RECLAMATION
Managing Water in the West

–FINAL–

THE CATHERINE CREEK TRIBUTARY ASSESSMENT

GRANDE RONDE RIVER BASIN

Tributary Habitat Program, Oregon

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region
Boise, Idaho

February 2012

U.S. DEPARTMENT OF THE INTERIOR

Protecting America's Great Outdoors and Powering Our Future

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The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Cover Photograph: View looking east (downstream) along Catherine Creek, Reach 2 at river mile 26.0, in the Cove area, Mt. Fanny (upper left) and Phys Point (upper right) can be seen in the background.

Bureau of Reclamation photograph – Catherine Creek Tributary Assessment-Grande Ronde River Basin-Tributary Habitat Program, Oregon – July 29, 2010.

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TABLE OF CONTENTS

Acronyms and Abbreviations

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

Appendices

TABLE OF CONTENTS (CONTINUED)

List of Figures

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

List of Tables

Executive Summary

This report describes the first phase in an assessment process that identifies channel and floodplain processes that are relevant to salmonid habitat in Catherine Creek, a tributary to the Grande Ronde River located in northeast Oregon. The objective of this assessment is to provide resource managers and area stakeholders with a summary document of the pertinent scientific information that will help them prioritize future assessment and project action in salmon habitat planning and decision making. This report focuses on Catherine Creek, from its confluence with the Grande Ronde River to the confluence of the North and South Forks of Catherine Creek. The work described in this report was accomplished by a multidisciplinary team with expertise in fisheries, vegetation, and physical processes (hydraulics, hydrogeology, geomorphology, and hydrology). All work was coordinated with local stakeholder involvement that consisted of meetings with an interdisciplinary team (IDT).

As a result of this tributary scale assessment, the 55-mile area is subdivided into three valley segments and seven geomorphic reaches that distinguish sections of Catherine Creek with relatively distinct physical characteristics. The lower valley segment, from the mouth at the Grande Ronde River to near Pyles Creek contains two distinct reaches (reach 1 and reach 2) that are separated due to the redirection of the Grande Ronde River into State Ditch. The middle valley segment contains one unique reach (reach 3) that consists of the Catherine Creek alluvial fan, beginning just upstream of the mouth of Pyles Creek, and ending just upstream of Union, Oregon. The mountainous upper valley segment is segregated into four reaches (4, 5, 6, and 7) based on lateral valley confinement; reaches 4 and 6 are unconfined with moderate floodplain interaction, while reaches 5 and 7 are confined and naturally have little to no floodplains.

Historically, the assessment area provided important habitat for Chinook salmon for all freshwater life cycle needs including spawning, incubation, juvenile rearing, migration, and holding. Rearing and overwintering habitats were likely abundant throughout the assessment area as woody debris, meandering, beaver complexes, and vigorous riparian communities were common. Large-scale changes to the landscape and directly to the creek have significantly altered the historic habitat. Changes have included channel manipulation, floodplain development, vegetation alteration, water supply development, the near extirpation of beaver, and the introduction of invasive species. Cumulatively, these changes have reduced available salmon habitat quantity and complexity. The lower valley segment has been affected the most, followed by the middle valley segment, and lastly by the upper valley segment.

All valley segments have been identified as having potential for habitat improvements from minimal potential to high potential. The first four reaches (reaches 1 through 4) were identified as having the greatest potential for improvements, in part, due to the substantial habitat degradation in these reaches. For each reach, data gaps were identified for future reach assessment and project scoping. Data gaps range from the identification of mortality pathways of juvenile fish in reaches 1 and 2 to identifying the sediment budgets of reaches 3 and 4. It is anticipated that many of the data gaps will be addressed in future reach assessments and project planning efforts.

Through this tributary assessment (TA), the Bureau of Reclamation (Reclamation) provided a strategy to continue salmon habitat improvements that include the next phase of assessments to provide details at the reach scale and further Oregon Department of Fish and Wildlife (ODFW) research activities for reaches 1 through 4.

1. Introduction

The Bureau of Reclamation (Reclamation) and Bonneville Power Administration (BPA) contribute to the implementation of salmonid habitat improvement projects in the Grande Ronde subbasin to help meet commitments contained in the 2010 Supplemental Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp) (NOAA Fisheries 2010). This BiOp includes a Reasonable and Prudent Alternative (RPA), or a suite of actions, to protect listed salmon and steelhead across their life cycle. Habitat improvement projects in various Columbia River tributaries are one aspect of this RPA. Reclamation provides technical assistance to States, Tribes, Federal agencies, and other local partners for identification, design, and construction of stream habitat improvement projects that primarily address streamflow, access, entrainment, and channel complexity limiting factors. Reclamation's contributions to habitat improvement are intended to be within the framework of the FCRPS RPA or related commitments.

2. Purpose of the Study

The purpose of the tributary assessment (TA) is to provide further assessment toward efficient implementation of habitat projects with a final goal of increasing the abundance and productivity of Endangered Species Act (ESA)-listed spring Chinook salmon and steelhead trout. In doing so, Reclamation will be working toward meeting tributary habitat commitments contained in the 2008 FCRPS BiOp (NOAA Fisheries 2008a).

The primary objectives of the TA are to:

1. Understand current ESA-listed fish use and known biological limiting factors both spatially and temporally.
2. Identify the causes of biological limiting factors in relation to level of function or impacts of the three habitat forming regimes – hydrologic, geomorphic, and vegetation.
3. Delineate geomorphic reaches based on differing geomorphology and the degree of channel/floodplain confinement.
4. Prioritize the reaches based on potential to address the identified limiting factors.
5. Characterize watershed conditions and large-scale impacts to geomorphic, riparian, and hydrologic regimes based on previous work including additional data that may need to be collected in order to move forward with development and implementation of habitat rehabilitation actions.

3. Study Area

Catherine Creek is a large tributary of the Grande Ronde River that drains 402 square miles (mi$^{2)}$ of the Wallowa Mountains in northeast Oregon (Figure 1). At the current confluence with Catherine Creek, the Grande Ronde River drains 735 mi^2 (for a total of 1,137 mi^2 below the confluence). The majority of Catherine Creek and the Grande Ronde River to this point lie within Union County and are in the Blue Mountains Ecoregion (Omernik 1995). Catherine Creek drains steep mountainsides with elevations over 8,671 feet before crossing a wide and flat valley where it meets the Grande Ronde River at an elevation of 2,677 feet above sea level. The Grande Ronde River continues downstream through northeast Oregon, eventually flowing through the southeast corner of Washington State before joining the Snake River upstream of Lewiston, Idaho, and Clarkston, Washington.

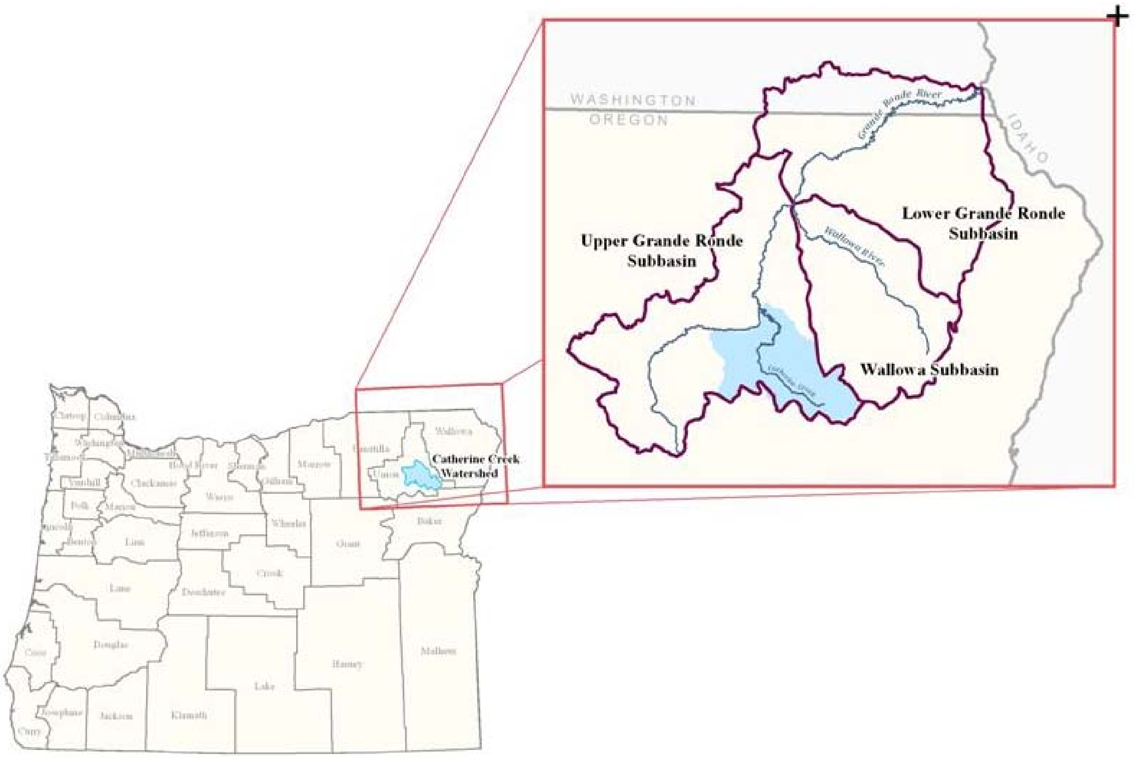


Figure 1. Location map for the Catherine Creek assessment area.

The study area for the Catherine Creek TA includes Catherine Creek from river mile (RM) 0 at the confluence of Catherine Creek and State Ditch (Grande Ronde River), upstream to the U.S. Forest Service (USFS) boundary at the confluence of the North and South Forks of Catherine Creek (RM 55). The study area includes both the floodplain and channel migration zone of Catherine Creek within this reach (Figure 2).

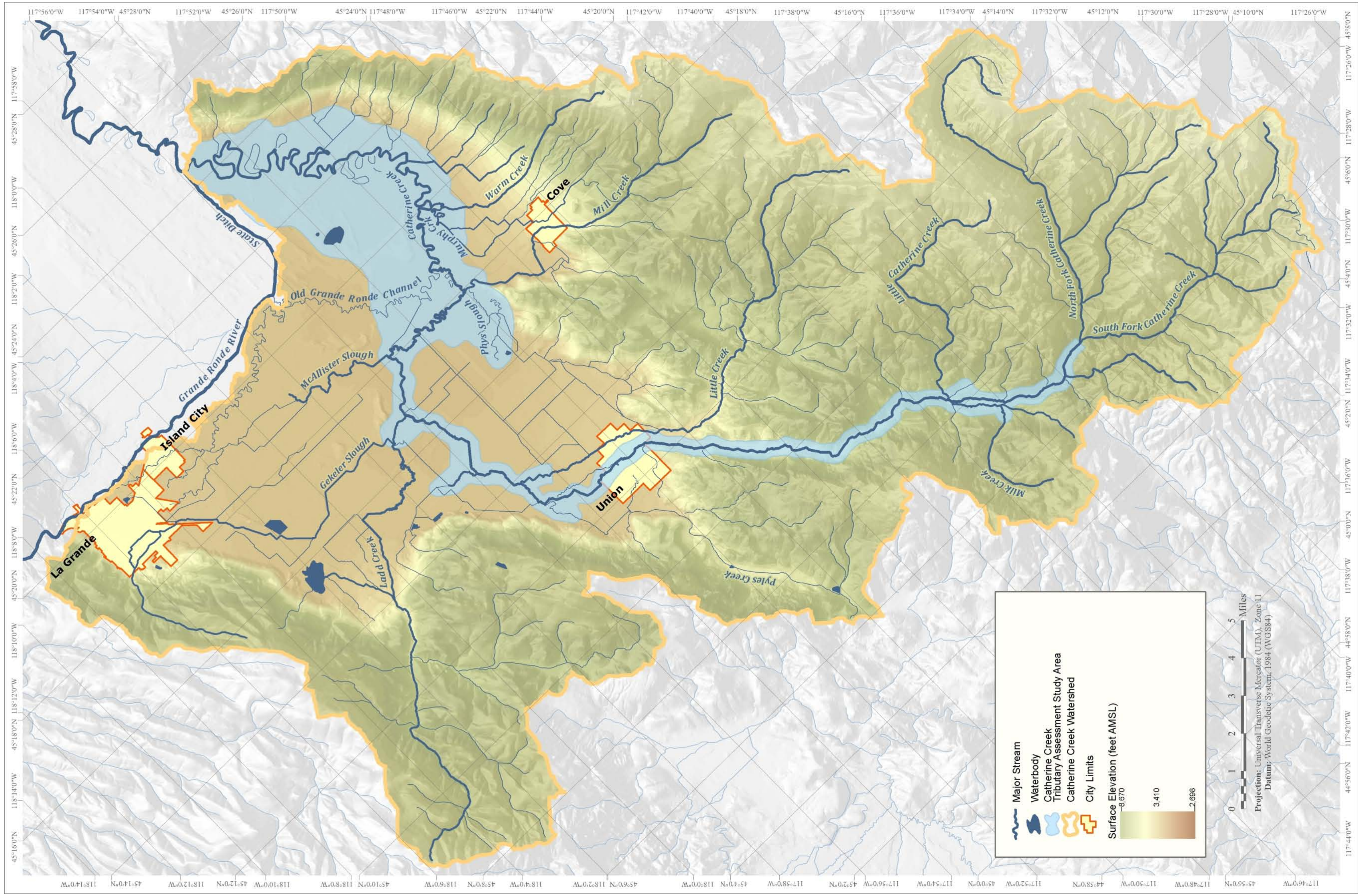


Figure 2. **The Catherine Creek watershed and the asessment study area.**

4. Report Organization

This TA was developed through a combination of literature review, field reconnaissance, data collection, and analysis. The TA focuses on the physical condition, historic and present, of Catherine Creek related to the needs of spring Chinook salmon and steelhead. Emphasis was given to hydrology, water quality, fluvial geomorphology, and stream hydraulics. In addition, groundwater thermo-profiling studies, fish habitat surveys, and juvenile Chinook salmon tracking have been added to focus on known limits of knowledge with respect to fish needs. Stand-alone appendices have been developed for each subject and should be referenced for specific methods and results for each.

This assessment combines and summarizes the findings from each appendix to provide an overview of the historic and present conditions and provides a discussion on the changes that have occurred and the existing needs. This is done in general terms for Catherine Creek as well as for each specific reach identified as part of this assessment.

A primary objective of the TA is to present a logical and consistent scientific overview of the tributary to provide a plan, which will lead to development of individual projects that are the most beneficial to the target species. This is done in part by dividing the tributary into reaches for more detailed assessment, as necessary, and ranking them with local stakeholder input based on their priority for habitat rehabilitation needs and potential. As part of this goal, the tributary is divided into reaches where the creek within a reach has a relatively similar geomorphic character, impacts, and potential, and is decidedly different from adjacent reaches.

5. Technical Approach

Based on the *Draft Conservation and Recovery Plan for Oregon Spring/Summer Chinook Salmon and Steelhead Populations in the Snake River Chinook Salmon Evolutionarily Significant unit and Snake River Steelhead Distinct Population segment* (NOAA Fisheries 2008b), the primary in-basin limiting factors that are present in Catherine Creek for both spring Chinook salmon and steelhead include:

- Water quality and quantity
- Habitat quantity and diversity
- Fish passage (steelhead)
- Riparian conditions
- Predation (steelhead)
- Excess fine sediment

Individual studies for this assessment were designed to address details of known limiting factors as listed above. Evaluation of Catherine Creek was performed for several scientific discipline areas including: hydrology, water quality, fluvial geomorphology, stream hydraulics, hydrogeology, biology, and habitat biology. Each of the individual areas of study is documented in stand-alone appendices to this report. A synopsis of the methods performed for this TA within each area of study follow.

5.1 Hydrology

The hydrologic assessment involved a literature review to interpret past conditions and events that resulted in the current hydrologic regime. Data from active and inactive stream gages, climate stations, and Natural Resources Conservation Service (NRCS) snotel stations were collected and examined throughout the study area to document historic and current conditions and recent trends including potential climate change.

While several long-term stream gages exist within the Grande Ronde River and Catherine Creek channel networks, there was a lack of information in the lower Catherine Creek watershed. In 2010, Reclamation installed nine stream gages to better monitor and understand the complex hydrologic regime, backwater effects, and tributary inputs in the lower valley.

Data from the June 2010 flood was collected within the Grande Ronde Valley from active stream gages; high water elevations were marked and later surveyed to better understand the flood hydrology and to improve hydraulic models of flooding within the valley. Oblique aerial photographs were also taken just after the spring peak flow of 2009 to document the valley flooding and provide a basis for validating future hydraulic models.

Peak flow recurrence interval discharges were computed for the hydraulic model using annual instantaneous peak flows from the Catherine Creek near Union, Oregon stream gage and a combination of Grande Ronde River at La Grande, Oregon, and Grande Ronde River near Perry, Oregon data. Peak flow data for Catherine Creek were used in a Log-Pearson III analysis to develop recurrence interval discharges at the stream gage. The data were then extrapolated to downstream locations by adjusting the discharge by the ratio of average annual watershed precipitation volumes in order to account for the increasing contributing area downstream and the reduced average annual precipitation depth. Grande Ronde discharge data were directly combined (stream gages locations are relatively close to one another with a negligible difference in watershed area) to create a single and longer data record that was then used in a Log-Pearson III analysis to develop recurrence interval discharges.

