restoration Category	Restoration Techniques	Ameliorates temperature increase	Ameliorates base flow decrease	Ameliorates peak flow increase	Improves fish population resilience
Longitudinal connectivity (barrier removal)	Removal or breaching of dam	+	+	0	+
	Address fish passage barriers (access to water temperature refugia and habitat)	+	0	0	+
Lateral connectivity (floodplain connection)	Levee Removal	+	0	+	+
	Reconnection of floodplain features (e.g., side channels, alcoves	+	0	+	+
	Creation of new floodplain habitats	+	0	+	+
Vertical connectivity (incised channel Restoration	Reintroduce beaver (dams increase sediment storage)	+	+	+	+
	Remove cattle (restored vegetation stores sediment)	+	+	+	0
	Install wood or material as grade controls	+	+	+	0
Stream flow regimes	Restoration of natural flood regime	+	+	0	–
	Reduce water withdrawals, restore summer base flow	+	+	0	0
	Disconnect road drainage from streams	0	0	+	0
	Stormwater management: natural drainage infiltration systems, retention ponds and other techniques	0	–	+	0
Erosion and sediment delivery	Road resurfacing	0	0	0	0
	Reduced cropland erosion	0	0	0	0
	Reduced grazing adjacent to streams (e.g., fencing)	–	0	0	0
Riparian functions	Grazing removal, fencing, controlled grazing	+	0	0	0
	Planting trees and other native vegetation along streams	+	0	0	0
	Remove nonnative plants from riparian area	–	–	0	0
Instream habitat enhancement	Re-meandering or realignment of straightened stream channel	–	0	0	–

Restoration Category	Restoration Techniques	Ameliorates temperature increase	Ameliorates base flow decrease	Ameliorates peak flow increase	Improves fish population resilience
	Addition of large wood structures, jams	–	0	0	0
	Brush bundles, cover structures	0	0	0	0
	Gravel augmentation	0	0	0	0

Population Growth

Washington County's population is projected to double between 2021 and 2070 (Figure 18) nearly. The population increase, with associated development, will likely lead to more degradation of riparian and aquatic habitats, decreased water quality, and reduced fish and wildlife diversity and populations. The combined effects of climate change and urban development will further exacerbate existing water quality problems (Praskievicz and Chang 2011) and contribute to more nonnative weedy vegetation throughout the landscape, particularly in riparian areas. If late summer streamflow is reduced by climate change and there are no improvements in riparian vegetation cover, stream temperatures may increase. However, increases in riparian cover in the Tualatin tributaries could partly counteract these effects in the mainstem Tualatin River. This climate change scenario raises small tributaries' importance as cold water and habitat refuges for the future steelhead, coho salmon, cutthroat trout, and Pacific lamprey populations.

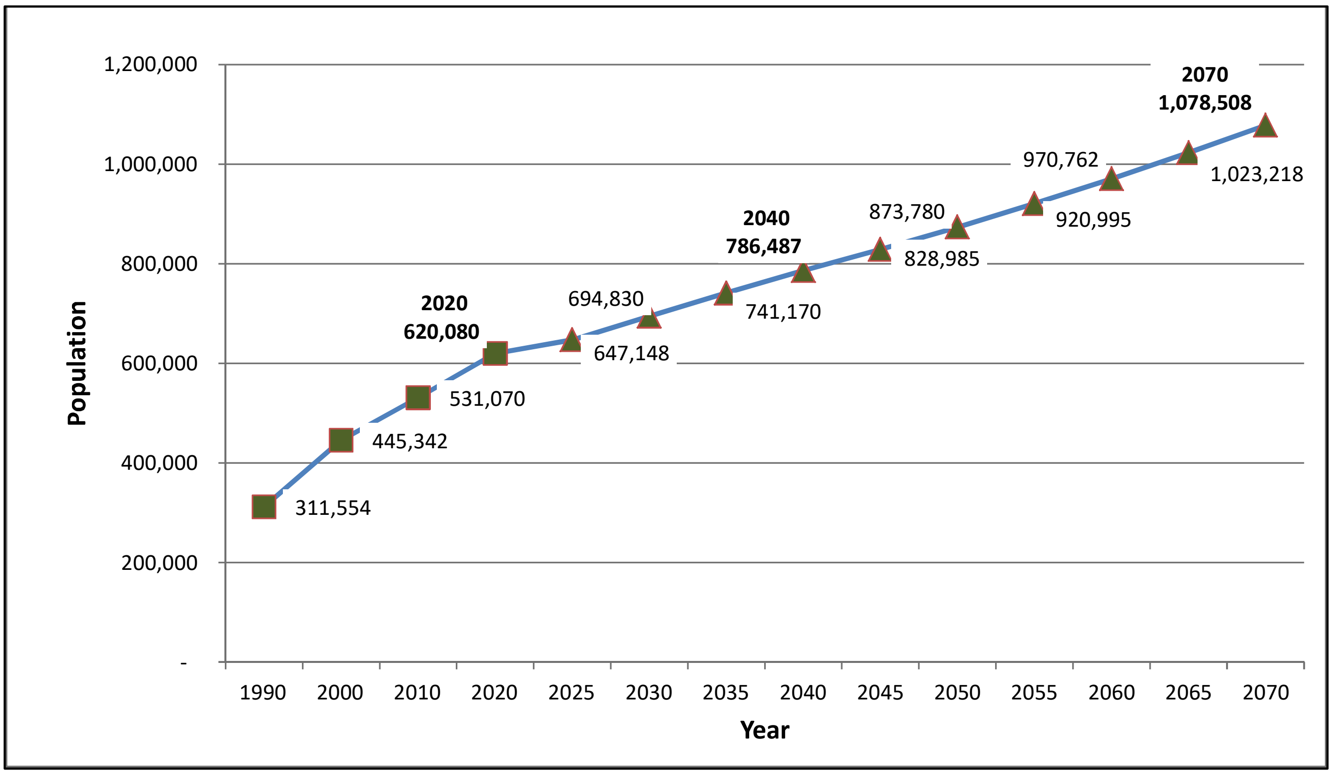

Figure 20. Washington County population 1990 – 2020, and forecasted population 2025 – 2070. Source: PSU Population Research Center 2021

Figure 21 shows Dairy-McKay Sub-Basin historical vegetation patterns based on interpretation of public land survey records of the federal government's General Land Office (GLO). The GLO maps, based on surveys in the mid-1800s, depict vegetation at a coarse scale (forest, woodland, savanna, prairie, etc.). Historically, sub-basin terrestrial habitats included emergent wetlands, oak savannas, and prairies. These habitats are concentrated in the lower portions of the sub-watershed near the growing population centers.

Population growth and land use activities have dramatically altered Dairy-McKay Sub-Basin's historical vegetation – only small and fragmented remnants of the historical habitats remain.

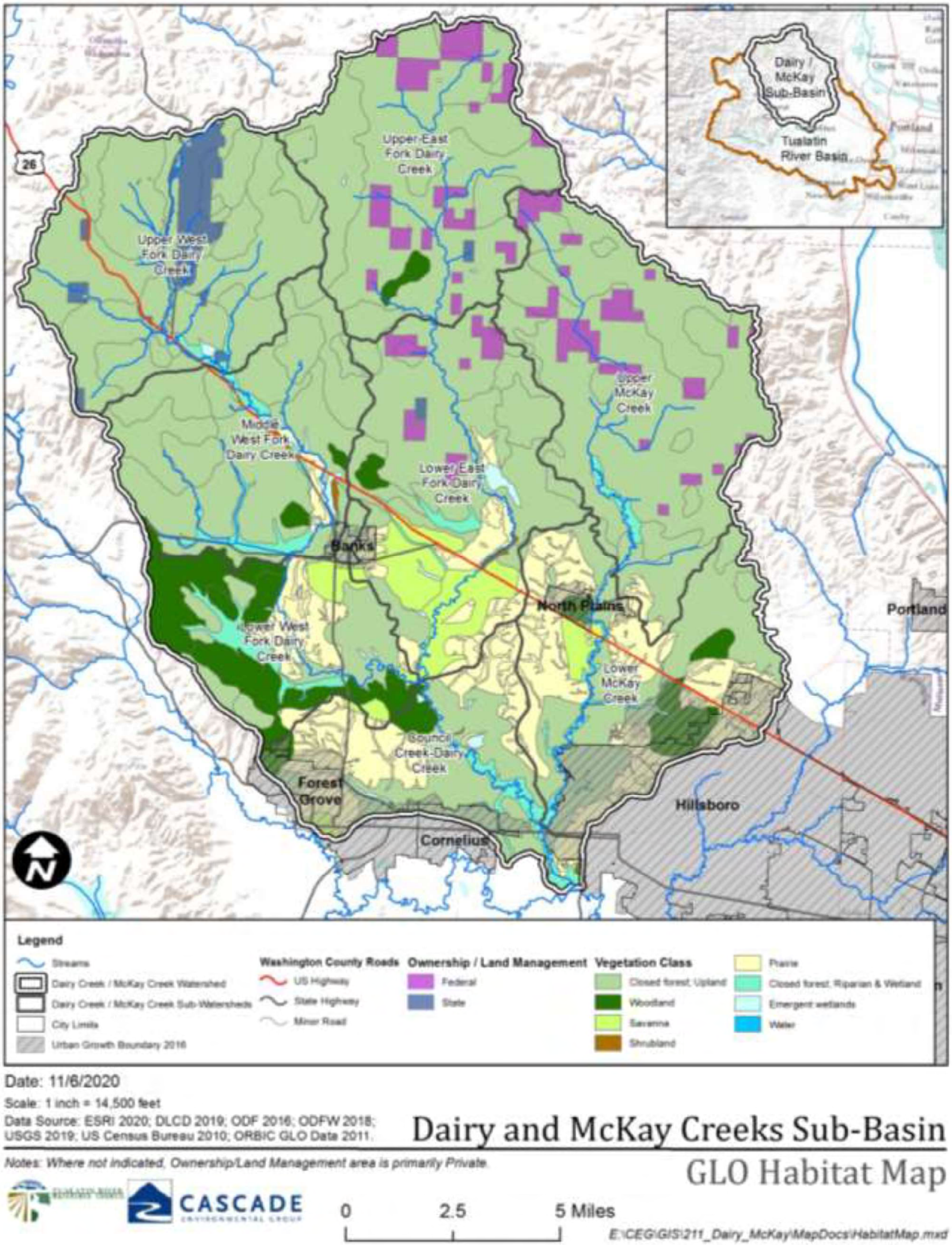

Figure 21. Dairy-McKay Sub-Basin historical habitats

8. Summary of Watershed Restoration Accomplishments

The Tualatin River Watershed Council, the timber industry, landowners, CWS, Washington County, Tualatin Soil and Water Conservation District (SWCD), and others have worked on habitat restoration actions throughout the Tualatin River Basin and the Dairy-McKay Sub-Basin. Restoration activities include improving roads to minimize peak flows and sediment delivery to streams; wetland, riparian, and upland enhancement; large wood placement in stream channels; and replacement of culverts that are fish passage barriers. The most common restoration activity in the sub-basin is planting native vegetation in riparian areas and associated wetlands. The actions are designed to improve shade and riparian functions. More than 860 acres along 26.5 miles of stream have been restored in the Dairy-McKay Sub-Basin, with most of the work completed by the SWCD (Table 10).

Table 10. Riparian planting restoration projects completed in the Dairy-McKay Sub-Basin. Source: CWS

Sub-Watershed	# of Projects	Total Acres	Total Stream Miles
Upper West Fork Dairy Creek	1	31.9	1.5
Middle West Fork Dairy Creek	1	11.6	0.5
Lower West Fork Dairy Creek	7	28.6	1.4
Upper East Fork Dairy Creek	2	43.0	0.5
Lower East Fork Dairy Creek	9	109.4	5.2
Upper McKay Creek	5	62.7	3.0
Lower McKay Creek	30	152.3	6.7
Council Creek-Dairy Creek	33	420.8	7.7
Totals:	**88**	**860.3**	**26.5**

TRWC is currently working on an extensive restoration project in a 3-mile reach on East Fork Dairy Creek's mainstem. The restoration area was identified in the RBA as an anchor habitat area for winter steelhead and coho salmon.

The project is designed to address multiple objectives as follows:

- Install 58 large wood structures on the main stem of East Fork Dairy Creek and its side channels. The intent is to trap substrate and aggrade the active channel for flood events to more frequently connect into legacy side channel habitats.
- Enhance six alcoves for off-channel habitat that result in linked alcoves to provide lower velocity winter habitat.
- Treat and/or site prep 41 acres of riparian forest habitat and 2 acres of scrub-shrub habitat and plant

native vegetation on 29.3 acres on one project property.

- Treat riparian invasive weed species and plant conifer trees and other native vegetation on the remaining six project properties.
- Backwater a perched culvert on Plentywater Creek to enhance both adult and juvenile passage to upstream habitat.
- Change pasture management practices on one project property and install a bio-revetment to address a 200-foot segment of failing stream bank located on the mainstem of East Fork Dairy Creek.