5.2 Water Quality

A literature search was conducted to gather information and data pertaining to water quality in Catherine Creek. Readily available literature was obtained and local agencies contacted to prepare this report. In particular, the Oregon Department of Environmental (ODEQ) Quality's Total Maximum Daily Load (TMDL) report for the Grande Ronde River (ODEQ 2000) and corresponding forward-looking infrared (FLIR) imagery from August of 1999 were used.

5.3 Fluvial Geomorphology

Assessing the fluvial geomorphology of Catherine Creek included the collection and review of existing literature and data, fish passage mapping efforts, existing geologic data, and ortho-rectified aerial photography for 1937, 1956, 1964, 1971, 2008, and 2009. In addition, light distance and ranging (LiDAR) elevation data and associated imagery from 2007 and 2009 were used. Much of the information was electronic and formatted for use with geographic information system (GIS) software.

Field methods for data collection included accessing the river by boat or foot. Bed and bank material were collected and analyzed for visual and lab classification using the Unified Soil Classification system (USCS), and the data were used to develop sediment size gradation curves. Locations of all observed anthropogenic features such as culverts, levees, diversions, and bridges were recorded on printed maps. In addition, Catherine Creek was documented with digital photographs.

Data generated in the field such as maps of anthropogenic features and photo locations were converted to electronic files in a GIS format. Ortho-rectified aerial photographs were analyzed to understand the timing of the placement of anthropogenic features and impacts to the channel (length/percent shortening). Aerial photographs were used to map channel centerlines for the years of 1937, 1956, 1964, 1971, 2007, and 2009 to develop an estimated historic migration zone. Aerial photographs from 2007 and 2009 (see "Mapping and Database Development") were also used to analyze current geomorphic characteristics of the channel including sinuosity, channel gradient, and valley gradient as well as the changes to these characteristics temporally.

5.4 Hydraulics

A hydraulic model was developed to evaluate how water moves through Catherine Creek, what the capacity of the creek is, where and to what extent flooding occurs, and how the creek interacts with structures (e.g., bridges, diversions) and the landscape. A one-dimensional, steady state, hydraulic model was developed and used to analyze channel and floodplain connectivity for this TA. The U.S. Army Corps of Engineers (USACE)

Hydraulic Engineering Center's River Analysis System (HEC-RAS) was used and is documented in the hydraulics appendix (Appendix D).

5.5 Hydrogeology

Surface-groundwater interaction within the study area was investigated on a coarse scale through analysis of Oregon Water Resources Department (OWRD) well data, the 2000 FLIR study by Watershed Sciences (ODEQ 2000,) and by performing a field investigation of the thermal profile of Catherine Creek.

Reclamation conducted a field investigation in July 2010 to collect a thermal profile on part of Catherine Creek in order to define the spatial variation of temperature due to groundwater contributions. An additional area was profiled in March 2011. A total of 42.1 miles of Catherine Creek were evaluated for thermal changes in the profile. The method used was developed in 2001 by the U.S. Geological Survey (USGS) in the Yakima River basin in Washington to document the longitudinal distribution of a river's temperature regime and areas of groundwater discharge (Vaccaro and Maloy 2006). The thermal profile method consisted of towing a temperature probe from a boat along sections of Catherine Creek to measure the temperature near the creek bottom while concurrently logging spatial coordinates with a Global Positioning System (GPS). During the sampling period, portable temperature loggers were placed at the upstream and downstream ends of the profiled reach to provide additional information on the diurnal temperature change entering and leaving the sampled reach of Catherine Creek. Both broad and localized groundwater discharge areas were then identified by locating deviations from the diurnal heating pattern.

5.6 Biology

Establishing historic and existing conditions for ESA-listed spring Chinook salmon and steelhead within Catherine Creek included a review of existing literature and published research from the ODFW, National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NOAA Fisheries), Grande Ronde Model Watershed (GRMW), USFS, U.S. Fish and Wildlife Service (USFWS), and others. Additionally, Reclamation funded a habitat assessment of Catherine Creek performed by ODFW throughout the study area during the summer of 2010 (Appendix G). Reclamation also partially funded a research study by ODFW during the fall of 2009 and the winter of 2010 using radio transmitters to track juvenile salmonids that overwinter within the Grande Ronde Valley. This study was extended to the fall of 2010 through the spring of 2011 (Appendix H).

5.7 Mapping and Database Development

To prepare the Catherine Creek TA, geospatial data needs were identified and a plan was established to build a common, distributable geospatial database library. New datasets, such as high-resolution aerial imagery and LiDAR data were acquired. Existing datasets, produced and maintained by federal, state, and non-governmental agencies were used. The geospatial datasets were organized into a library structure for distribution among the tributary assessment team and partners. Geospatial datasets within the library fall into the four following generalized categories:

1. **Aerial Photography (historic and current) –** High-resolution (1-foot ground resolution) true-color orthophotographs were obtained through airborne data acquisition in 2007. The 2007 imagery covered the middle of the Catherine Creek river corridor and floodplain (Figure 3). Additional orthophotography for upper Catherine Creek, lower Catherine Creek, and the Grande Ronde River was acquired in 2009. This imagery provides a record of current land use and location of the present-day stream channel.

   Historical imagery for 1937, 1956, 1964, and 1971 was obtained, scanned to digital format, and geo-rectified and geospatially referenced for use in GIS software applications. This imagery provides a historical record of changes in land use and the stream channel.

Figure 3. Catherine Creek floodplain and river corridor aerial photo and LiDAR data set collection areas including year of acquisition.

2. **Elevation –** LiDAR data were acquired during the orthophotograph acquisitions in 2007 and 2009. The LiDAR covers the same extent as the orthophotography and provides a detailed surface model of the Catherine Creek floodplain and stream corridor.

   USGS 30-meter and 10-meter National Elevation Datasets (NED) were acquired to provide extensive coverage for surface analysis within the Catherine Creek Watershed and Upper Grande Ronde subbasin.

3. **Surveys –** Ground surveys were performed by the local engineering firm Anderson Perry and Associates in the fall of 2010. A survey control network was established at 45 locations throughout the study area by establishment of bench marks and re-occupation of existing points. Topographic surveys were performed at 54 structures within the study area including: 39 bridge surveys, 5 culvert surveys, and 10 diversion dam surveys. Surveys of structures included measuring the physical dimensions of each structure, sketching each, and providing topographic-surveyed cross sections at four locations, two upstream and two downstream of each structure for inclusion into the hydraulic model.

   Additional surveys of the channel bathymetry were performed by Reclamation in October 2010 – Reclamation completed bathymetric surveys (depth to creek bottom) of Catherine Creek for accessible reaches of Catherine Creek between RM 0 and 36.5 excluding two sub-reaches between RM 27 to 30 and RM 32 to 34.5. Additionally, approximately 20 miles of bathymetric survey were performed on the Grande Ronde River between Rhinehart Lane and Pierce Bridge (including State Ditch). Bathymetric surveys were performed utilizing a raft-mounted Acoustic Doppler Profiler and GPS survey equipment.

4. **Baseline Geospatial Data –** Other baseline data in the TA geospatial data library includes precipitation (PRISM Climate Group), hydrography (USGS), forest fire history and timber harvest (USFS), landcover (USGS), water quality data (Oregon Department of Ecology), geology (Oregon Department of Geology and Mineral Industries), soils (NRCS), and fish species and habitat distribution (StreamNet).

The acquired geospatial datasets were generally incorporated into the TA geospatial data library as unmodified source data. In some cases, the data were spatially filtered and/or processed to meet specific needs for the TA. Any alterations made to source data are documented in the appurtenant metadata.

6. Interdisciplinary Team (IDT) and Stakeholder Involvement

Local stakeholder involvement was a critical component throughout this TA process. Local involvement included working with an IDT comprised of local stakeholders, resource managers, local, state, and federal action agencies, and tribes. Represented action agencies that have participated in the planning and execution of the Catherine Creek TA include:

- Union Soil and Water Conservation District (USWCD)
- GRMW
- ODFW
- USFS
- NOAA Fisheries
- USFWS
- Confederated Tribes of the Umatilla Indian Reservation (CTUIR)
- U.S. Department of Agriculture (USDA)
- OWRD

Reclamation requested direction and feedback at key decision points throughout the assessment. Meetings were held with the IDT to obtain input regarding assessment scoping, updates, field preparation, notification, and permission of landowners, draft report and results discussion, public outreach, and reach selection for further study. Several meetings were conducted in La Grande, Oregon. Table 1 summarizes IDT meetings held in association with this assessment.

Table 1. Summary of IDT meetings for the Catherine Creek TA.

Date	Meeting	Local Participants	Summary
April 14-15, 2009	Initial meeting	UCSWCD/GRMW/BPA/NOAA/ CTUIR/ODFW	Discussion of Reclamation assessments/ field site tour
May 20, 2009	Initial follow-up meeting	GRMW/CTUIR/ODFW/DOGMI/ UCSWCD/AP	Solidify local involvement
October 7, 2009	Initial TA discussion	IDT	Assessment IDT
January 19, 2010	Scoping presentation	IDT	Identified goals and objectives
February 23, 2010	Draft scope	IDT	Distributed and discussed draft Scope
April 27, 2010	Field scoping	IDT	Planned upcoming field season
June 24, 2010	Landowner briefing	Valley landowners/ GRMW/UCSWCD/ODFW/CTUIR/ Columbia River Inter-Tribal Fish Commission (CRITFC)	Updated landowners regarding field season/CRITFC
October 27, 2010	Field update	IDT	Update from each lead investigator
May 26, 2011	Draft update	IDT	Initial results briefing
June 28, 2011	Public open house	IDT/Valley landowners/interested public	Informed landowners and interested public of assessment findings and other efforts and projects.
September 7, 2011	Reach prioritization	IDT	Discussed and prioritized reaches

7. General Study Area Physical Overview

Located in the southwest portion of the Blue Mountains Ecoregion, the Grande Ronde subbasin (Figure 4) is characterized by rugged mountains where the headwaters of the Grande Ronde River begin. It is defined by the Blue Mountains to the west and northwest, with peaks as high as 7,700 feet, and the Wallowa Mountains along the south with peaks of nearly 10,000 feet elevation. The headwaters of Catherine Creek are in the far western portion of the Wallowa Mountains and have a peak elevation of 8,761 feet.

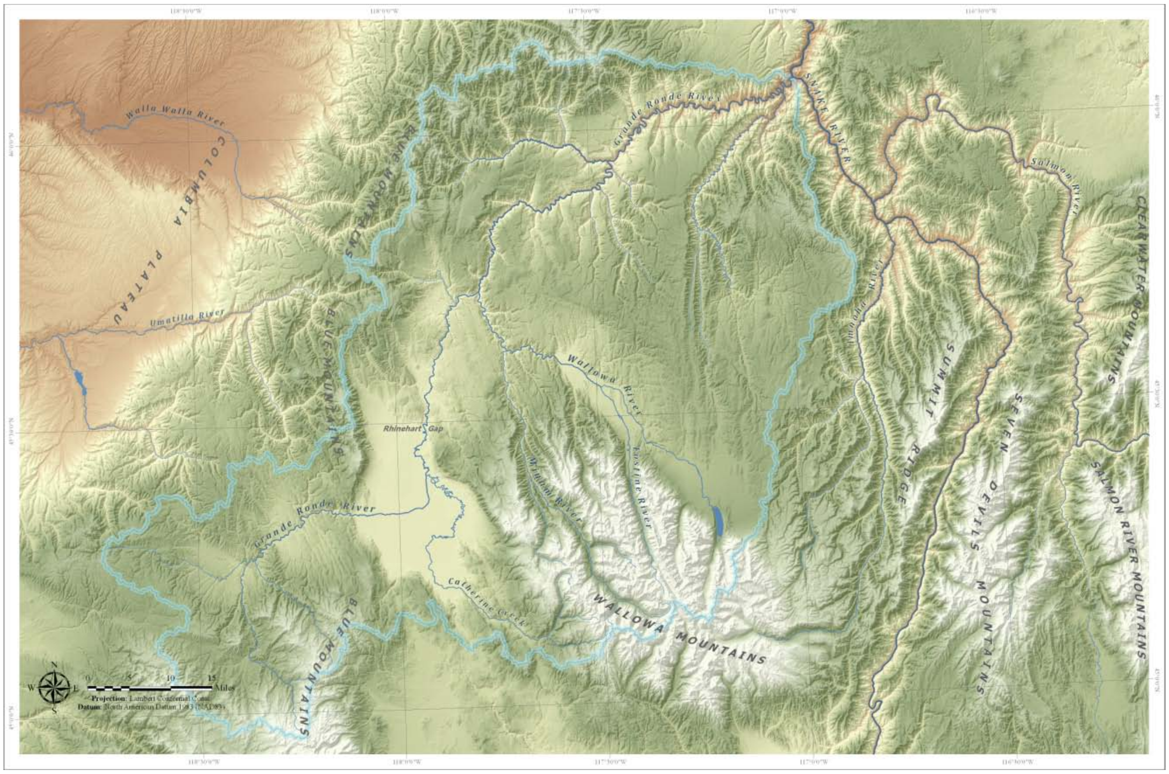


Figure 4. Catherine Creek floodplain and river corridor aerial photo and LiDAR data set collection areas including year of acquisition.

The Grande Ronde River flows northeast for 212 miles from its origin to join the Snake River at RM 169, about 20 miles upstream of Asotin, Washington, 493 miles from the mouth of the Columbia River. The Grande Ronde River begins in the Blue Mountains, flows north and then northeast through the Grande Ronde Valley near the city of La Grande, Oregon. Here, the river slows and meanders through the valley before flowing northeast through a geologic feature that constricts the river and forms the downstream end of the valley, locally known as Rhinehart Gap (Figure 5). Continuing northeasterly, the river flows through a predominantly confined canyon section with a markedly increased slope as it moves downstream through the towns of Elgin and Troy, Oregon, crossing into Washington State at RM 38.7 before joining the Snake River. Eight major hydroelectric dams are located on the Snake and Columbia Rivers between the mouth of the Grande Ronde and the Pacific Ocean.

Catherine Creek originates in the Eagle Cap Wilderness Area of the Wallowa Mountains and flows northwest, passing through the town of Union. Near Union, Catherine Creek turns north and flows through the Grande Ronde Valley, where it meets the Grande Ronde River at approximately RM 140.

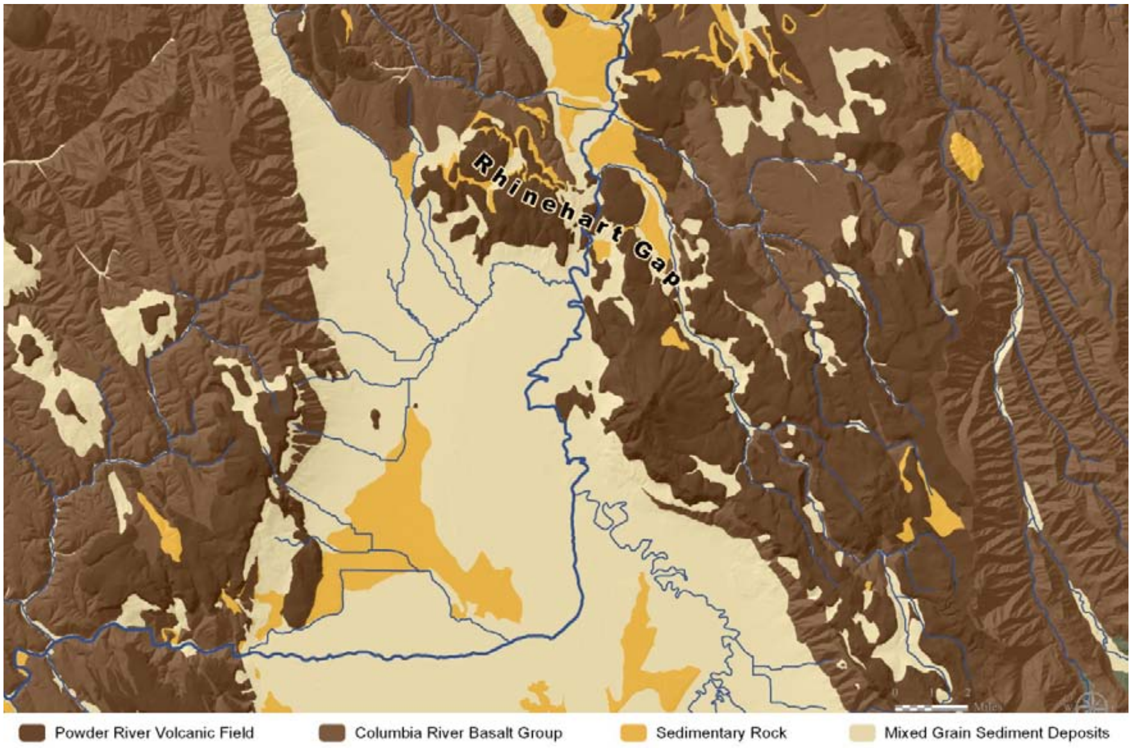


Figure 5. **Geologic features comprising Rhinehart Gap.**

7.1 Regional and Study Area Geology

The Grande Ronde Valley is a large structural basin situated along the eastern flank of the Blue Mountain uplift (Carson 2001). Rhinehart Gap, located at the north end of the valley, acts as a natural base level control for the Grande Ronde River. The valley is filled with up to 1,550 feet of sandy silt interbedded with thin seams of gravel and sand derived from glaciers and alluvial processes (Van Tassell 2001; Ferns et al. 2002). Deposition during the Pleistocene resulted from three episodes of alpine glaciation in the highlands of the Elkhorn and Wallowa Mountains when the Grande Ronde River and Catherine Creek carried glacial outwash into the valley (Ferns et al. 2002). The sediments developed into terraces and alluvial fan delta deposits. Braided streams formed as sedimentation rates fluctuated during glacial advances and retreats (Ferns et al. 2010). Lacustrine sediments on the valley bottom are indicative of a very low energy environment and hints that intermittent damming of the outflow of the basin may have occurred or large floods resulted in substantial backwater affects that resulted in long-term inundation of the valley bottom.