9. Sub-Watershed Summaries

The Following section provides watershed condition summaries for the Dairy-McKay Sub-Basin's eight sub-watersheds. The map inserts show floodplain elevations and coho densities for the RBA-inventoried sub-watersheds.

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Upper West Fork Dairy Creek

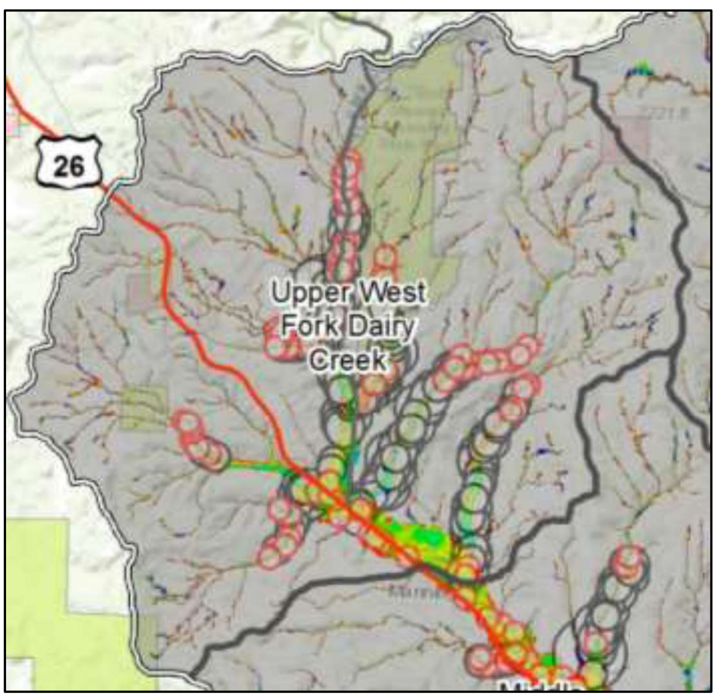
Upper West Fork Dairy Creek Sub-Watershed is primarily managed as working forest land (publicly and privately owned) and Stub Stewart State Park in the upper sub-watershed. There are some agricultural and rural residential lands in the lower sub-watershed. Based on the RBA results, the upper sub-watershed mainstem and tributaries provide anchor habitats for coho salmon, winter steelhead, and cutthroat trout.

Watershed Area and Land Uses

- 21,196 acres; private and state forest lands in the upper portions; some agricultural and rural residential land uses in the lower sub-watershed
- 2,253 acres of state owned lands, including 1,600-acre Stub Stewart State Park

Riparian and Upland Habitat Conditions

- Riparian areas are relatively intact in the upper sub-watershed and more limited riparian tree cover in the lower portions
- For the most part, few larger trees (>50 cm dbh) in riparian areas, with the exception of a number of scattered riparian areas with larger trees
- The lower sub-watershed along the West Fork of Dairy Creek included historical emergent wetland habitats



Lager circles correspond to higher densities of juvenile coho in pools; red circles = no coho observed

Physical Conditions

- The geology consists of primarily sedimentary formations with some harder basalt formations in the headwaters
- Steep tributaries and a lower gradient mainstem with alluvial deposits with wider floodplains in the lower sub-watershed
- Ample sediment and gravel sources from the tributaries with suitable spawning substrate available in the upper partitions of the subwatershed

Fish, Habitat, and Water Quality

- Rearing fish coccupy both West Fork Dairy Creek mainstem and tributaries
- After East Fork Dairy Creek, the Upper West Fork is characterized by the second highest densities of coho salmon, winter steelhead and cutthroat trout in the Sub-Basin
- Limited instream large wood in channels wood due to past practices
- The lower mainstem is characterized by a wider floodplain, with wetland areas and off-channel habitats
- Relatively cool water temperatures in the upper portions, with warmer temperatures in the lower sub-watershed mainstem
- NetMap identified a number of small tributaries (19) in the upper sub-watershed that potentially provide cool water temperatures to the mainstem (thermal refugia)
- Climate change prediction: In 2080 water temperatures will increase, but relative to other portions of the Diary-McKay Sub-Basin, the Upper West Fork Dairy Sub-Watershed will provide some relatively cool water areas, particularly in the tributaries

Habitat Restoration and Fish Passage Barriers

- Key anchor habitat area where the priority is to restore and protect access to off-channel habitats, create complexity and maintain and improve cold water refugia areas and enhance riparian shade and function in both the mainstem and tributaries
- 78 potential fish passage barriers; 6 fish passage barriers rated as high priority for replacement and 2 fish passage barriers rated as moderate priority

Middle West Fork Dairy Creek

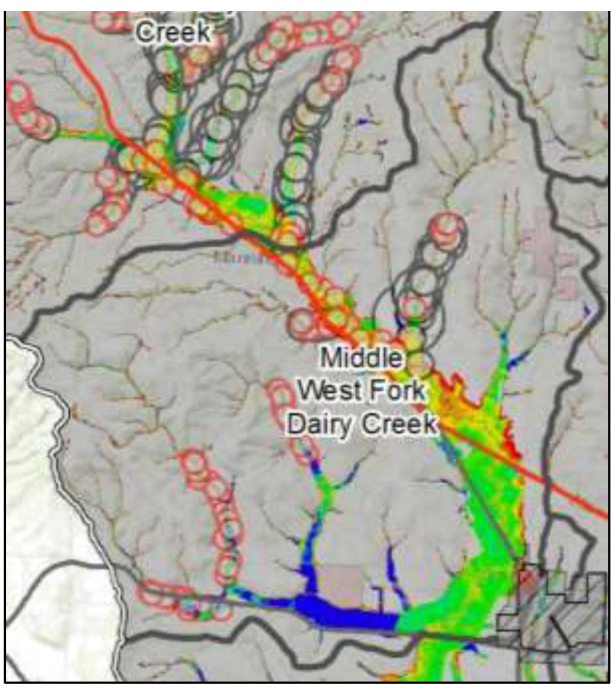
Middle West Fork Dairy Creek Sub-Watershed is primarily managed as privately-owned working forest land in the upper portions and extensive agricultural and rural residential lands in the lower sub-basin. Metro's Killin Wetlands Natural Area is in the lower sub-watershed near the community of Banks. The RBA noted low numbers of fish in the West Fork Dairy Creek mainstem and few fish in the tributaries.

Watershed Area and Land Uses

- 21,196 acres; private forest lands in the upper portions; agricultural and rural residential land uses in the lower sub-watershed
- A portion of the City of Banks UGB is within the lower sub-watershed
- Metro's Killin Wetlands Natural Area, a rare example of a peat wetland, is in the lower sub-watershed near the town of Banks

Riparian and Upland Habitat Conditions

- Riparian areas are relatively intact in the upper sub-watershed and more limited riparian tree cover in the lower portions, particularly on agricultural lands where there are extensive areas with minimal riparian shade
- For the most part, few larger trees (>50 cm dbh) in riparian areas
- Historically the lower sub-watershed along the West Fork of Dairy Creek included emergent wetland habitats



Lager circles correspond to higher densities of juvenile coho in pools; red circles = no coho observed

Physical Conditions

- The geology consists of mostly of harder basalts with some sedimentary formations in the headwaters
- The mainstem is low gradient with alluvial deposits and wide floodplains
- Some gravel sources from the tributaries with suitable spawning substrate available

Fish, Habitat, and Water Quality

- The RBA observed low numbers of fish in the West Fork Dairy Creek mainstem, but few fish in the tributaries
- Limited instream large wood in channels wood due to past practices
- The mainstem is characterized by a wider floodplain, with some side channels and off-channel wetland habitats
- Relatively cool water temperatures in the upper tributaries, with warmer temperatures in the lower sub-watershed mainstem limits summer rearing opportunites
- NetMap identified some tributaries (6) in the upper sub-watershed that potentially provide cool water temperatures to the mainstem (thermal refugia); very few cool tributaries in the lower portions of the sub-watered
- Climate change prediction: In 2080 water temperatures will increase to the point were there is very little suitable summer rearing habitat in the sub-watershed

Habitat Restoration and Fish Passage Barriers

- Extensive areas where improved riparian shade on the mainstem and tributary streams could reduce water temperatures and improve habitat
- 77 potential fish passage barriers; 1 fish passage barrier rated as high priority for replacement and 6 fish passage barriers rated as moderate priority
- There is the potential to restore historical wetland habitats along the mainstem and tributary areas

Lower West Fork Dairy Creek

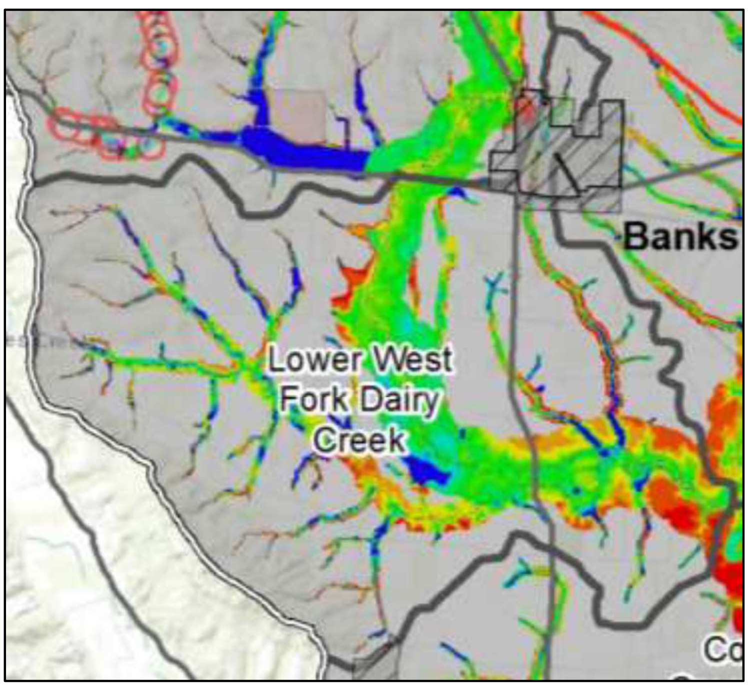
Lower West Fork Dairy Creek Sub-Watershed is primarily managed as privately-owned working forest land in the upper portions and extensive agricultural and rural residential lands in the lower sub-basin. Based on the RBA results, the upper sub-watershed mainstem provides anchor habitats for coho salmon, winter steelhead, and cutthroat trout.

Watershed Area and Land Uses

- 12,620 acres; primarily private ownership with agricultural and rural residential areas and scattered forest lands
- A portion of the City of Bank's UGB is within the lower sub-watershed

Riparian and Upland Habitat Conditions

- Limited riparian tree cover and shade throughout the sub-watershed
- For the most part, few larger trees (>50 cm dbh) in riparian areas
- Historically the lower sub-watershed included extensive savanna, prairie, and wetland habitats



Physical Conditions

- The geology consists of extensive Missoula flood deposits throughout the sub-watershed, with alluvaial material within West Fork Dairy Creek's channel and floodplain
- Channels substrate consists of fine-grained sediments with little suitable spawning gravels
- Large portions of West Fork Dary Creek's channel is deeply incised, which limits the channel's interaction with the floodplain

Fish, Habitat, and Water Quality

- Limited instream large wood in channels wood due to past practices
- The mainstem is characterized by a wider floodplain, with some side channels and off-channel habitats that are now isolated due to channel incision
- Unsuitable summer salmonid rearing temperatures; salmonid use is largly restricted to winter and spring periods
- NetMap identified 4 tributaries in sub-watershed that potentially could provide cool water temperatures to the mainstem (thermal refugia)
- Climate change prediction: Currently summer temperatures are unsitable for salmonids and by 2080 climate change will continue to increase water temperatures and limit fish use

Habitat Restoration and Fish Passage Barriers

- Extensive areas where improved riparian vegetation on the mainstem and tributary streams will improve habitat
- 43 potential fish passage barriers; no priority fish passage barriers
- There is the potential to restore floodplain off-channel areas to improve winter salmonid rearing habitat through actions such as reconnecting side-channels and floodplains
- Opportunities to restore historical savanna, prairie, and wetland habitats