The Grande Ronde Valley is a broad, flat, alluvial plain surrounded by bedrock highlands. Exposed granitic rocks (granodiorite, tonolite, and diorite out crops) of the Wallowa batholith (Cretaceous) can be seen along the upper reaches of Catherine Creek. The margins of the valley have interfingering boulder, and alluvial fan deposits (Van Tassell 2001). Recent faults surround the valley and downward movement of the valley floor has resulted in a structural trap that is being filled by the deposition of alluvial sediments. Where the Grande Ronde River, Catherine Creek, Mill Creek, and Ladd Creek enter the valley, large alluvial fan deltas form gently sloping topography. The shape and gradient of the stream changes at the fan delta-alluvial plain interface, shifting from a single thread, and higher energy section on the fan structure to a lower energy environment on the valley floor as noted by the meandering planform. As a result, there is a decrease in channel and floodplain deposit grain size from gravel and sand to silt and clay and a broader distribution of the alluvial channel deposits into the meander zone (Figure 6).

The alluvial deposits vary in gradation, composition, and permeability; depending on their location within the valley and the energy under which they were deposited (e.g., coarser-grained, higher energy deposits on the fan delta or finer-grained, lower energy deposits on the alluvial plain). Alluvium, composed of moderately to well-sorted gravel, sand, and silt is found in the active stream channels and on adjoining floodplains of the Grande Ronde River, Mill Creek, Catherine Creek, and Ladd Creek. The alluvial deposits are reworked by the river and area approximately 15 to 30 feet thick (Ferns et al. 2002). They interfinger with fan delta deposits and are hydraulically connected to older, deeper, abandoned channels (Figure 6).

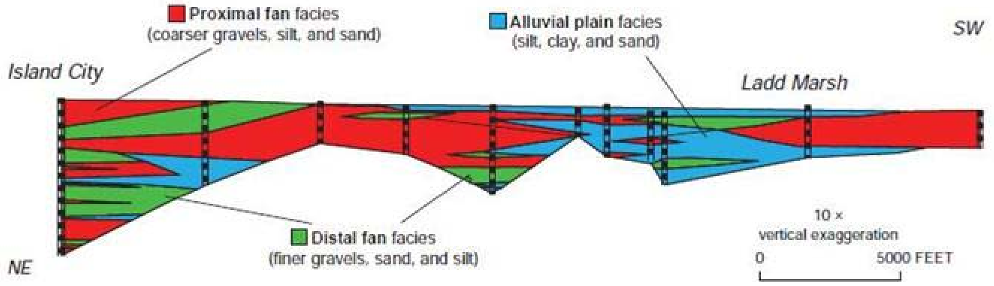


Figure 6. Interpretive cross section in the Grande Ronde valley illustrating interfingering valley fill deposits (Ferns et al. 2010).

7.2 Regional and Watershed Hydrology

Catherine Creek and nearby creeks and rivers are dominated by spring snowmelt. Figure 7 depicts an average hydrograph for the Catherine Creek near Union, Oregon stream gage (RM 46.7) along with present-day spring Chinook salmon life stages across the average annual hydrograph. Most of the annual precipitation in the Blue and Wallowa mountains occurs during the winter in the form of snow. Peak flows generally occur in May (Catherine Creek near Union gage has an average peak date of May 13), but can occur from April through June. Flood peaks for the Grande Ronde River in the Grande Ronde Valley tend to occur earlier, having snowmelt peaks as early as February in some years. Late fall, winter, and early spring rain-on-snow events can develop into substantial peak flow events that can approach the magnitude of the annual snowmelt peak. Winter freeze-thaw events are common in the region and can contain large quantities of ice that cause locally damaging floods, scour, and bank erosion. Due to the high variation in elevation among tributaries and the Grande Ronde River, runoff timing and magnitudes can vary substantially.

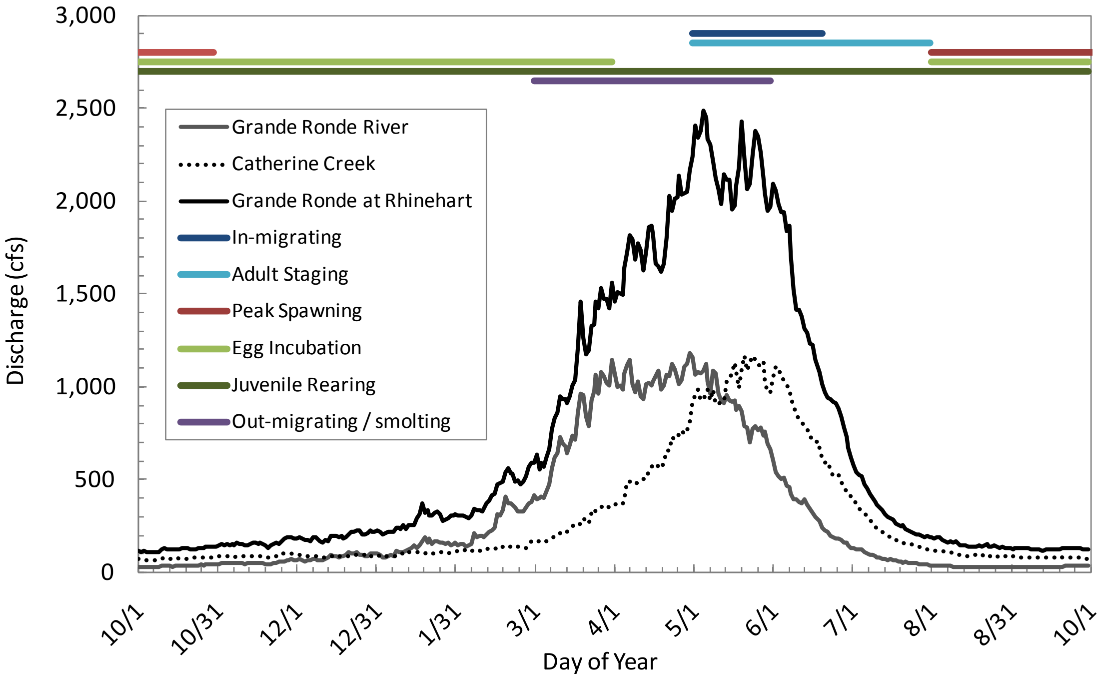


Figure 7. **Average annual hydrograph for Catherine Creek near Union, Oregon (RM 46.7) and combined annual hydrographs for Grande Ronde River near Perry, Oregon and Grande Ronde River at La Grande, Oregon stream gages displaying present-day spring Chinook salmon life stages. The shaded area represents the approximate irrigation season during an average year.**

Summers are relatively dry with lowest flow conditions occurring in August and September. Summer precipitation accounts for a very small percentage of the annual yield and is typically the result of small, localized thunderstorms that may or may not lead to noticeable changes in flow in the smaller tributaries. High intensity thunderstorms have led to flash floods and debris flows, which have caused documented fish kills and substantial geomorphic change in small tributaries to Catherine Creek (Gildemeister 1998). Typically, summer flows are low and exacerbated by withdrawals for urban and agricultural uses, which can completely dry the creek in locations below Union.

Current land use mapping in the Catherine Creek watershed illustrates the extent of urbanization and agriculture that has altered the landscape (Figure 8). Agricultural lands are situated in the Grande Ronde Valley, which encompasses lower portions of the watershed and is the majority of “developed” area. The headwater areas of the upper Catherine Creek watershed are mostly forested.

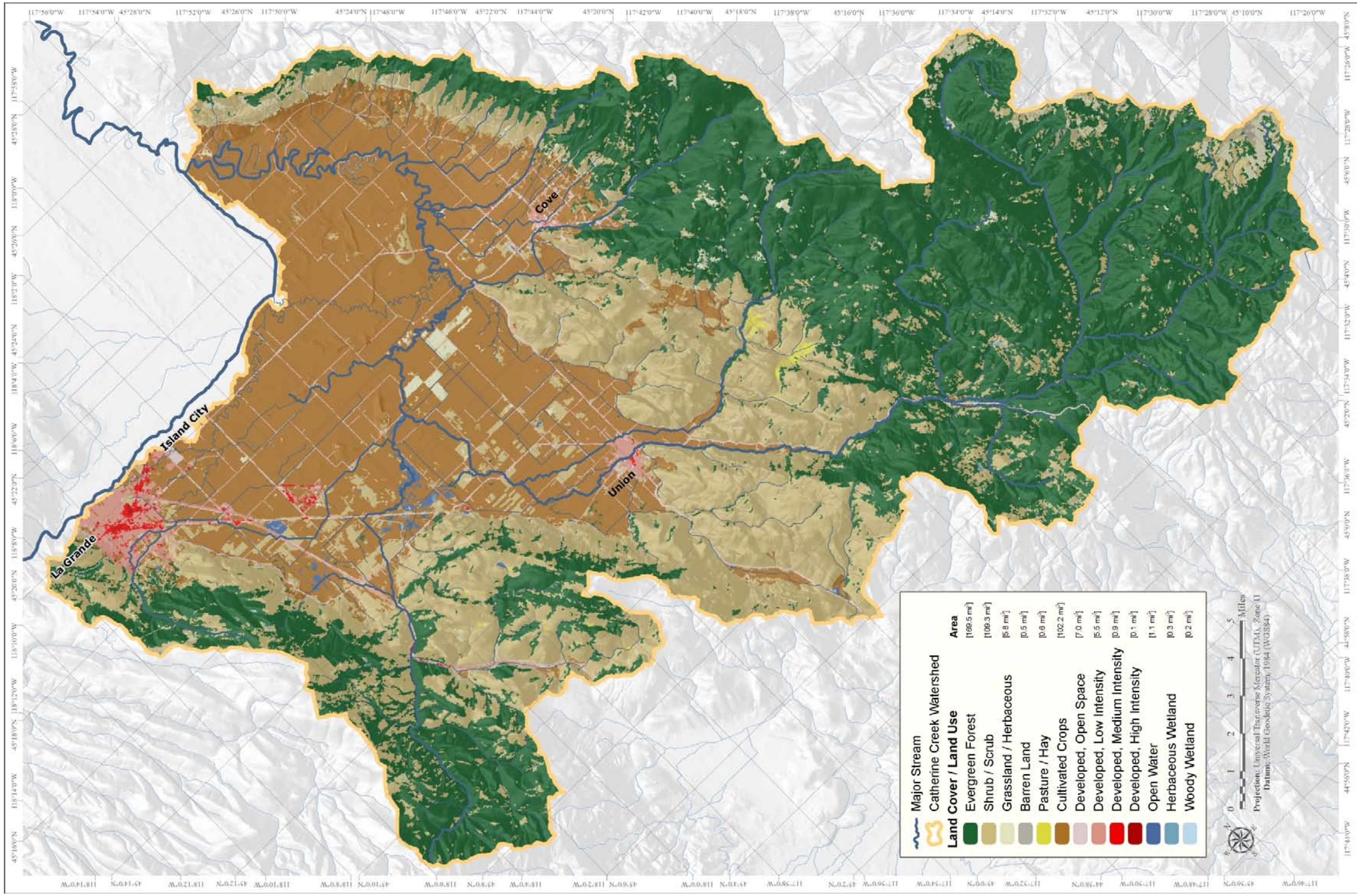


Figure 8. **Current land use (land cover types) in the Catherine Creek wathershed area.**

7.2.1 Climate Change

Hydrologic changes resulting from climate change over the past 60 years have also been trending in ways that contribute additional pressure to strained summer water resources and fish populations (Mote et al. 2003; Rote et al. 2005; Regonda et al. 2005; and Stewart, Cayan, and Dettinger 2005). Peak spring discharges are occurring earlier in the year by as many as 11 days in Catherine Creek and 6 days in the Grande Ronde River and the irrigation season becomes extended proportionally (Appendix A). In addition, the average annual water yields have decreased over the same period by 13 percent in Catherine Creek and by 8 percent in the Grande Ronde River.

7.3 Groundwater

Groundwater bearing stratum in the Grande Ronde Valley can be separated into three general hydrogeologic zones:

- Near surface groundwater zone within the current Catherine Creek alluvial plain (+ 50-feet depth).
- Shallow aquifer within the fan delta and alluvial plain sediments (+ 700-feet depth).
- Deep (volcanic) bedrock aquifer (+ 3,000-feet depth).

The geologic units that make the best aquifers in the Grande Ronde Valley occur at two levels, the shallow fan delta sediments that underlie the Grande Ronde and Catherine Creek fan deltas, and the deep volcanic bedrock (Figure 9). The shallow fan delta and bedrock aquifers are used for water supply wells (irrigation and municipal) in the area; the near-surface groundwater zone is used primarily for residential wells.

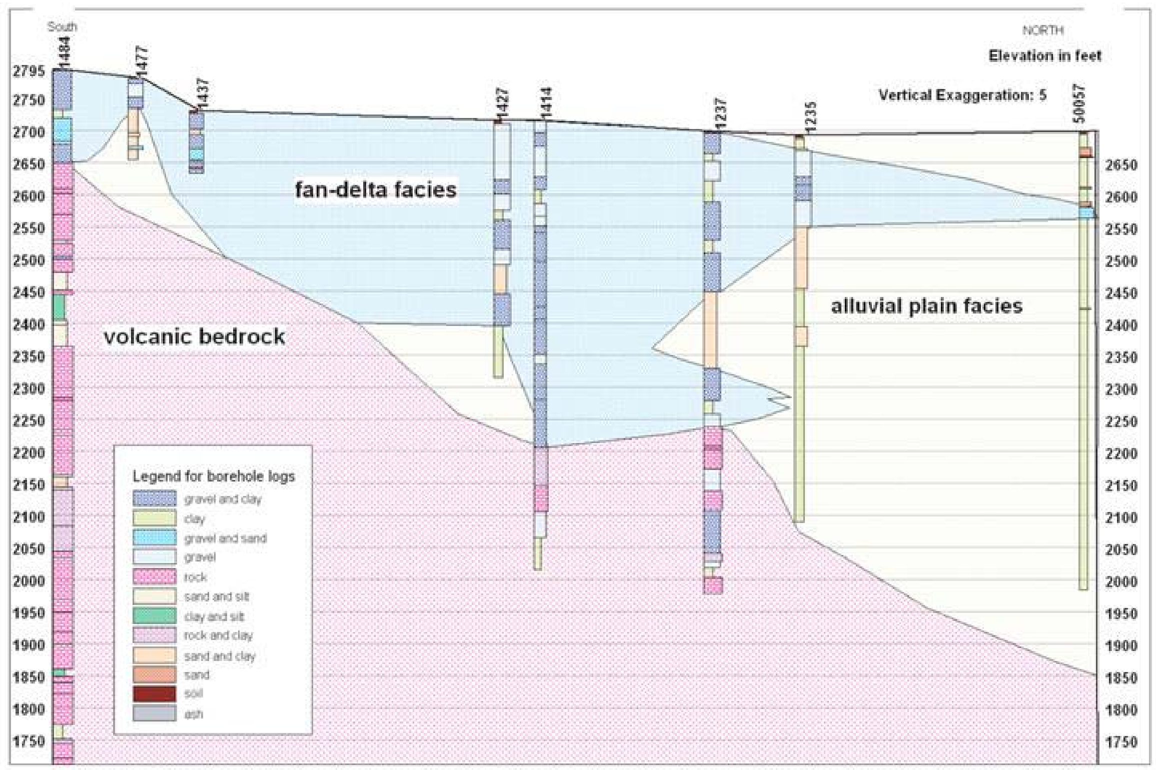


Figure 9. **A schematic of the facies, associated rock types, and well log data across the Catherine Creek fan delta. The transect runs roughly north - south from Union to approximately 0.3 miles west of Phys Point (Ferns et al. 2010).**

7.3.1 Near-surface Groundwater

The interaction of groundwater and surface water along Catherine Creek and its tributaries generally occurs within the upper 50 feet of the ground surface. The fine-grained clay and silt deposits in the alluvial plain have very low permeability and capacity for storing groundwater and are poorly connected to the active river channels (Ferns et al. 2002). Wells produce moderate amounts of water from gravel and sand lenses at shallow depths within the fine-grained alluvial plain sediments, but the water-bearing lenses are generally randomly located, unpredictable, and variable as a potential aquifer (Ferns et al. 2002).

A more detailed discussion of the interaction between Catherine Creek streamflows and the near surface groundwater using FLIR data and thermal profile information can be found in Appendix E.

7.3.2 Shallow Aquifer

The most productive shallow cold-water wells are those that intersect the well-sorted gravel and sand deposits that extend beneath the Grande Ronde and Catherine Creek fan deltas.