Upper East Fork Dairy Creek

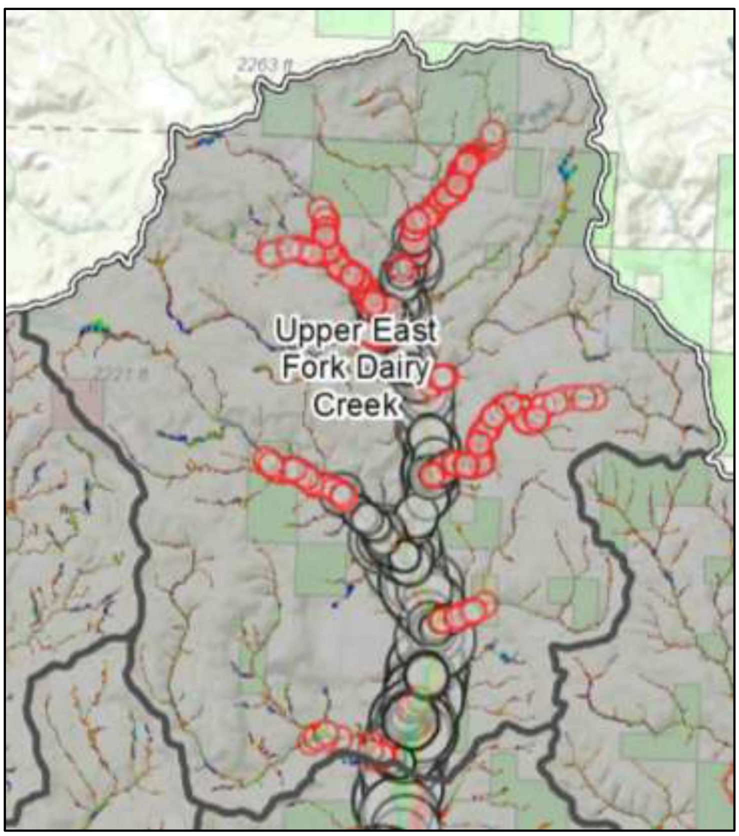
The Upper East Fork Dairy Creek Sub-Watershed is primarily managed as working forest land (publicly and privately owned) with some residential and agricultural lands in the lower sub-watershed. Based on the RBA results, the mainstem provides summer cool water and important anchor habitats for coho salmon, winter steelhead, and cutthroat trout.

Watershed Area and Land Uses

- 20,722 acres, mostly privately-owned forest lands
- 2,867 acres federal forest ownership

Riparian and Upland Habitat Conditions

- Mostly second- and third-growth forests
- Riparian areas relatively intact, with mostly continuous cover/shade
- For the most part, few larger trees (>50 cm dbh) in riparian areas, with the exception of a number of scattered riparian areas with larger trees



Lager circles correspond to higher densities of juvenile coho in pools; red circles = no coho observed

Physical Conditions

- The geology consists of harder basalt and sedimentary formations in the headwaters
- Steep tributaries and a lower gradient mainstem with alluvial deposits with wider floodplains in the lower sub-watershed
- Ample sediment and gravel sources from the tributaries with suitable spawning substrate available

Fish, Habitat, and Water Quality

- The majority of rearing fish are in the mainstem; lower reaches contain the highest densities of coho salmon, winter steelhead and cutthroat trout in the Diary-McKay Sub-Basin
- Limited instream large wood in channels wood due to past practices
- The lower mainstem is characterized by wider floodplains and some available off-channel habitats
- Relatively cool water temperatures
- NetMap identified a large number of tributaries (27) that potentially provide cool water temperatures to the mainstem (thermal refugia)
- Climate change prediction: In 2080 water temperatures will increase, but relative to other portions of the Dairy-McKay Sub-Basin, the East Fork Dairy Sub-Watershed will provide relatively cool water areas in the upper mainstem and tributaries

Habitat Restoration and Fish Passage Barriers

- Key mainstem anchor habitat area where the priority is to restore and protect access to off-channel habitats, create complexity and maintain and improve cold water refugia areas and enhance riparian shade and function
- 57 potential fish passage barriers, all on tributary streams; 3 fish passage barriers rated as moderate priority for replacement

Lower East Fork Dairy Creek

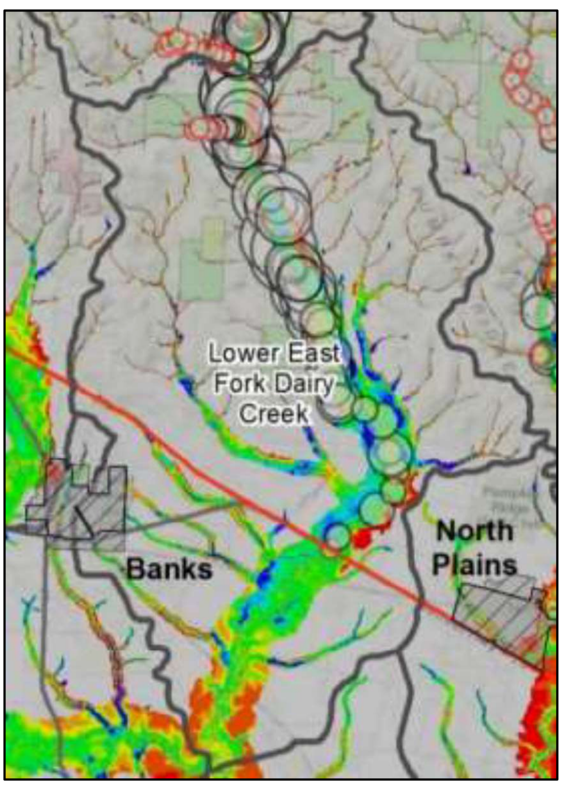
The Lower East Fork Dairy Creek Sub-Watershed is primarily managed as working forest land (publicly and privately owned) in the upper portions and extensive agricultural and rural residential lands in the lower sub-watershed. Based on the RBA results, the upper sub-watershed mainstem provides important anchor habitats for coho salmon, winter steelhead and cutthroat trout.

Watershed Area and Land Uses

- 20,374 acres: private and public forest lands in the upper portions; agricultural and rural residential land uses in the lower sub-watershed
- 1,021 acres federal forest ownership
- A portion of the City of Banks' UGB is within the lower sub-watershed

Riparian and Upland Habitat Conditions

- Riparian areas are relatively intact in the upper sub-watershed and more limited riparian tree cover in the lower portions, particularly on agricultural lands where there are extensive areas with minimal riparian shade
- For the most part, few larger trees (>50 cm dbh) in riparian areas
- Historically the lower sub-watershed included extensive savanna, prairie, and wetland habitats



Lager circles correspond to higher densities of juvenile coho in pools; red circles = no coho observed

Physical Conditions

- The geology consists of harder basalt and some sedimentary formations in the headwaters; broad floodplains within a wide valley with alluvial deposits; and extensive Missoula flood deposits in the lower sub-watershed within the lowlands of the Tualatin Plain
- Ample sediment and gravel sources in the upper sub-basin and more fine-grained sediments in the lower mainstem

Fish, Habitat, and Water Quality

- The majority of rearing fish are in the mainstem; the upper reaches contain the highest densities of coho salmon, winter steelhead and cutthroat trout in the Dairy-McKay Sub-Basin
- Limited instream large wood in channels wood due to past practices
- The mainstem is characterized by a wider floodplain, with side channels and off-channel habitats
- Relatively cool water temperatures in the upper portions, with warmer temperatures in the lower sub-watershed mainstem and tributaries; unsuitable summer salmonid rearing temperatures below Highway 26
- NetMap identified some tributaries (13) in the upper sub-watershed that potentially provide cool water temperatures to the mainstem (thermal refugia); very few cool tributaries in the lower portions of the sub-watered
- Climate change prediction: In 2080 water temperatures will increase to the point where there is very little suitable summer rearing habitat in the sub-watershed

Habitat Restoration and Fish Passage Barriers

- The upper mainstem is a key anchor habitat area where the priority is to restore and protect access to off-channel habitats, create complexity, and maintain and improve cold water refugia areas and enhance riparian shade and function
- Extensive areas where improved riparian shade on tributary streams could reduce water temperatures and improve habitat
- 77 potential fish passage barriers, all on tributary streams; no priority fish passage barriers identified
- Opportunities to restore historical savanna, prairie, and wetland habitats

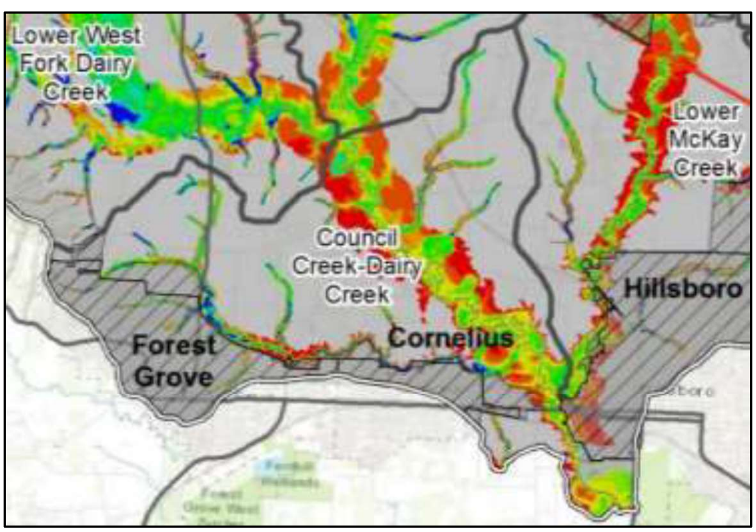
Council Creek-Dairy Creek

The Council Creek-Dairy Creek Sub-Watershed is entirely within the lowlands of the Tualatin Plain. Most of the sub-watershed is privately owned and agriculture and urban areas are the primary land uses. Water temperatures are high and consequently there is minimal salmonid fish presence in Dairy Creek during summer and early fall. Historically the sub-watered included diverse wetland, savanna, and prairie habitats that have largely been lost due to land use conversion.

Watershed Area and Land Uses
- 13,083 acres, all in private ownership
- A portion of the city of Forest Grove's, Cornelius', and Hillsboro's UGBs are within the lower sub-watershed

Riparian and Upland Habitat Conditions
- There is limited riparian tree cover throughout the sub-watershed on agricultural and urban lands where there are extensive areas with minimal riparian shade
- Few larger trees (>50 cm dbh) in riparian areas
- Historically the lower sub-watershed included extensive savanna, prairie, and wetland habitats

Physical Conditions
- The geology consists of extensive Missoula flood deposits throughout the sub-basin, with alluvaial material within Dairy Creek's channel and floodplain
- Channels substrate consists of fine-grained sediments with little suitable spawning gravels
- Large portions of Dary Creek's channel is deeply incised, which limits the channel's interaction with the floodplain



Fish, Habitat, and Water Quality
- Limited instream large wood in channels wood due to past practices
- The mainstem is characterized by a wider floodplain, with some side channels and off-channel habitats that are now isolated due to channel incision or land management activities
- Unsuitable summer salmonid rearing temperatures; salmonid use is largly restricted to winter and spring periods
- NetMap identified no tributaries in sub-watershed that potentially could provide cool water temperatures to the mainstem (thermal refugia)
- Climate change prediction: Currently summer temperatures are unsitable for salmonids and by 2080 climate change will continue to increase water temperatures and limit fish use

Habitat Restoration and Fish Passage Barriers
- Extensive areas where improved riparian vegetation on the mainstem and tributary streams will improve habitat
- 35 potential fish passage barriers; no priority fish passage barriers
- There is the potential to restore floodplain off-channel areas to improve winter salmonid rearing habitat through actions such as reconnecting side-channels and floodplains
- There is the potential to restore historical savanna, prairie, and wetland habitats

Upper McKay Creek

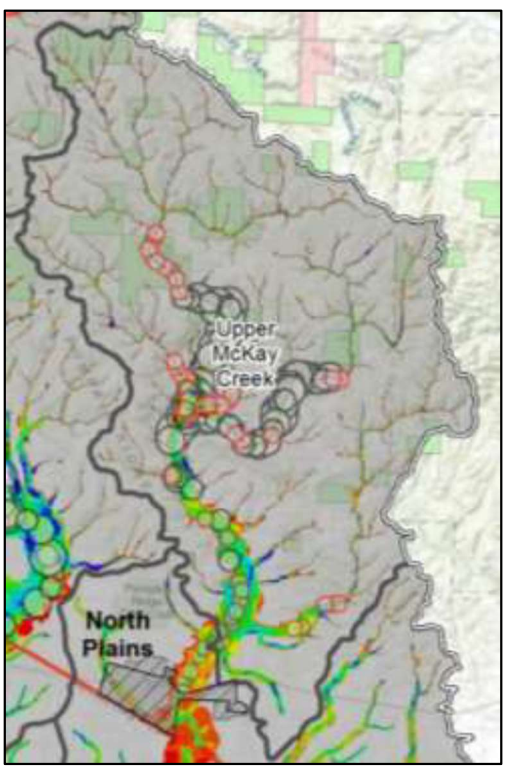
Upper McKay Creek Sub-Watershed is primarily managed as working forest land (publicly and privately owned) in the upper portions with agricultural and rural residential lands in the lower sub-basin. McKay Falls, a natural fish passage barrier, prevents coho salmon and steelhead from accessing the upper sub-watershed. Habitat above the falls is occupied by cutthroat trout and Pacific lamprey may be able to navigate the falls access upstream habitats, but this needs to be confirmed.