The Grande Ronde River fan delta enters the valley from the west at La Grande and includes gravel, sand, and silt deposits that grade laterally into silty sand and silt alluvial plain deposits (the deposits become finer-grained in the downstream direction). Grande Ronde fan delta gravel deposits are relatively free of clay, potentially as much as 540 feet thick, and have been the most important shallow aquifer in the Grande Ronde Valley (Ferns et al. 2002).

The Catherine Creek/Little Creek fan delta enters the south end of the valley and merges with the alluvial plain to the north. The Catherine Creek/Little Creek fan delta deposits appear to contain a higher proportion of clay and silt than the Grande Ronde fan delta; perhaps from the introduction of glacial flour during glaciation of the upper drainage basin (Ferns et al. 2002). Catherine Creek fan delta gravel has a maximum thickness of 500 feet (Ferns et al. 2002). At Union, the unit is at least 290 feet thick and has historically been an important source of groundwater for the city. For much of its extent, the Catherine Creek fan delta appears to lie directly on bedrock, unlike the Grande Ronde fan delta, which overlies older alluvial plain deposits.

The Mill Creek fan likely has relatively low permeability (Ferns et al. 2002). The apex or upstream end of the fan near the town of Cove, Oregon, appears to contain interbedded clays and poorly sorted clayey gravels with limited permeability. The existence of local low permeability deposits in the subsurface may influence groundwater flow direction and gradients.

Ferns et al. (2002) describe the location and connectivity of permeable, water-bearing gravel channels within the fan deltas as random and unpredictable. The abandoned, alluvial material (sand and gravel) filled channels are thought to provide preferential groundwater flow back to the active channels. This groundwater discharge may influence surface water temperatures. Geologic factors controlling the deposition of alluvial sediments, including rapid lateral and vertical changes in type of valley fill, influence the distribution of permeable zones in the subsurface.

7.3.3 Deep Bedrock Aquifer

Basalt rock of the Grande Ronde Formation of the Columbia River Basalt Group is the most extensive aquifer in the valley. Wells in the deep aquifer generally produce warmer water, and in places provide artesian flow of more than 2,000 gallons per minute (gpm) (Ferns et al. 2002). In the southern Grande Ronde Valley and Lower Catherine Creek areas, the aquifer is tapped only by municipal wells at La Grande and Union. The city of

Imbler and about six irrigation wells produce water from the Grande Ronde Basalt in the northern part of the valley (Ferns et al. 2002). Even though the deep volcanic aquifer has potential for high initial production rates, the low vertical permeability could potentially limit recharge (Ferns et al. 2002).

8. Historic Physical Conditions Overview

Native Americans lived in the Grande Ronde subbasin for thousands of years before settlers began exploring the area in 1811 (Duncan 1998; Gildemeister 1998). The Grande Ronde Valley and lower Catherine Creek was covered in grasslands, wetlands, and a 1,600 to 2,300-acre perennial lake known as Tule Lake (Beckham 1995; Gildemeister 1998). Seasonal high water from snowmelt runoff created a seasonal lake that could reach tens of thousands of acres in size in the lower section of Catherine Creek and the Grande Ronde Valley (Duncan 1998; Gildemeister 1998). Beckham (1995) recounts many early pioneers and explorers’ notes on the Grande Ronde Valley. In general, they document the valley bottom as having the following characteristics; woody trees are only present along the banks of the creeks and rivers, springs are common along the margins of the valley, camas and grasses covered much of the valley bottom while willows, alders, and cottonwoods lined the creeks and rivers (Duncan 1998; Beckham 1995). Areas adjacent to the creek had an abundance of willows and patches of cottonwoods and the soil was “excellent” but swampy in most places along the flat valley (Beckham 1995). The streambanks were noted to be “high and muddy” (Beckham 1995).

Beaver were common in the area before being trapped in excess (ISG 2000; Beckham 1995) and may have been the initiator of Tule Lake (Beckham 1995). With the removal of beavers came the loss of the beaver dam and reservoir complexes and ecological benefits that accompany them including increased habitat and ecological diversity. Beaver complexes provide diverse water depths and velocities contributing to important refugia for salmonids. Indirectly, the complexes supply unique habitat for vegetation contributing to shade, refugia, and a food source for salmonids. Otter were also abundant (Beckham 1995) and typically found in areas inhabited by beavers because of the habitat created by beavers including ponds, wetlands, dens, and food storage.

Interpreting and understanding the historic hydrologic conditions of Catherine Creek is a difficult task since climate and hydrologic data were not collected or reported prior to the early 20th Century. However, inferences can be made based upon known historic changes to physical processes that have known hydrologic relationships. By applying these relationships, a conceptual model of the historic conditions can be developed.

For example, several sections of lower Catherine Creek were channelized to advance draining of the land after peak flows and to reduce flooding (Beckham 1995; Duncan 1998; Gildemeister 1998). Reducing overbank flows decreases the amount of water on the floodplain, which infiltrates the soil. Deep channelized sections also drain adjacent lands quicker and reduce soil moisture deeper than would otherwise occur. These can have substantial effects on baseflow, as less water is available to be released later in the season once high flows have subsided.

Early descriptions of the valley as swampy with lakes, “snaking” channels, and full of springs and rivulets, with abundant beaver describes a valley bottom that is generally wet with soils that are moist a substantial part of the year. These conditions slow spring snowmelt peaks from the mountains and dissipate floods over the valley bottom. This would tend to attenuate flood peaks downstream of the valley while likely increasing the duration (flood peaks would have been lower but flooding would have lasted longer). A portion of the floodwaters would have likely infiltrated soils and been stored in wetlands, Tule Lake, and beaver ponds, from which it was slowly released slowly over the summer. Although unknown, the stored flow could have provided cool water habitat throughout the warm summer in the wetlands and lakes; and higher baseflows would have provided better instream habitat and fish passage than presently exists.

An account of historic floods on the Grande Ronde River in or near the Grande Ronde Valley is provided in Gildemeister (1998) including events that occurred before stream gages were installed. Table 2 includes only those that occurred after European settlement in 1865 to 1911, when stream gages began operation. Several historical photographs that document some of the flooding as far back as 1894 are shown in Figure 10.

Table 2. Historic account of floods affecting Rhinehart Gap.

Year	Discharge [cfs]*	Notes
1865	10,000	Grande Ronde River (Gildemeister 1998)
1865	3,000	Catherine Creek (USACE 1950)
1876	9,000	Grande Ronde River (Gildemeister 1998)
1876	2,500	Catherine Creek (USACE 1950)
1881	10,000	Spring flood on Catherine Creek, December flooding on Grande Ronde River (Gildemeister 1998)
1882	2,600	Catherine Creek (USACE 1950)
1891	unknown	July thunderstorm on Catherine Creek (Gildemeister 1998)
1893	1,500	Catherine Creek (USACE 1950)
1894	9,500	April 1st Grande Ronde River
1895	2,000	Catherine Creek (USACE 1950)
1907	unknown	5-7 foot wall of debris at Oro Dell, Grande Ronde River (Gildemeister 1998)
1908	unknown	Dam at Perry partially destroyed, Grande Ronde River
1908	1,600	Catherine Creek (USACE 1950)
* cfs – cubic feet per second		

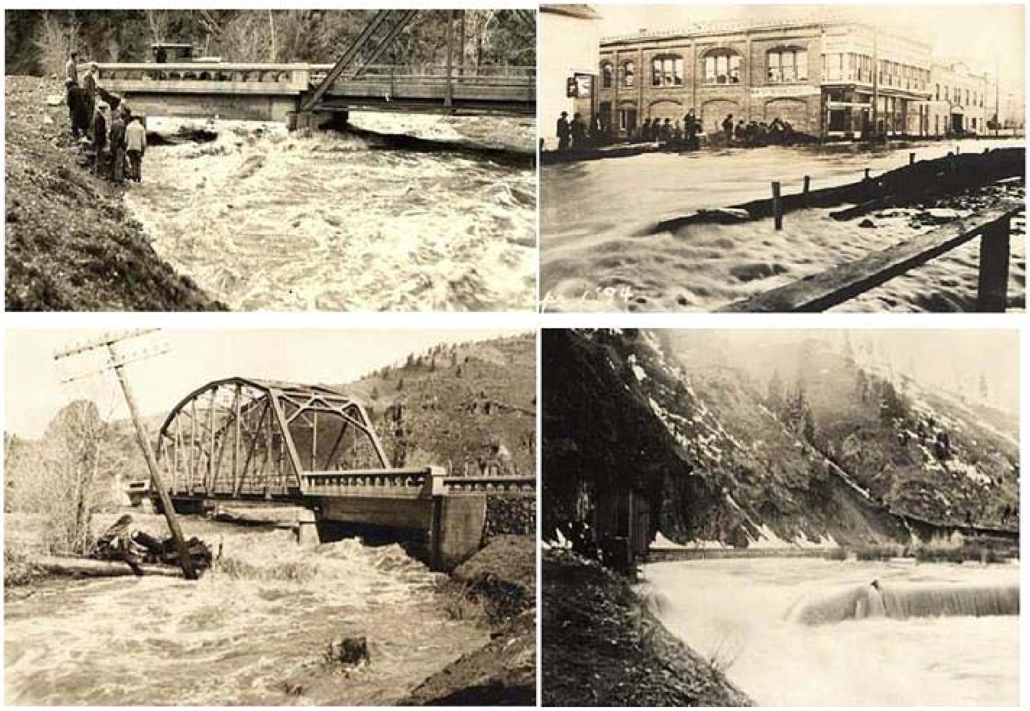


Figure 10. The Grande Ronde Valley endured a large flood in the spring of 1894. The picture of downtown La Grande, Oregon, was taken on April 1. Oregon State Planning Board Records, Oregon State Planning Board Photograph Box, Grande Ronde Flood (Oregon State Planning Board Photographs – OSPB0002).

Logging has increased steadily in the Grande Ronde subbasin since 1896, with demand and production of timber surging in the period following World War II (McIntosh et al. 1994; Duncan 1998). Following the growth of the local population and surge in logging, intensive road building took place into remote areas, particularly from the 1970s onward (Duncan 1998). Today there is an average of 3 miles of roads per square mile in the Catherine Creek watershed. The roads often constrain the creek contributing to excess fine sediment and increasing peak discharge while limiting infiltration and baseflow contributions.

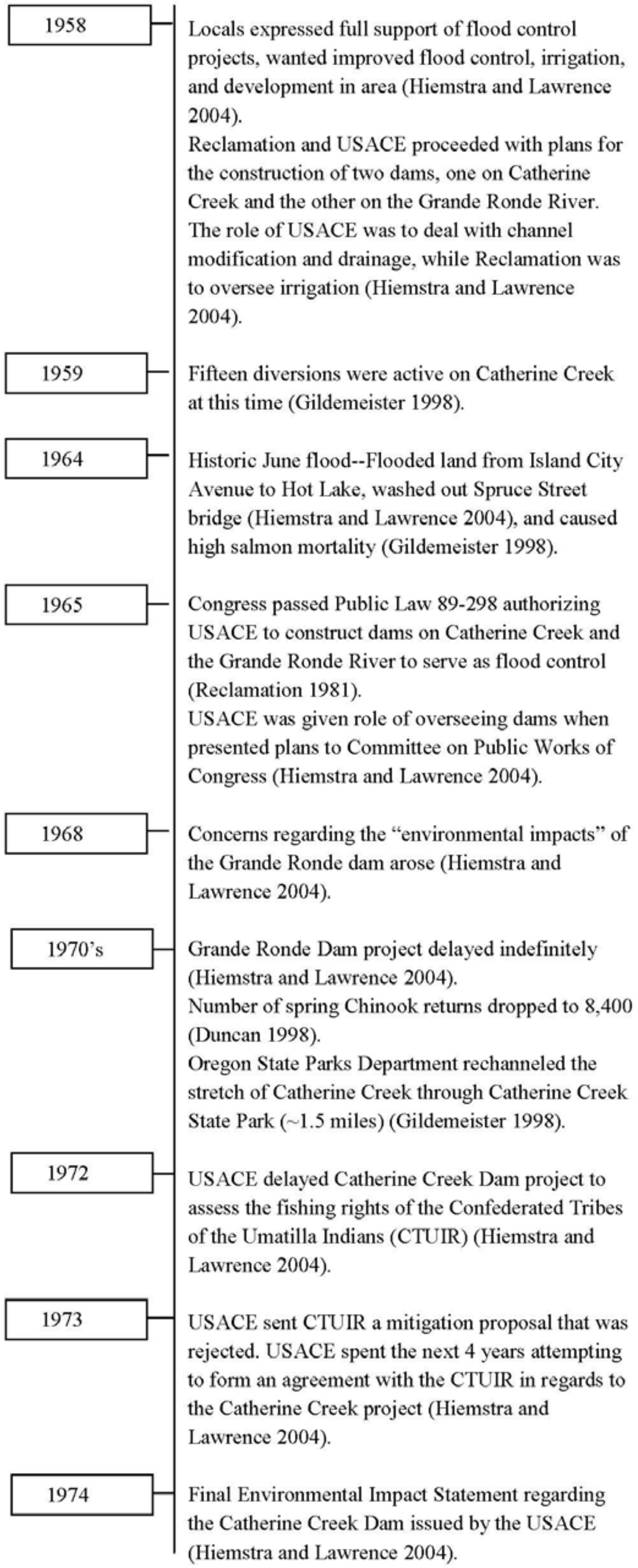
Further relevant historical information related to Catherine Creek and the Catherine Creek watershed is presented in the timeline below.

Table 3. Timeline of the history of Catherine Creek

Early 1800s	Grande Ronde Basin occupied by the Cayuse, Umatilla, Walla Walla, and Nez Perce Tribes (Reclamation 1981). Traders, trappers, missionaries began inhabiting the basin (Reclamation 1981).
1812	Robert Stuart notes otters reached their greatest numbers in Catherine Creek (Gildemeister 1998).
1855	Treaty formed between U.S. and several tribes regarding fishing stations along Catherine Creek (Hiemstra and Lawrence 2004).
1861	Non-Indian settlement (Reclamation 1981).
1863	First irrigation on Catherine Creek via Godley Ditch (push-up gravel dam) (Gildemeister 1998). First water rights established on Catherine Creek (Hattan 2011).
1864	First sawmill established on Catherine Creek by Hasbrooks included dam and catch trough located near present day library in Union. Dam was a significant barrier for salmon. Grande Ronde River and Catherine Creek used to float logs to mills (Hug 1961). A second sawmill and 15-foot high dam were established 6 miles upstream of Union (Gildemeister 1998). Earliest water rights on Swackhammer Ditch and the State diversion on Catherine Creek (Hattan 2011).
1865	Flour mill was built on east side of Union on Catherine Creek (Gildemeister 1998).
1868	October 27--State of Oregon appropriated $15,000 for construction of 4.5-mile State Ditch, which originally had a 6-foot bottom width (USACE 1950).
1869	To expand agriculture the 3-mile Catherine Creek ditch was dug, draining Tule Lake and surrounding marshland (Gildemeister 1998). Completion of State Ditch occurred as specified by local contractors (Gildemeister 1998).
1880's	Railroad moved into to Grande Ronde Valley and stimulated local growth and development in the basin (Reclamation 1981).
1894	Historic flood in June--50,000 acres flooded in valley (Duncan 1998).