Watershed Area and Land Uses

- 21,307 acres, mostly privately-owned forest lands with agricultural and residental land uses in the lower sub-watershed
- 2,443 acres federal forest ownership

Riparian and Upland Habitat Conditions

- Mostly second- and third-growth forests
- Riparian areas relatively intact, with mostly continuous cover/shade in the upper sub-watershed
- In the lower sub-watershed there is more limited cover and shade on tributaries and McKay Creek
- For the most part, few larger trees (>50 cm dbh) in riparian areas, with the exception of a number of scattered riparian areas with larger trees
- Historically the lower sub-watershed included extensive wetland habitats adjacent to McKay Creek



Lager circles correspond to higher densities of juvenile coho in pools; red circles = no coho

Physical Conditions

- The geology consists of harder basalt formations in the headwaters
- Steep tributaries and a lower gradient mainstem with alluvial deposits with wider floodplains in the lower sub-watershed
- Ample sediment and gravel sources in the upper sub-watershed with suitable spawning substrates

Fish, Habitat, and Water Quality

- The majority of rearing fish are in the mainstem; the lower reaches below the water fall contain the highest densities of coho salmon, winter steelhead and cutthroat trout.
- McKay Falls, a natural fish passage barrier, prevents fish from accessing the upper sub-watershed; Pacific lamprey likely can access areas above the falls
- Limited instream large wood in channels wood due to past practices
- The lower mainstem is characterized by wider floodplains and some available off-channel habitats
- Relatively cool water temperatures in the upper sub-watershed and warmer water temperatures in the lower sub-watershed
- NetMap identified a large number of tributaries (39) that potentially provide cool water temperatures to the mainstem (thermal refugia)
- Climate change prediction: In 2080 water temperatures will increase, but relative to other portions of the sub-basin, the upper McKay Creek Sub-Watershed will provide relatively cool water areas, primarily in the tributaries

Habitat Restoration and Fish Passage Barriers

- Address areas where improved riparian shade on tributary streams in the lower sub-watshed could reduce water temperatures and improve habitat
- Opportunities in the lower sub-watershed to restore floodplain interaction, increase stream complexity, and restore historical wetland habitats
- 52 potential fish passage barriers; 1 priority fish passage barrier identified on East Fork McKay Creek; two passage barriers indentified above the falls

Lower McKay Creek

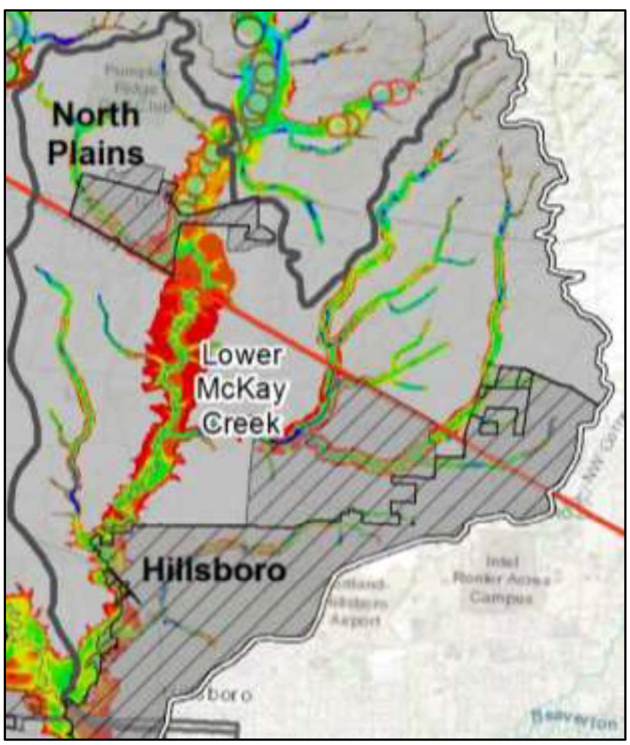
The Lower McKay Creek Sub-Watershed is mostly within the lowlands of the Tualatin Plain. Most of the sub-watershed is privately owned and agriculture, rural homes, and urban areas are the primary land uses. Water temperatures are high and consequently there is minimal salmonid fish presence in McKay Creek during summer and early fall. Historically the sub-watered included diverse wetland, savanna, and prairie habitats that have largely been lost

Watershed Area and Land Uses

- 19,024 acres, all in private ownership
- A portion of the city of North Plains's, and Hillsboro's UGBs are within the lower sub-watershed

Riparian and Upland Habitat Conditions

- There is limited riparian tree cover throughout the sub-watershed on agricultural, residential, and urban lands where there are extensive areas with minimal riparian shade
- Few larger trees (>50 cm dbh) in riparian areas
- Historically the lower sub-watershed included extensive savanna, prairie, and wetland habitats



Lager circles correspond to higher densities of juvenile coho in pools; red circles = no coho observed

Physical Conditions

- The geology consists of extensive Missoula flood deposits throughout the sub-basin, with alluvaial material within McKay Creek's channel and floodplain
- Channels substrate consists of fine-grained sediments with little suitable spawning gravels
- Large portions of McKay Creek's channel is deeply incised, which limits the channel's interaction with the floodplain

Fish, Habitat, and Water Quality

- Limited instream large wood in channels wood due to past practices
- The mainstem is characterized by a wider floodplain, with some side channels and off-channel habitats that are now isolated due to channel incision or land management activities
- Unsuitable summer salmonid rearing temperatures; salmonid use is largly restricted to winter and spring periods
- NetMap identified no tributaries in sub-watershed that potentially could provide cool water temperatures to the mainstem (thermal refugia)
- Climate change prediction: Currently summer temperatures are unsitable for salmonids and by 2080 climate change will continue to increase water temperatures and limit fish use

Habitat Restoration and Fish Passage Barriers

- Extensive areas where improved riparian vegetation on the mainstem and tributary streams will improve habitat
- 56 potential fish passage barriers; no priority fish passage barriers
- There is the potential to restore floodplain off-channel areas to improve winter salmonid rearing habitat through actions such as reconnecting side-channels and floodplains
- Opportunities to restore historical savanna, prairie, and wetland habitats

10. Restoration Goals, Strategies, and Actions

Goal A: Protect and restore mainstem anchor habitats

Description

Focus restoration efforts on securing and enhancing anchor habitats: Stream habitats that provide all of the essential habitat features and processes necessary to support the focal fish species' freshwater life history stages: Egg incubation, summer rearing with cool water, and refugia (e.g., off-channel areas) from floods. Based on the RBA findings, anchor habitats and corresponding fish prescience are confined to mainstem and tributaries in Upper and Lower East Fork Dairy Creek, and Upper West Fork Dairy Creek subwatersheds.