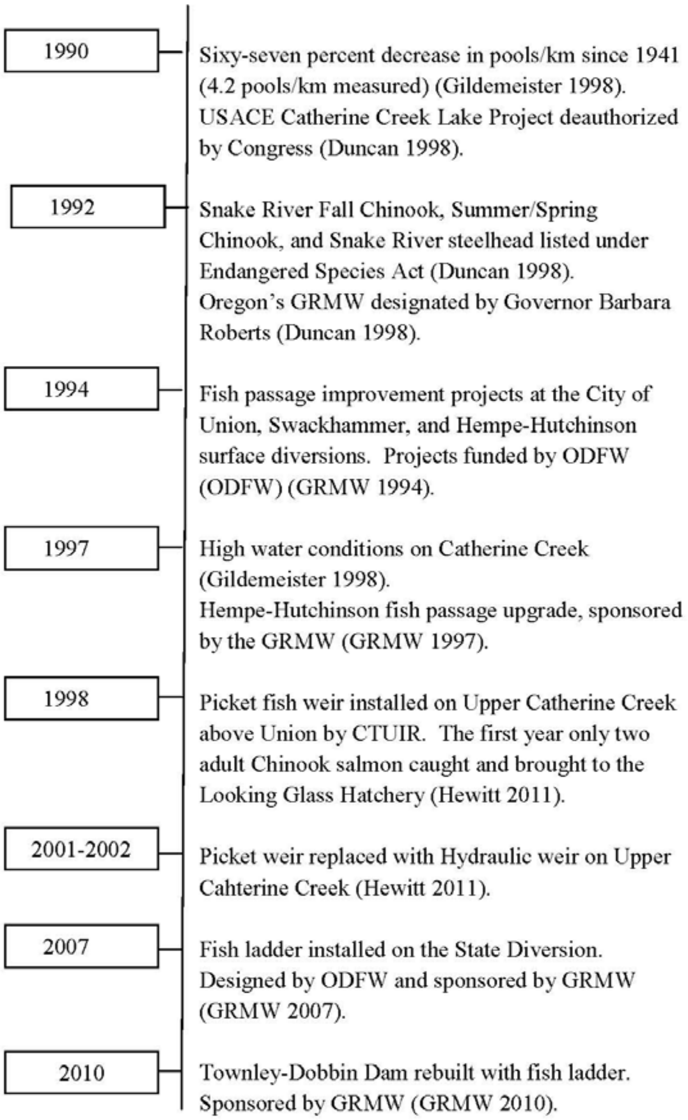
1900	Approximate date of construction of Davis Dams (Gildemeister 1998).
1910's-1930's	Native Americans from the Umatilla Reservation fished hundreds of salmon each year (Gildemeister 1998).
1917	Flood (Hiemstra and Lawrence 2004).
1920	Fish hatchery was completed (under supervision of Bonney family). Designed to rear rainbow and eastern brook trout. First couple of year's waterspouts caused siltation in the hatchery (Gildemeister 1998).
1925	"Flood-irrigation" used on 30,000 acres of farmland (Duncan 1998).
1928	First logging trucks in the area of Catherine Creek (Gildemeister 1998). Flash floods on Catherine Creek cause large fish losses at the hatchery (Gildemeister 1998).
1931	Reclamation released report in regards to water storage, flood control, irrigation possibilities, and stream channel improvements in the Grande Ronde watershed (Hiemstra and Lawrence 2004).
1933/1934	Public Works Administration and U.S. Geological Survey performed surveys of possible dam sites on Catherine Creek. Reclamation surveyed additional dam sites (Hiemstra and Lawrence 2004).
1936	The Flood Control Act passed, requiring local cooperation in "dam construction efforts by a federal agency" (Hiemstra and Lawrence 2004).
1940	August 9 to 12, Bureau of Fisheries survey on Catherine Creek noted 19 dams on Catherine Creek-2 Davis Dams, City of Union Intake, and 16 other diversions (Gildemeister 1998).
1941	Flash flood killed "every" Chinook salmon in Catherine Creek (Gildemeister 1998).
1944	USACE and Reclamation conducted studies on flood control in the Grande Ronde Valley. Storage reservoirs and irrigation projects were proposed for the Grande Ronde River and Catherine Creek, including channel improvements and levees (Hiemstra and Lawrence 2004).
1946	Union County Soil and Water Conservation District created with the purpose of flood control, leveling for flood irrigation, and drainage (Gildemeister 1998).

1948	Historic June flood caused by heavy snow pack and cool spring. Area was diked after the incident (Gildemeister 1998). Flood "inundated" approximately 8,000 acres of farmland and pastures (USACE 1959). Deer loss on Catherine Creek (Gildemeister 1998). City of Union water intake dam dynamited and replaced (Gildemeister 1998).
1949	Hearing held in La Grande by the Upper Columbia River Basin Commission to assess local support for proposed projects. Locals did not express support for irrigation or flood control (storage reservoirs) projects (Hiemstra and Lawrence 2004). 5,900 acres inundated by flood (Duncan 1998). USACE performs emergency work in Catherine Creek at Union (raised and revetted banks within select reaches) (USACE 1998).
1950	Flood Control Protection Project by USACE authorized by Congress in 1950 Flood Control Act, which consisted of 54-miles of levees and channelization on the Grande Ronde River and Catherine Creek and 15-miles of Willow and Ladd Creeks (USACE 1959).
1951	December ice jam flood on Catherine Creek causes damages in Union. USACE performs emergency "repairs" (USACE 1998).
1952	Emergency repairs to Catherine Creek in Union reported by USACE (USACE 1998).
1954	Locals expressed change of opinion at a second hearing held in La Grande regarding flood control reservoirs. They voiced support of flood control through storage reservoirs instead of channel modification (afraid to lose land to "cutoffs" and "realignments of channels") (Hiemstra and Lawrence 2004). 1950 flood control project postponed by the USACE to allow time to "test feasibility of reservoirs for flood control" (Hiemstra and Lawrence 2004).
1956	20,000 spring Chinook estimated to have returned to basin (Duncan 1998).
1957	New fishway constructed at City of Union Intake Dam and Lower Davis Dam (Gildemeister 1998).



1958	Locals expressed full support of flood control projects, wanted improved flood control, irrigation, and development in area (Hiemstra and Lawrence 2004). Reclamation and USACE proceeded with plans for the construction of two dams, one on Catherine Creek and the other on the Grande Ronde River. The role of USACE was to deal with channel modification and drainage, while Reclamation was to oversee irrigation (Hiemstra and Lawrence 2004).
1959	Fifteen diversions were active on Catherine Creek at this time (Gildemeister 1998).
1964	Historic June flood--Flooded land from Island City Avenue to Hot Lake, washed out Spruce Street bridge (Hiemstra and Lawrence 2004), and caused high salmon mortality (Gildemeister 1998).
1965	Congress passed Public Law 89-298 authorizing USACE to construct dams on Catherine Creek and the Grande Ronde River to serve as flood control (Reclamation 1981). USACE was given role of overseeing dams when presented plans to Committee on Public Works of Congress (Hiemstra and Lawrence 2004).
1968	Concerns regarding the “environmental impacts” of the Grande Ronde dam arose (Hiemstra and Lawrence 2004).
1970’s	Grande Ronde Dam project delayed indefinitely (Hiemstra and Lawrence 2004). Number of spring Chinook returns dropped to 8,400 (Duncan 1998). Oregon State Parks Department rechanneled the stretch of Catherine Creek through Catherine Creek State Park (~1.5 miles) (Gildemeister 1998).
1972	USACE delayed Catherine Creek Dam project to assess the fishing rights of the Confederated Tribes of the Umatilla Indians (CTUIR) (Hiemstra and Lawrence 2004).
1973	USACE sent CTUIR a mitigation proposal that was rejected. USACE spent the next 4 years attempting to form an agreement with the CTUIR in regards to the Catherine Creek project (Hiemstra and Lawrence 2004).
1974	Final Environmental Impact Statement regarding the Catherine Creek Dam issued by the USACE (Hiemstra and Lawrence 2004).

	Grande Ronde River closed to salmon and steelhead sport fishing (Reclamation 1981). The CTUIR sued to prevent construction of the Catherine Creek Dam (Hiemstra and Lawrence 2004).
1975	1,007 Chinook and 403 steelhead estimated to be spawning in Catherine Creek (Gildemeister 1998).
1976	Most of salmon "fingerling" collected on Catherine Creek identified to be Coho (Gildemeister 1998).
1977	Court ruled in favor of the CTUIR, Catherine Creek Dam was indefinitely postponed on grounds that the dam would flood and destroy Native American fishing stations (Hiemstra and Lawrence 2004).
1978	Approximately half of riparian area along Catherine Creek is closed off to cattle grazing (OSU Agricultural Experiment Station 1985).
1980's	Two programs considered by Reclamation (one for riparian rehabilitation and one for water conservation) in the Grande Ronde River basin (Reclamation 1981).
1984	Historic spring flooding in Catherine Creek (Gildemeister 1998). USACE performs snagging and clearing of log jams and streamside vegetation within Catherine Creek post flood **(USACE, Walla Walla District Digital Project Notebook).** Ice jams on Catherine Creek in February (Gildemeister 1998).
1985	Oregon State University's (OSU) Agricultural Experiment Station conducted research on the ecology and diversity of the riparian area along Catherine Creek (OSU Agricultural Experiment Station 1985). USACE cleared vegetation along Catherine Creek including large willows and cottonwood (Gildemeister 1998).
1986	Last wild Snake River coho adult passes Lower Granite Dam. Grande Ronde coho considered to extinct (Duncan 1998). USACE Grande Ronde Flood Control Project (Grande Ronde Dam, Levees, and Channelization) was deauthorized by Congress (Duncan 1998). Floods (Gildemeister 1998). Streambank protection implemented on Catherine Creek. Included the use of riprap, jetties, and fencing (Gildemeister 1998).



1990 – Sixty-seven percent decrease in pools/km since 1941 (4.2 pools/km measured) (Gildemeister 1998). USACE Catherine Creek Lake Project deauthorized by Congress (Duncan 1998).

1992 – Snake River Fall Chinook, Summer/Spring Chinook, and Snake River steelhead listed under Endangered Species Act (Duncan 1998). Oregon's GRMW designated by Governor Barbara Roberts (Duncan 1998).

1994 – Fish passage improvement projects at the City of Union, Swackhammer, and Hempe-Hutchinson surface diversions. Projects funded by ODFW (ODFW) (GRMW 1994).

1997 – High water conditions on Catherine Creek (Gildemeister 1998). Hempe-Hutchinson fish passage upgrade, sponsored by the GRMW (GRMW 1997).

1998 – Picket fish weir installed on Upper Catherine Creek above Union by CTUIR. The first year only two adult Chinook salmon caught and brought to the Looking Glass Hatchery (Hewitt 2011).

2001-2002 – Picket weir replaced with Hydraulic weir on Upper Cahterine Creek (Hewitt 2011).

2007 – Fish ladder installed on the State Diversion. Designed by ODFW and sponsored by GRMW (GRMW 2007).

2010 – Townley-Dobbin Dam rebuilt with fish ladder. Sponsored by GRMW (GRMW 2010).

9. General Study Area Fish Use Overview

This section generally describes historical and existing biological use by ESA-listed salmonids including spring Chinook salmon, steelhead, and bull trout within the assessment area and documents physical and biological processes that are and are not functioning adequately to contribute to the habitat that affects the viability of ESA-listed populations of salmon and trout in the Catherine Creek subbasin.

Currently, there are ESA-listed Snake River spring/summer Chinook salmon, Snake River steelhead, and bull trout within Catherine Creek. Coho salmon also existed but have been declared extinct within the subbasin. Pacific lamprey occurred historically in the Grande

Ronde subbasin (NPPC 2004). ODFW reported observing both adult lampreys and ammocoetes in Catherine Creek in the 1950s (Jackson and Kissner 1996). A petition in 2003 to list the Pacific lamprey under the ESA was determined by USFWS to be not warranted. In their determination, USFWS acknowledged that Pacific lamprey have declined in the Columbia River Basin.

Lamprey have high cultural and subsistence significance to Native American tribes and served as a primary food source for aquatic, mammal, and avian predators that also prey on ESA-listed salmonids and other recreational and commercially important fish species. Remnant populations may persist in the Grand Ronde subbasin but their distribution and abundance are unknown and make assessment of this species distribution and habitat conditions difficult (NPPC 2004).

9.1 Historic Occurrence/Abundance of ESA Fish Species

9.1.1 Spring Chinook Salmon

According to the Northwest Power and Conservation Council (NPCC) (2004), it is estimated that prior to the construction of the Snake River and Columbia River dams more than 20,000 adult spring Chinook salmon returned to spawn in the Grande Ronde subbasin annually (Figure 11). Estimated spring Chinook spawning escapement in the subbasin was 12,200 fish in 1957 (NPCC 2004). Recent escapement levels have numbered fewer than 1,000 fish. Estimated escapements for the Grande Ronde subbasin during 1979 to 1984 ranged from 474 to 1,080 (Howell et al. 1985). These low levels prompted listing of spring Chinook salmon under the ESA, including Grande Ronde spring Chinook salmon in 1992.

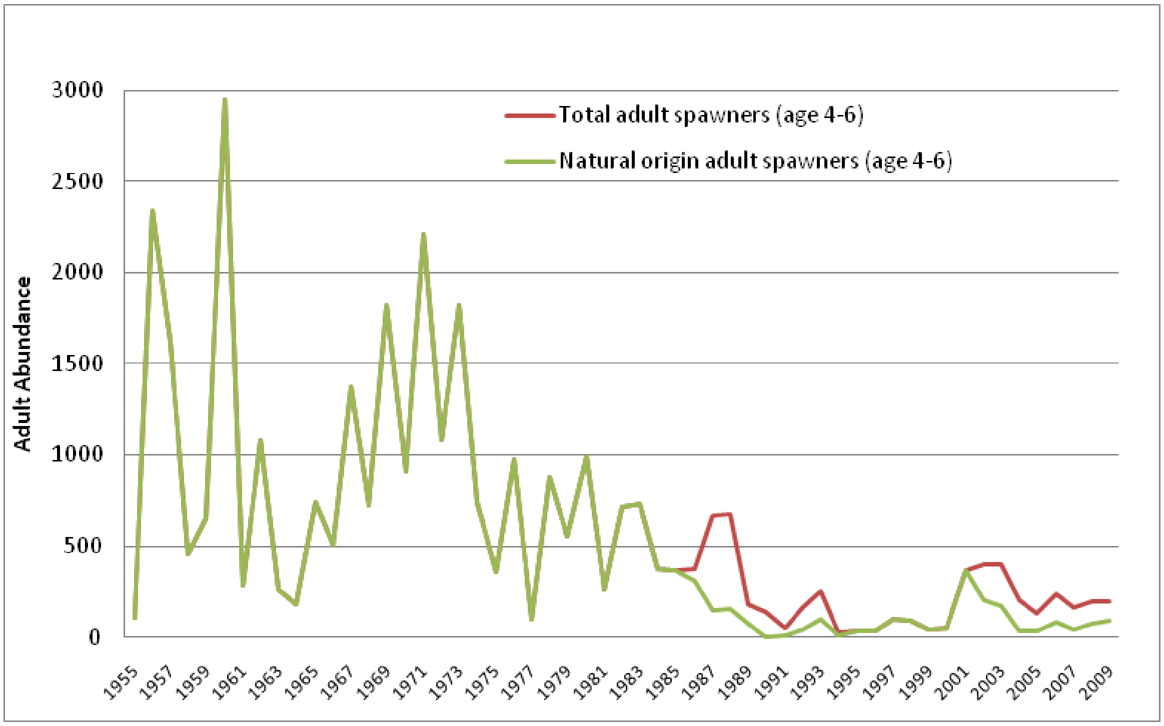


Figure 11. **Catherine Creek Spring Chinook Salmon population spawner abundance estimates (data from NPCC 2004).**

9.1.2 Summer Steelhead

The Grande Ronde subbasin historically produced large runs of summer steelhead (NPCC 2004). The size of those runs is unknown but an estimate of nearly 16,000 to the mouth of the Grande Ronde River was given for 1957, prior to construction of the lower Snake River dams (NPCC 2004). The Interior Columbia River Technical Recovery Team (ICRTRT) (2010) classified the Upper Grande Ronde River steelhead population as “Large” based on historical habitat potential. A steelhead population classified as “Large” has a mean minimum abundance threshold of 1,500 naturally produced spawners. The number of returning adult steelhead above the Catherine Creek weir trap from 2003 to 2010 ranges from just over 100 to nearly 300 fish (Figure 12).

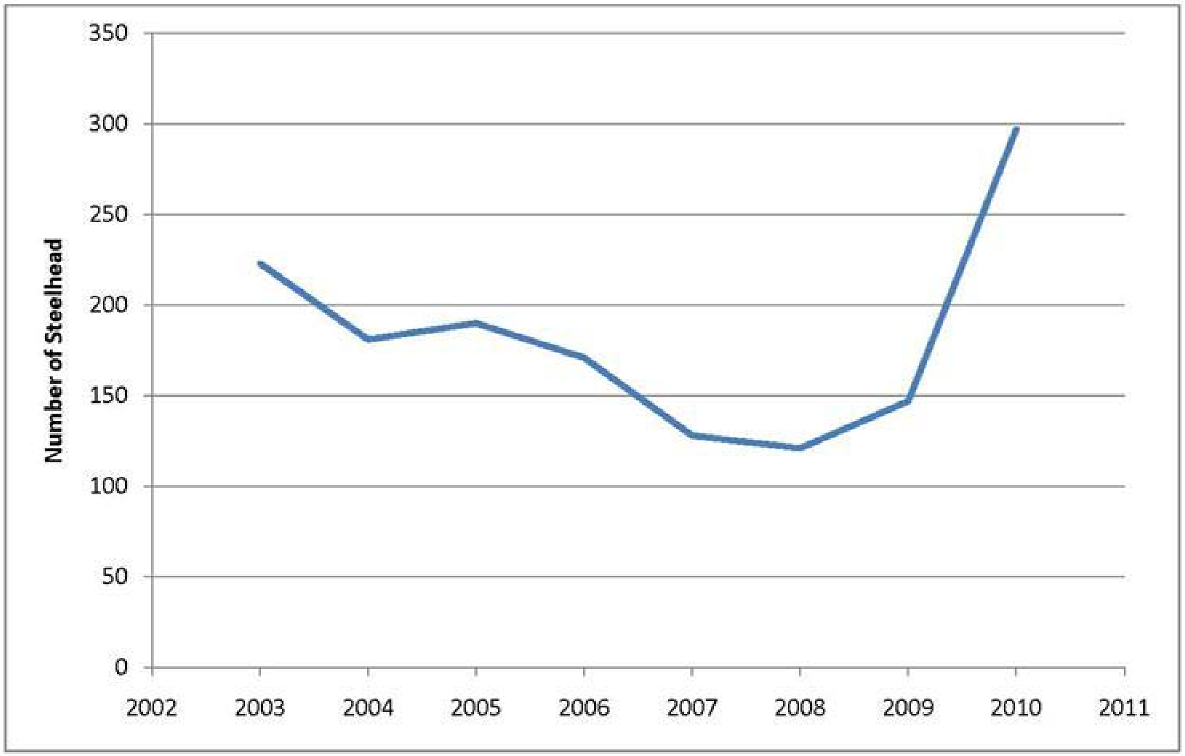


Figure 12. **Adult steelhead passing above Catherine Creek weir from 2003 through 2010 using data from Feldhaus (2011) (Appendix F).**

9.1.3 Bull Trout

There is limited information on bull trout population productivity and abundance in the Grande Ronde subbasin. Historically, bull trout were distributed throughout the subbasin, and although they were never as abundant as other salmonids, they were certainly more abundant and more widely distributed than they are today (NPCC 2004). As a result of declines in populations, bull trout were listed under the ESA in 1998 as threatened primarily due to habitat threats. Bull trout in the Grande Ronde subbasin fall into the “mid-Columbia” recovery unit. In 2010, critical habitat for bull trout was designated from the mouth of Catherine Creek to headwater locations by the USFWS.

9.2 Spatial Distribution of Present Fish Use

Figures 12, 13, and 14 illustrate the extent of spring Chinook salmon, steelhead, and bull trout presence and spawning activity within Catherine Creek, respectively. The majority of Chinook salmon spawning in Catherine Creek occurs from Union, Oregon to the confluence of the North and South Fork of Catherine Creek (Figure 13).

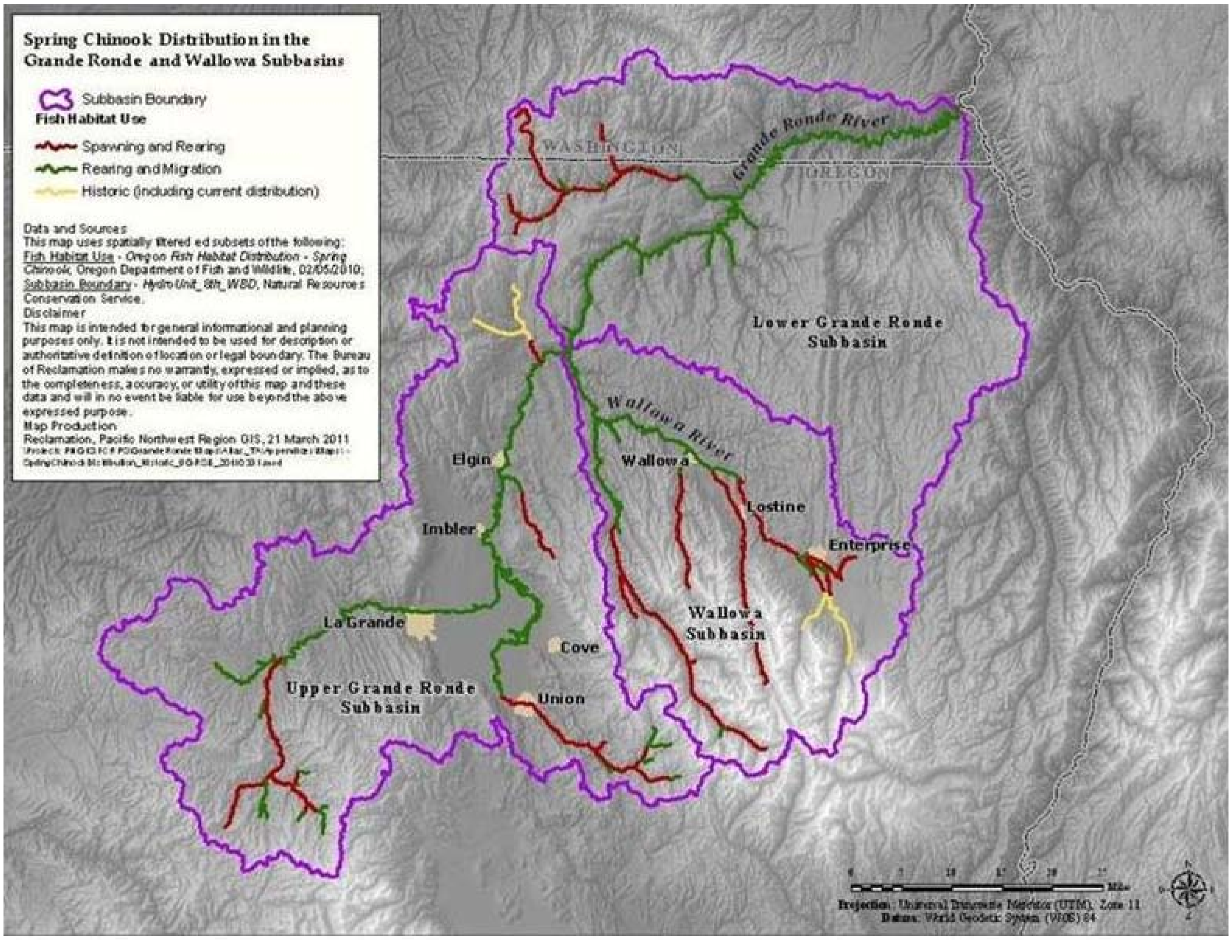


Figure 13. **Spring Chinook salmon distribution in the Grande Ronde and Wallowa subbasins.**

Summer steelhead typically spawn and rear upstream of the town of Union. Steelhead use Catherine Creek downstream from Union for migration and rearing (Figure 14). Approximately one-third overwinter in downstream areas and are considered early migrants (Yanke et al. 2008).

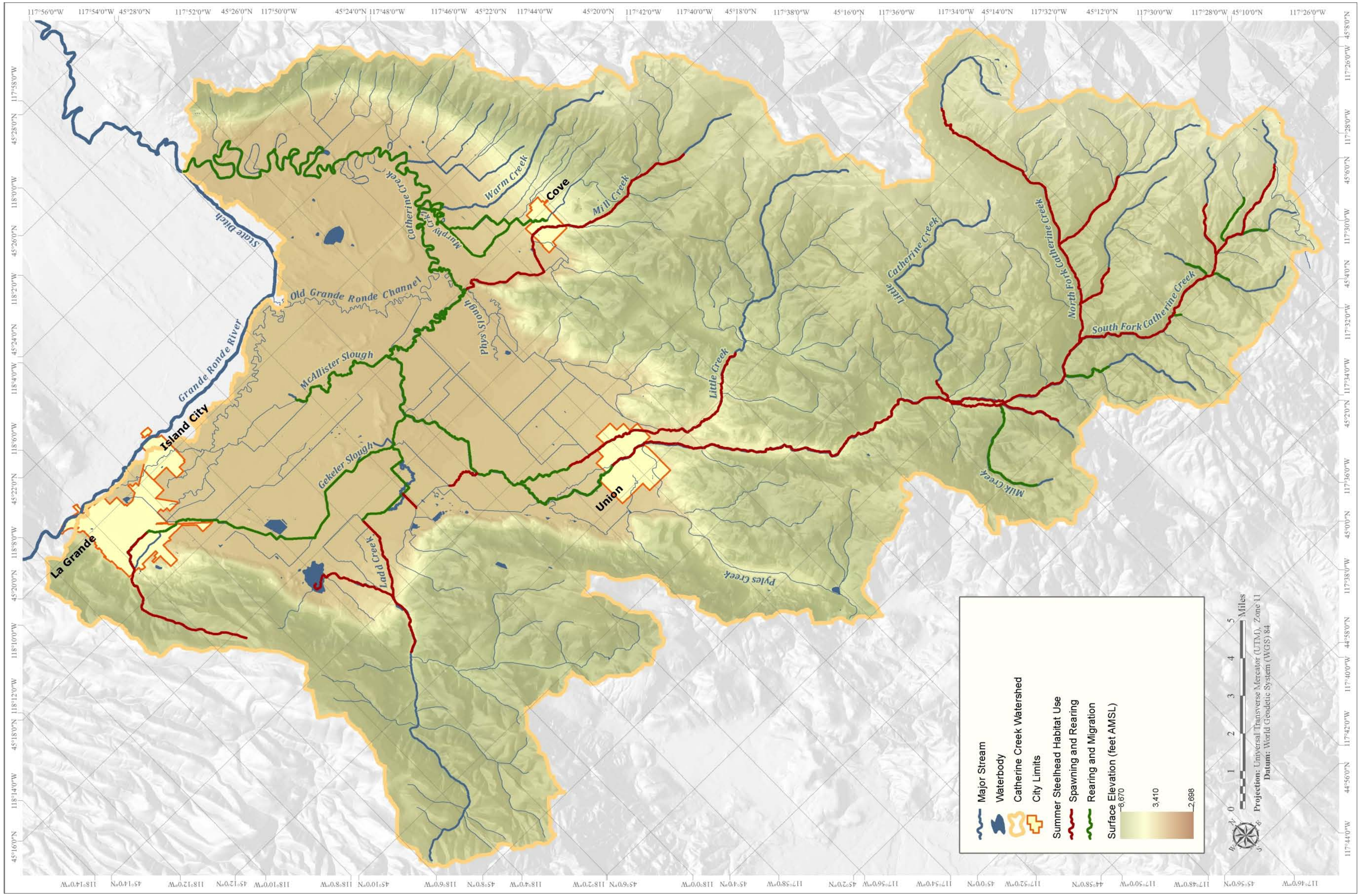


Figure 14. **Catherine Creek watershed summer steelhead habitat.**

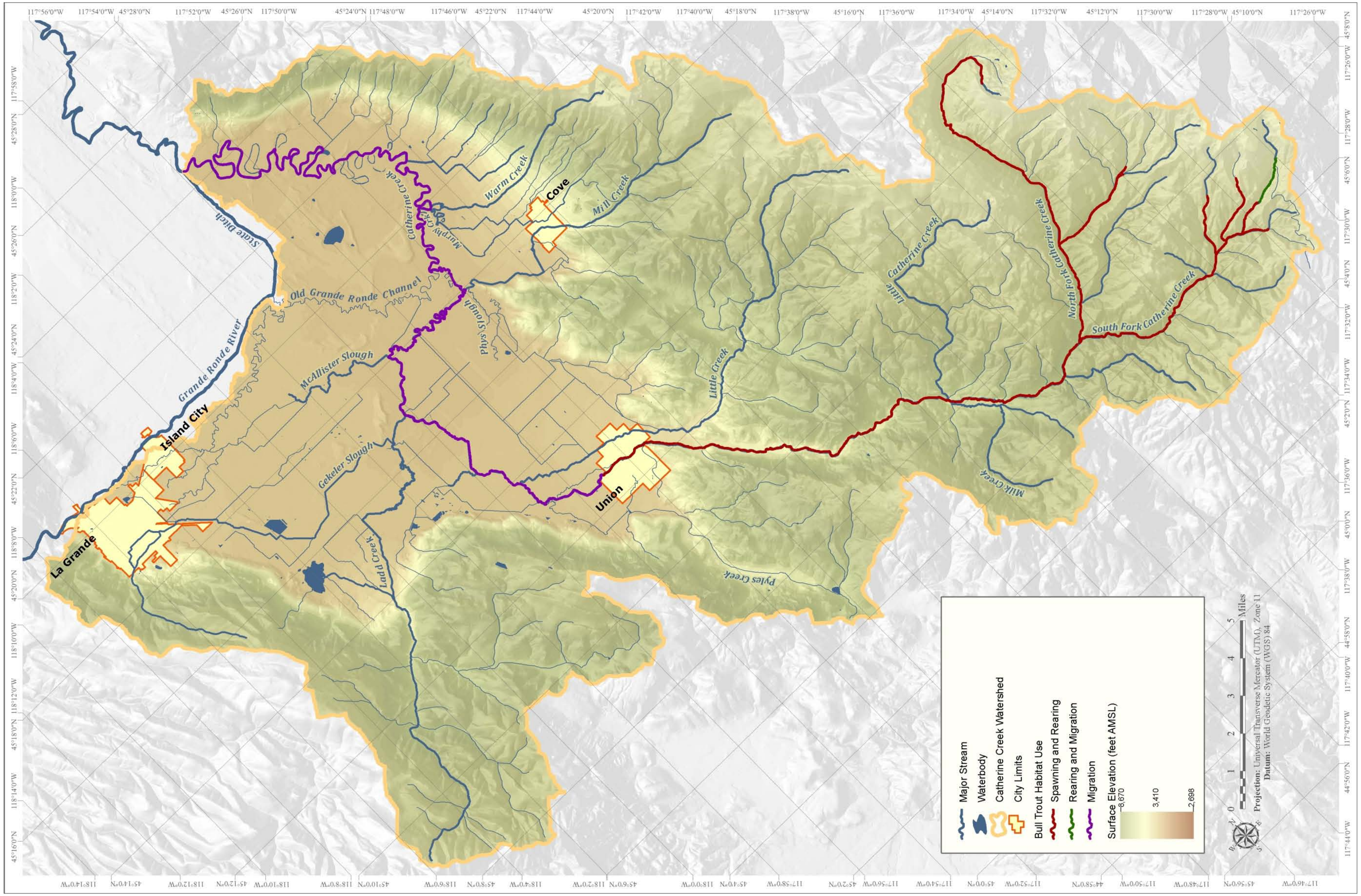


Figure 15. **Bull trout distribution in the Catherine Creek watershed.**

In the Grande Ronde subbasin, bull trout currently exhibit two distinct life history forms: fluvial bull trout that mature in their natal streams and move to large streams and rivers after maturation; and resident bull trout that live in their natal streams (small tributaries at high elevations) year round and are generally smaller in size (NPCC 2004). Catherine Creek supports both life history forms of bull trout. The fluvial form found in Catherine Creek likely utilize lower reaches downstream of Union as a migratory corridor based on habitat conditions. Distribution (spawning and rearing) of bull trout is restricted to headwater areas and rivers with high quality habitat and water quality, primarily on National Forest lands. Bull trout spawning in Catherine Creek would occur in headwater locations.

9.3 General Timing of Fish Use By Species and Life Stage

Most Grande Ronde River adult spring Chinook salmon pass Bonneville Dam and enter the Columbia River Basin in April and May (NPCC 2004). By June or July, the adults are typically holding in the Grande Ronde subbasin near spawning tributaries. Spawning usually occurs in August and September (NPCC 2004).

Following spawning, eggs incubate in the gravel over the winter and fry emerge between March and May. Spring Chinook salmon juveniles usually rear in the Grande Ronde subbasin for 1 year before migrating to the ocean as smolts from March through May. Some juveniles begin their downstream migrations June through October of their first year (NPCC 2004). Chinook salmon continue to rear in freshwater prior to smolting the following spring. Studies have shown that smolts from the Grande Ronde subbasin arrive at Lower Granite Dam about mid-June. Adult spring Chinook salmon return at ages 3 to 6 (after 1 to 4 years in the ocean), although age 4 is the dominant age class among spawners (NPCC 2004).

Wild adult summer steelhead returning to the Grande Ronde are generally 4 years of age at maturity, having spent an average of 2 years in freshwater, 1.5 years in the ocean, and 0.5 year migrating to the subbasin and holding there until spawning. Spawning occurs from March through mid-June, with peak spawning taking place from late April through May (NPCC 2004). Fry emerge from May through July (NPCC 2004). Steelhead may remain in Catherine Creek for up to 4 years before leaving the subbasin for their migration downstream to the ocean. The average ocean-going smolt age is 2 years (Yanke et al. 2008).

Bull trout in the Grande Ronde subbasin have both resident and migratory life history patterns. Resident bull trout complete their entire life cycle in a tributary stream. Migratory bull trout spawn in tributary streams where juveniles rear for up to 4 years before migrating to a river or lake. Migrating bull trout return to spawning tributaries from the end of June into October. Spawning occurs between mid-September and early November. Resident and migratory bull trout can be found together in spawning grounds and can spawn together. Offspring can express either life history.

In addition to spring Chinook salmon, steelhead, and bull trout, mountain whitefish (*Prosopium williamsoni*) are also present. Non-salmonid species are present, but their distributions are either not well documented or are not the subject of targeted studies. The list of observed fish includes Northern pike minnow (*Ptyhocheilus oregonensis*), carp (*Cyprinus carpio*), redside shiner (*Richardsonius balteatus*), brown bullhead (*Ameiurus nebulosus*), smallmouth bass (*Micropterus dolomieu*), and catfish (*Ictalurus species*). Other species that are found in the basin are listed in Nowack (2004).

9.4 Limiting Factors of Present Habitat Conditions

The decline in the Catherine Creek spring Chinook salmon population has been primarily attributed to passage problems at the mainstem Columbia and Snake River dams (NPCC 2004). These fish must pass a total of eight major dams, four on the Columbia River, and four on the Snake River during up and downstream migrations. Out-of-subbasin harvest and habitat degradation have also contributed to the population decline. However, recent information by Favrot et al. (2010) (included as Appendix H) indicates that winter rearing habitat quantity and quality in the Grande Ronde Valley may be an important factor in limiting spring Chinook salmon smolt production for Catherine Creek. According to ICRTRT (2010), there are currently two primary life history pathways for the freshwater juvenile life stages: fish rear from fry to smolt in the upper reaches of Catherine Creek or fish leave the upper reaches of Catherine Creek in the fall and overwinter in the Grande Ronde Valley reaches, including lower Catherine Creek. There is speculation that there have been reductions in the variation of juvenile pathways such as the loss of ability of fry and summer parr to move downstream from the upper rearing reaches into the Grande Ronde Valley. Favrot et al. (2010) indicated that early migrant survival (fish overwintering in the Grande Ronde Valley) to Lower Granite Dam is typically lower for the Catherine Creek population than other Chinook salmon populations in the Grande Ronde subbasin. Previous research estimated that travel times through the Grande Ronde Valley reach (lower Catherine Creek included) were considerably greater than any other reach, and accounted for 42 percent of the mortality incurred in freshwater for naturally-produced Chinook salmon (Monzyk et al. 2009). ODFW fish tracking research partially sponsored as part of this assessment process is currently underway. Preliminary results are informative and the study will likely provide a better understanding of the timing, location, and source of mortality for this depressed population of spring Chinook salmon (Appendix H).