Strategies

- Enhance habitat complexity, floodplain connectivity, and access to side channels and other off-channel habitats
- Enhance access into cool water areas
- Improve riparian function
- Where appropriate, enhance beaver habitat to attract beavers for the creation of ponds that offer fish habitat, cool water areas, and refuge from high flows
- To help sustain anchor habitats for the long-term, track climate change research and identify methods to measure and adaptively respond to climate change impacts on anchor habitats

Actions

- Add large wood to stream channels and off-channel features designed to promote pool formation, retention of gravels, and cover
- Reconnect the stream to isolated habitat features and enhance fish access to side-channels and other areas with cool water temperatures and high-flow refuge habitat
- Enhance riparian areas through weed removal and planting trees and other native vegetation
- Enhance beaver habitat
- Implement methods to measure and adaptively respond to climate change impacts on anchor habitats

Focal Sub-Watersheds

- Upper East Fork Dairy
- Lower East Fork Dairy
- Upper West Fork Dairy

Goal B: Enhance riparian function and water temperatures

Description

Enhance the future delivery of large wood to stream channels and improve shade and other riparian functions through targeted riparian restoration actions. Over the long term these actions will improve water temperatures and enhance stream complexity.

Strategies

- Maximize water temperature improvements by focusing on streams where NetMap identified optimal areas for enhancing riparian shade for water temperature improvement
- Enhance riparian function by controlling weeds and planting trees and other native vegetation
- Enhance streamside and floodplain wetlands by planting native vegetation, and where appropriate improving hydrologic connectivity between the stream and wetland areas
- Identify constructed in-line ponds that are impacting water temperatures and other water quality parameters

Actions

- Enhance riparian areas through weed removal and planting trees and other native vegetation
- Enhance streamside and floodplain wetlands by planting trees and native vegetation
- Enhance hydrologic connections between the stream and wetland areas
- Investigate constructed in-line ponds and develop an approach for addressing ponds impacting water quality

Focal Sub-Watersheds

- Lower East Fork Dairy
- Upper West Fork Dairy
- Middle West Fork Dairy
- Upper McKay Creek

Goal C: Enhance historical floodplain connectivity and habitats

Description

Enhance floodplain connectivity in the lower Dairy-McKay Sub-Basin where large floodplain areas were historically connected to stream channels. Reconnecting floodplain and off-channel features will slow floodwaters, enhance wetland and riparian habitat function, and create high flow refugia for fish. Restoration actions in this area should also focus on emergent wetlands, wet prairies, and other historical habitats.

Strategies

- Enhance habitat complexity, floodplain connectivity, and access to side channels and other off-channel habitats
- Aggrade incised stream channel to raise the water surface and enhance hydrologic connectivity between the stream and floodplain
- Improve riparian function by controlling weeds and planting trees and other native vegetation
- Enhance areas where emergent wetlands, wet prairies, and other historical habitats have been lost or impaired

Actions

- Add large wood to streams to trap substrate, aggrade the channel, and provide more frequent flood interaction between the channel and floodplain
- Reconnect the stream to isolated habitat features and enhance fish access to side-channels and other areas with cool water temperatures and high-flow refuge habitat
- Enhance riparian areas through weed removal and planting trees and other native vegetation
- Enhance historical wetlands and other habitats through native plantings and, where appropriate, improving hydrological connectivity between the channel and floodplain habitats

Focal Sub-Watersheds

- Lower McKay Creek
- Council Creek-Dairy Creek
- Lower East Fork Dairy
- Lower West Fork Dairy

Goal D: Enhance fish passage

Description

Enhance fish passage into cold-water tributaries that also provide habitat capacity. Consider addressing the Upper McKay Sub-Watershed fish passage barriers. Improving fish passage in Upper McKay Creek will not address passage for coho and winter steelhead because there is a waterfall blocking access. Improving passage would benefit the isolated cutthroat trout population and improve habitat access for Pacific lamprey potentially ascending the falls.

Strategies

- Investigate barriers where the fish passage status is unknown according to the barrier inventory
- Investigate Pacific lamprey access over McKay Falls
- Address barriers that limit access into cold water habitats for adult and juvenile fish by improving or removing the barrier

Actions

- Improve or replace barriers that restrict fish passage
- If appropriate, replace or remove Upper McKay Creek fish passage barriers to provide access for cutthroat trout and Pacific lamprey

Focal Sub-Watersheds

- Upper East Fork Dairy Creek
- Upper McKay Creek
- Middle West Fork Dairy Creek
- Upper West Fork Dairy Creek

Goal E: Provide information and outreach to landowners and stakeholders on watershed conditions and restoration opportunities

Description

Implementing the Action Plan relies on local landowners' and stakeholders' understanding and supporting restoration priorities. As the community becomes aware of opportunities and resources become available for restoration, landowners can engage in projects on their land.

Strategies

- Provide information at community gathering places and events
- Contact local groups such as churches, schools, and civic organizations to identify opportunities to engage residents and provide information
- Hold Council meetings or project tours in the Dairy-McKay Creek Sub-Watershed
- Interview landowners about their restoration needs
- Provide opportunities for all ages to engage in watershed activities and education, especially school-age children and university students
- Publish and distribute annual updates on Council activities
- Maintain a database of interested landowners
- Develop a user-friendly map on the TRWC website with project opportunity areas and their justification based on this Action Plan

Goal F: Engage landowners and stakeholders in restoration actions

Description

Landowners are the local experts on their land and can efficiently restore and maintain habitat on their property given adequate resources and support. Developing and leveraging partnerships that support landowners will deliver services more efficiently.

Strategies

- Develop strategic demonstration projects with willing landowners
- Host regular volunteer work parties in target watersheds
- Develop a model for financial, organizational, and technical assistance to engage and support landowner involvement

Goal G: Monitor and track watershed conditions, track aquatic organism population status and trends, and evaluate restoration actions

Description

A critical component of the Action Plan's implementation is the assessment of actions through the analysis of monitoring data. A strategic approach to monitoring and assessment provides a framework for TRWC to track and examine watershed conditions over time, assess restoration opportunities, and evaluate restoration outcomes to determine if activities are achieving the goals of supporting healthy fish and wildlife populations and improving water quality.

Strategies

- Develop a monitoring program to evaluate the effectiveness of actions described in the action plan
- Periodically assess fish numbers and distribution by repeating the RBA
- Apply the RBA and habitat inventory methods to survey restoration sites before and after implementation
- Work with Tualatin Basin partners to develop and apply a comprehensive water quality monitoring framework that can track changing conditions, including assessing climate change impacts

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