The in-basin factors limiting spring Chinook salmon populations in the Catherine Creek and middle Grande Ronde River systems are water quality (elevated summer water temperature), excess fine sediment, altered hydrologic function, predation, food, riparian conditions, habitat complexity/diversity, competition with hatchery fish, and pathogens (GRMW 1995; Huntington 1994; NPCC 2004; Nowak 2004; NOAA Fisheries 2008b). Altered hydrologic function is primarily a consequence of irrigation water management, which results in reduced instream flows during critical summer months, contaminated return water, elevated stream temperatures, and passage barriers. Habitat complexity issues are primarily due to reduced wetted widths and a lack of pools and large woody debris (LWD) (GRMW 1995; Huntington 1994; NPCC 2004; Appendix G). Additionally, some reaches of Catherine Creek have been channelized and armored to accommodate road construction, homesteads, and irrigated agriculture.

Limiting factors identified previously for Catherine Creek spring Chinook salmon are likely applicable to summer steelhead found in Catherine Creek. Those would include habitat quantity and quality, sediment conditions, water quality, and water quantity. The Ecosystem Diagnosis and Treatment (EDT) model attribute summary indicates that sediment and habitat quantity are the largest and most widespread impacts on the Upper Grande Ronde summer steelhead population (NPCC 2004). The EDT model is a tool to assist in the planning of supplementation projects, though its structure provides a way to examine other types of natural production improvement measures such as rating the quality, quantity, and diversity of habitat along a stream, relative to the needs of a focal species such as Chinook salmon (Lestell et al. 1994.

10. Reach Delineation

10.1 Valley Segments and Reach Delineation

The Catherine Creek TA identified seven “geomorphic reaches” (Figure 16) based on geomorphic characteristics. These reaches are combined into three more general valley segments (valley floor, alluvial fan, and upper valley) to facilitate discussion of general physical characteristics (Table 4).

Table 4. Geomorphic reaches in the Catherine Creek TA.

Geomorphic Reach	RM	Surficial Geology	Confinement Class	Valley Segment
1	0.0 – 22.5	Fluvial-Lacustrine	Unconfined	Valley Floor
2	22.5 – 37.2	Fluvial-Lacustrine	Unconfined	Valley Floor
3	37.2 – 40.78	Alluvium (Fan Delta)	Unconfined	Alluvial Fan
4	40.78 – 45.8	Alluvium/Bedrock	Unconfined	Upper Valley
5	45.8 – 50.11	Alluvium/Landslide	Confined	Upper Valley
6	50.11 – 52.0	Alluvium	Unconfined	Upper Valley
7	52.0 – 54.9	Alluvium/Bedrock	Confined	Upper Valley

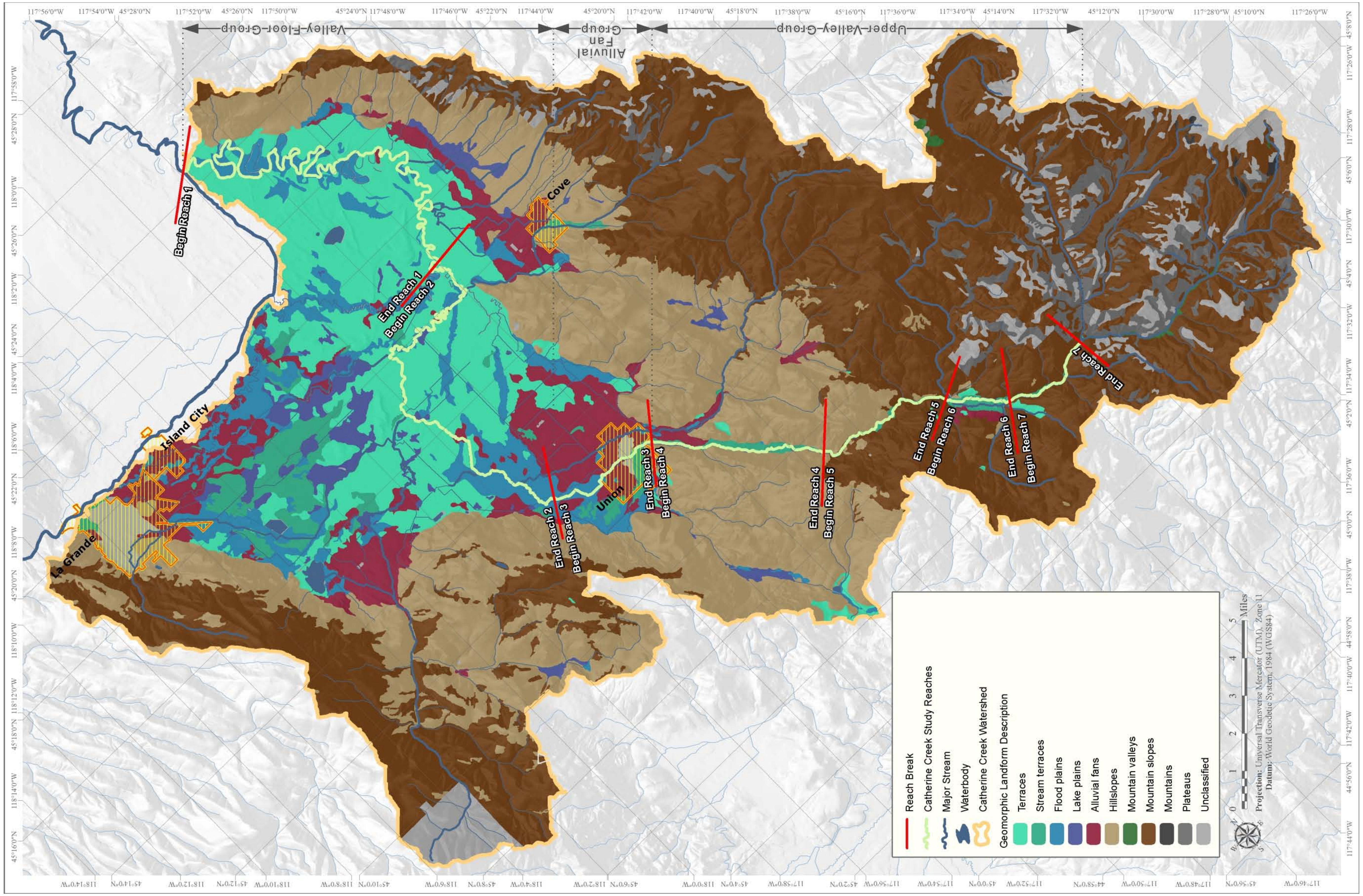


Figure 16. **Geomorphic reaches identified in the Catherine Creek TA.**

10.1.1 Valley Floor – Reaches 1 and 2

Reaches 1 and 2 comprise the valley floor segment on Catherine Creek (Figure 17). This group extends from the toe of the Catherine Creek alluvial fan, near RM 37.2 downstream to the confluence of Catherine Creek and State Ditch at RM 0. The valley floor segment reaches are unconfined with very broad, flat floodplains that developed through vertical accretion where sediment is deposited on the floodplain when water is out of bank during flood events. In some instances, near-vertical banks give the appearance of slight to moderate entrenchment (Figure 18).

The channel gradient is very low and the channel planform is meandering to tortuous. Bank materials are interbedded, cohesive silts, clays, clayey silts, and indurated fine sands deposited during frequent overbank events. Channel bed materials are loose fine sands and silts and dense cohesive clayey silts. Sediment removed from the channel may have provided the material to construct plugs across oxbow entrances and levees (Appendix C). Anecdotal evidence in the form of casual discussions described bulldozer tracks that still exist in the bottom of the channel (Kuchenbecker 2011). This suggests that in addition to straightening, the channel may have been artificially deepened to convey more flow.

Some natural lateral and vertical control appears to be provided by the cohesive material in the banks and channel bottom (Appendix C). Downstream of the Catherine Creek-Grande Ronde River (State Ditch) confluence, Rhinehart Gap provides a natural base level control that results in an extremely low gradient (0.004 percent in the lower end of the reach).

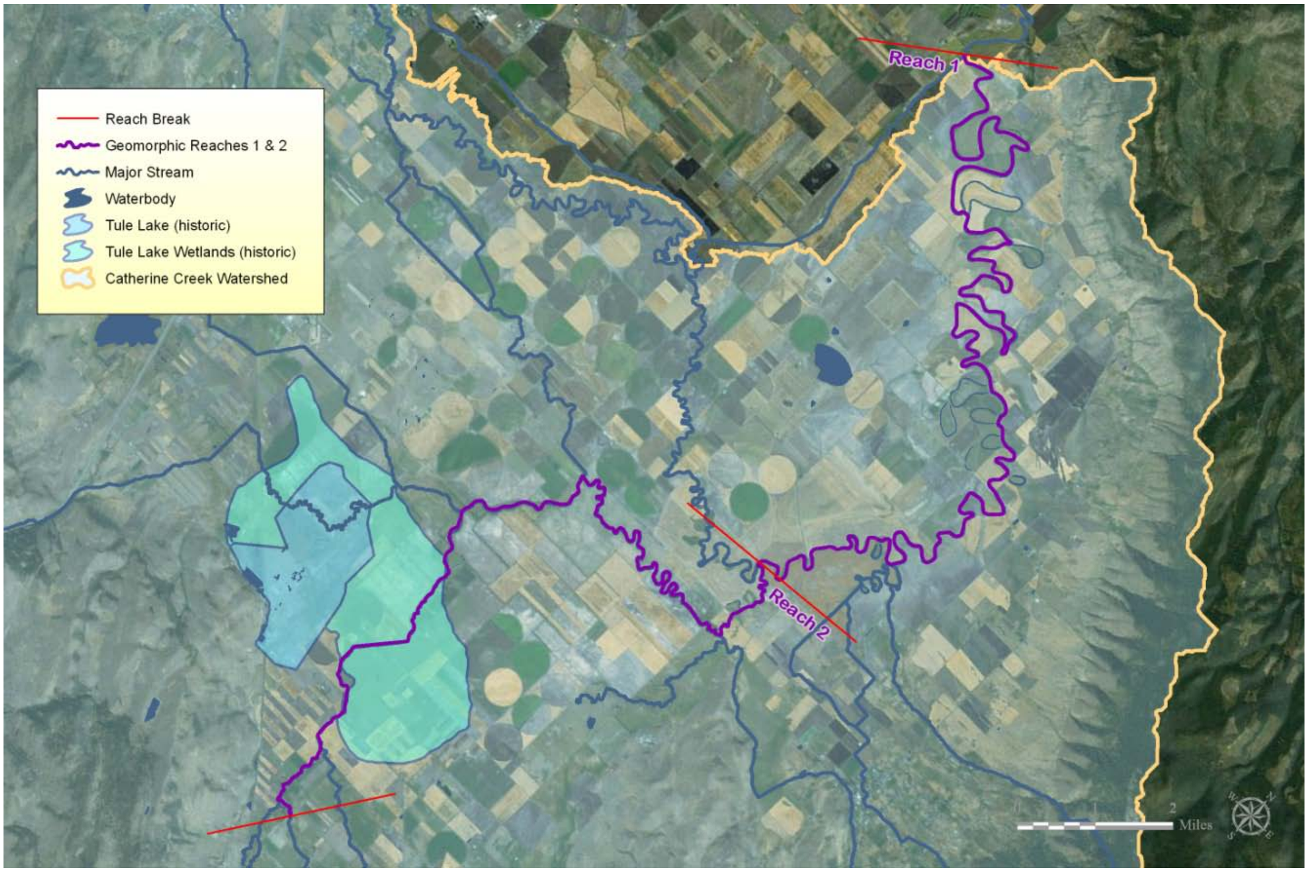


Figure 17. Valley floor segment of Catherine Creek showing reaches 1 and 2 as well as the historic extents of Tule Lake and associated wetlands as delineated from General Land Office maps (circa 1864 to 1876).

Figure 18. Typical streambank conditions and vegetation in the valley floor segment – Catherine Creek, Grande Ronde Subbasin (Reclamation photograph by D. Stelma – July 2010).

10.1.2 Alluvial Fan – Reach 3

Reach 3 is developed on an alluvial fan deposit from the Pleistocene and early Holocene (between 2.5 million and 12,000 years ago) which extends upstream and downstream from Union, Oregon (Figure 19). This reach is naturally a gently sloping alluvial fan that transitions to a fluvial fan delta depositional feature at the lower end (Ferns et al. 2010. The floodplain functions somewhat differently in this reach than a typical fluvial floodplain as most of the flows that overtop the banks are directed away from the channel only to re-enter the creek much further downstream.

Being on an alluvial fan, this reach was historically dynamic with multiple high-flow channels. Flooding would have spread out across the sloping fan surface as sheet and distributary flow and fine sediment would have been dispersed without building a typical depositional floodplain. Materials directly adjacent to the stream have been mapped as alluvium and are described as channels locally choked with overbank silt by Ferns et al. (2010). Channel bed materials are predominantly cobbles and gravels with some boulders in the uppermost end of the reach. Bank materials are inter-bedded sand, gravel, and cobble, indurated fine sand, and iron oxidized, moderately cemented gravel and cobble. Natural lateral and vertical control in reach 3 appears to come from a combination of larger substrate and cohesive and/or cemented materials. Banks range from gently sloping with grass, shrubs, and some mature trees, to banks that are vertical with some that are artificially constructed (Figure 20). The channel gradient ranges from 0.50 to 1 percent at the upstream end of the reach, flattening to 0.01 to 0.05 percent at the downstream end. Current use by spring Chinook salmon includes migration, rearing, and spawning (Appendix C).

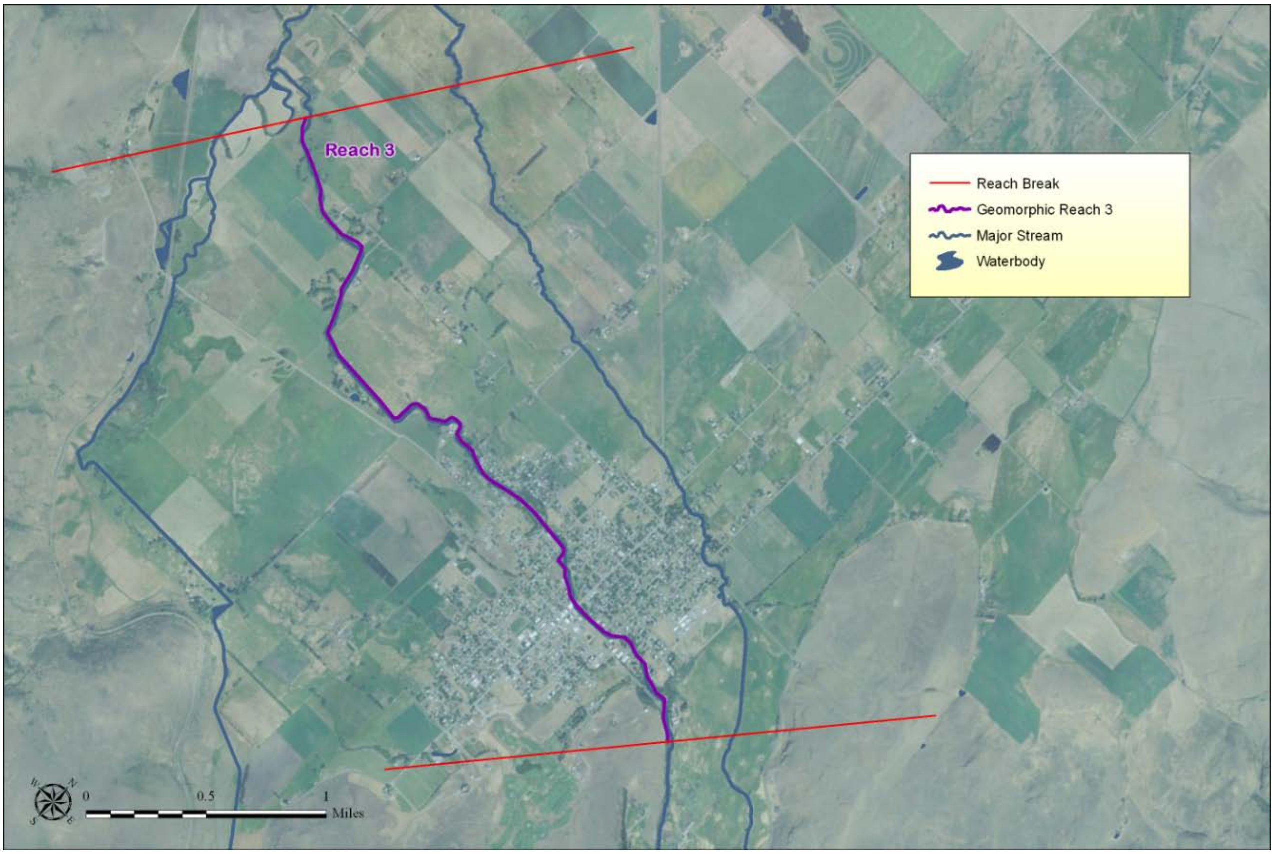


Figure 19. Reach 3 of the Catherine Creek which passes through the town of Union, Oregon.

Figure 20. Typical bank conditions, vegetation, and substrate in reach 3 – Catherine Creek, Grande Ronde Subbasin. Subbasin (Reclamation photograph by D. Stelma – August 2010).

10.1.3 Upper Valley – Reaches 4 through 7

Geomorphic reaches 4 through 7 comprise the upper valley segment. The group includes the area from the confluence of the North and South Forks of Catherine Creek (RM 54.9) downstream to the valley mouth, just upstream of the town of Union (RM 40.78). Reaches in this group range from those confined by bedrock hillslopes that form the valley walls to unconfined with the valley floor being mostly comprised of alluvium. The bedrock valley walls within these segments are typically dacite, basalt, andesite, and argillite (Ferns et al. 2010). Other units mapped by Ferns et al. (2010) include local landslides and a large debris flow/debris avalanche. Channel bed and bank materials were observed to range from boulders to silt-sized material. Natural lateral and vertical control comes from bedrock and the coarser fraction of alluvium and landslide material that includes boulders and cobble (Appendix C). The overall channel gradient averages 1.1 percent. The streambanks are typically gently sloped with grass, willow, small trees, and a few large trees (Figure 21). Vegetation along the banks includes willow, aspen, and small cottonwood trees. Small stands of relic cottonwood galleries are present along the banks and in the floodplain. Current use by spring Chinook salmon and steelhead includes migration, spawning, holding, and rearing (Appendix F).

Figure 21. Typical bank conditions, vegetation, and substrate in the upper valley reach – Catherine Creek, Grande Ronde Subbasin. (Reclamation photographs by D. Stelma – August and November, 2010).

11. Physical and Biological Description of Reaches

11.1 Reach 1 (RM 0 to 22.5)

11.1.1 General Location and Description

Reach 1 is located in the lower Grande Ronde Valley and flows into the Grande Ronde River at the confluence with State Ditch (Figure 22). This reach was historically the Grande Ronde River but the construction of State Ditch, which began in 1869, resulted in the eventual capture of the entire Grande Ronde River flow (Flow Technologies 1997; Gildemeister 1998). The Grande Ronde River now flows through the State Ditch and only Catherine Creek flows through the former Grande Ronde River channel in this reach. Reach 1 is characterized by fine and highly productive soils. This reach is atypical of most inner Columbia River Basin mountain stream reaches, as its gradient is nearly flat at 0.04 percent slope. The gradient is geologically controlled downstream by Rhinehart Gap. It is a single-thread meandering reach located within a broad valley. Disconnected meander bends or “oxbows” are evident throughout the reach. Due to its low gradient and sinuous to tortuous meanders, reach 1 is similar to an estuarine river with a very low energy regime, seasonally wet soils, a broad floodplain, high sinuosity, and oxbow lakes. No major tributaries enter reach 1, however, the eastern edge of the valley in this reach contains numerous springs that enter between RM 3 and 19. The springs are a result of groundwater upwelling along the fault system and bajada that form the southeast side of the Wallowa Mountains. The bajada is the material deposited at the valley margin in a series of overlapping and coalescing alluvial fans. The source for the springs is a combination of differential upwelling along the faults and water draining into the tops of the alluvial fans and then surfacing at the contact between the toes of the fans and the finer-grained valley bottom soils at the valley edge. Instream and floodplain processes in reach 1 are dominated by hydrology and hydraulics associated with seasonal floods that persist for months (approximately March through June) along with a dry season (late June through September).

Figure 22. Reach 1, bounded by the historic Grande Ronde River confluence upstream and the current confluence downstream. The active channel is shown and many lakes can be seen throughout the reach.

11.1.2 Historical Conditions

Historical Physical

Reach 1 (Figure 22) extends from the current confluence with the Grande Ronde River upstream to the historic confluence with the Grande Ronde River. Prior to construction of State Ditch, this 22.5-mile-long reach contained both Catherine Creek and the Grande Ronde River but it now only contains the discharge from Catherine Creek. Historic accounts, which indicate that this part of Catherine Creek would have been classified as a wetland complex throughout much of the floodplain, are supported by geomorphology, hydrology, valley controls, substrate, and evidence of a highly sinuous channel (Figure 23). Historic data is minimal, but the few historic descriptions that do exist indicate a wet environment with abundant beaver, seasonal and extended flooding, and an array of wetlands and their associated habitats throughout the valley, which would have likely been complex and diverse salmonid habitat.

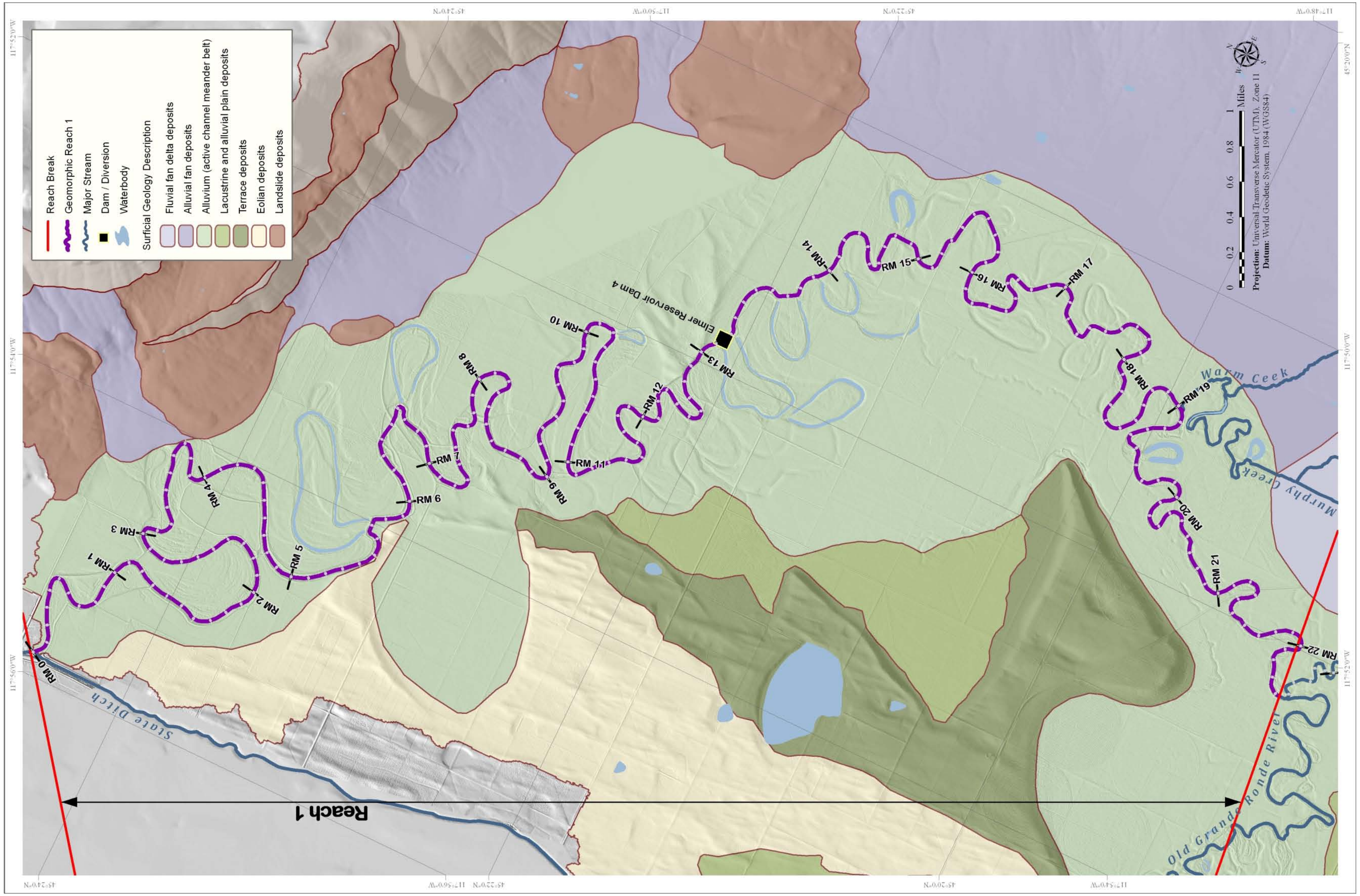


Figure 23. **Reach 1 surficial geology and "bare earth" hillshade topography.**

Historical Description

Beaver were common in the area before being trapped in excess (ISG 2000; Beckham 1995). Beaver complexes would have provided diverse habitats including a variety of water depths and velocities that supplied important habitat for salmonids. The beaver complexes would have provided unique habitat for vegetation contributing to shade, refugia, and a food source for salmonids. Although the channel was likely a single thread channel, the beaver would have directly and indirectly helped form secondary channels, increased the area inundated during high flows, and the length of time water was present in the valley bottom.

Early account state the streambanks were tall, muddy, and covered with cottonwood, willow and other underbrush (Beckham 1995; Duncan 1998). Vast wetlands covered the valley floor, which was inundated for long periods of time beginning during the spring flood (Beckham 1995; Duncan 1998). Adjacent to the reach would have been wet meadows, emergent wetlands, and open water complexes (NOAA Fisheries 2008a). Historical accounts also mentioned abundant small creeks and rivulets, which ran through the valley bottom (Duncan 1998).

This reach has the most influence from the backwater affects of Rhinehart Gap and as a result this reach would likely have experienced the deepest ponding of water and it would have been inundated for the longest period.

The early descriptions of this portion of the valley as swampy with lakes, abundant beaver, “snaking” channels, and full of springs and rivulets describes a valley bottom that is generally wet with soils that are moist a substantial part of the year. These conditions slow spring snowmelt peaks from the mountains and dissipate the floods over the valley bottom. This would tend to attenuate flood peaks downstream of the valley while increasing the duration. A portion of the floodwaters were likely stored in wetlands throughout this reach and released slowly over the summer and perhaps even into early fall. The stored flow would have likely provided abundant and diverse habitat throughout the warm summer in wetlands and lakes within reach 1. With its low valley gradient and extended flooding, reach 1 would have been highly connected with its floodplain, providing water storage and release in a manner that would extend and cool baseflow to the stream channel through hyporheic and shallow groundwater exchange. In addition, the eastern boundary of most of this section of the historic Grande Ronde River within this reach was adjacent to cool ephemeral and perennial springs that would have provided a source of cool water in the warm extended summer dry season (Figure 24). A few warm water springs may have exacerbated summer water temperatures but they would also have provided a buffer against extreme cold temperatures in the winter. It is possible that this reach of Catherine Creek was a rearing area for both Grande Ronde and Catherine Creek juvenile salmonids that would have provided diverse habitat conditions for rearing that include slow moving water, varied water depth, ponds, and pools associated with off-channel beaver complexes. The beaver complexes likely would have contributed to good vegetative cover and provided riparian inputs of food sources.

Historical Fish Presence

Historically, this reach was the Grande Ronde River and in addition to Catherine Creek spring Chinook and steelhead, it also supported Grande Ronde River Chinook salmon and steelhead, which migrated into and out of the upper Grande Ronde River. This reach would have functioned as a migration corridor for returning adults, out-migrating smolts, and because of the likelihood of having complex aquatic habitat, it may have been habitat for juvenile rearing. Because of the exceptionally low gradient and subsequent low energy, the substrate was always composed of fines and would not have been suitable for spawning.

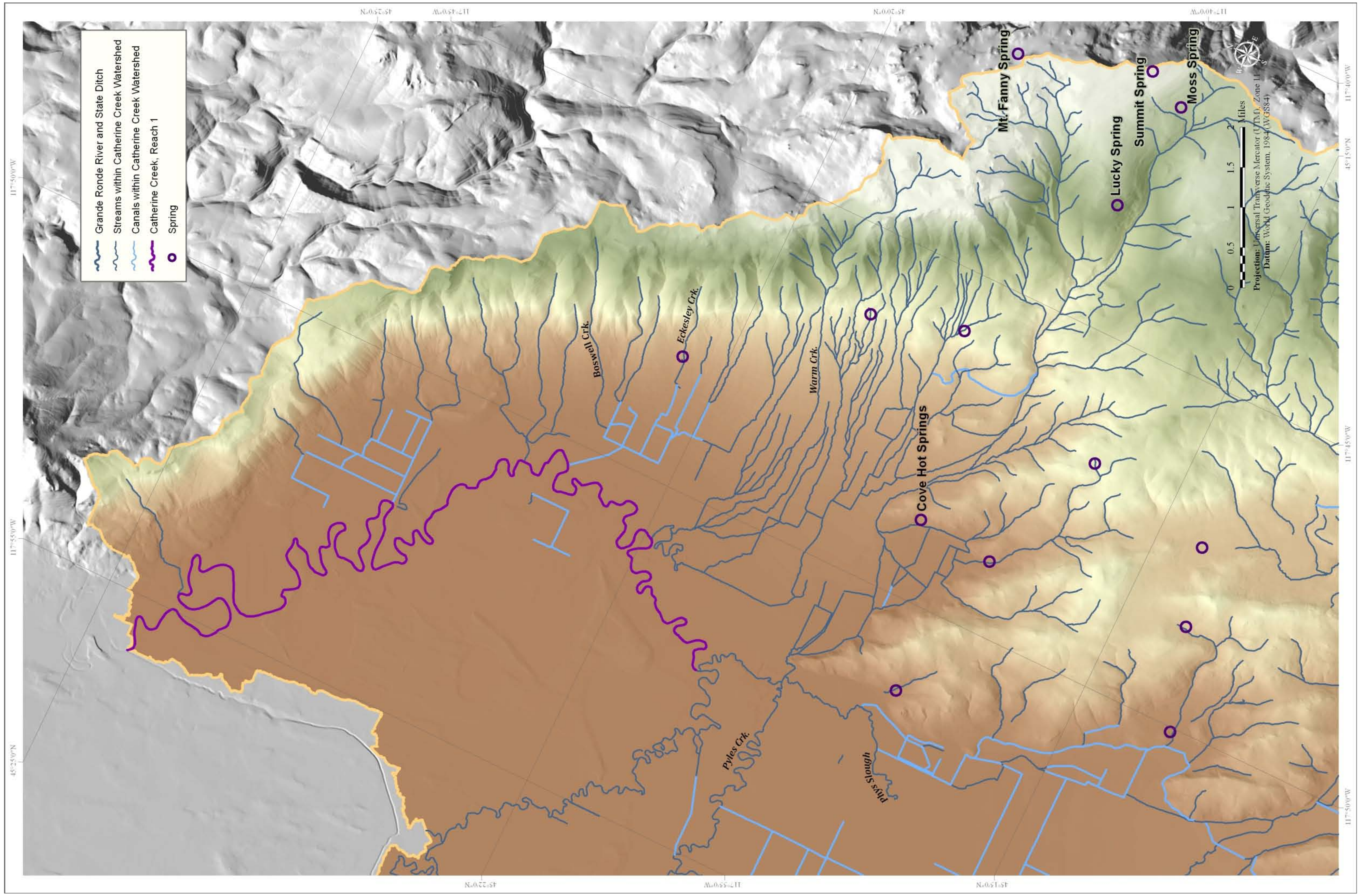


Figure 24. Springs are common along the eastern boundary of reach 1 which historically would have provided a temperature buffer against summer high temperatures and winter low temperatures, at least on a small habitat patch scale.

11.1.3 Present Conditions

Modifications

Within reach 1, one of the earliest known and most significant modifications was the excavation of what would become the State Ditch section of the Grand Ronde River during the 1860s. The original excavation was 6 feet wide and 3 feet deep (Duncan 1998) (Appendix C). Aerial photographs from 1937 suggest that most of the water still flowed down the original Grande Ronde River main channel while 1964 aerial photographs suggest only a small amount of water still flowed down the main channel during high water events. In 1950, State Ditch was reported to be 100 to 130 feet wide and up to 26 feet deep with a capacity of 4,500 cfs. Currently, the entire discharge of the Grande Ronde River flows through State Ditch. When this capture occurred, the confluence of Catherine Creek and the Grande Ronde was shifted and all of reach 1 of Catherine Creek now flows in the former Grande Ronde River channel without the input and benefit of the main Grande Ronde River. Other large alterations to Catherine Creek within reach 1 include the reduction in channel length of nearly 5.5 miles that has occurred since 1937 through channel straightening accomplished by cutting off large meanders (Appendix C). Most of the meanders disconnected since 1937 now act as irrigation storage areas that are filled during the spring flood either by the opening of valves, gates, or by inundation from overbank flows from Catherine Creek and/or spring melt of valley floor snowpack. Channel cut-off sections are concentrated within reach 1 in the downstream half between RM 5.6 and 14.0.

In addition to rerouting the Grande Ronde River and channel straightening, Elmer Dam (Figure 25) located mid-way within the reach at RM 13.1, has significant effects on the hydraulics, water quality, and habitat complexity within this reach. Elmer Dam is used for agricultural irrigation storage within the Catherine Creek channel. The dam backs up water for up to 14.6 miles (to near Godley Lane at RM 26.7). Water is pumped from the resulting “reservoir” at multiple locations. Water rights associated with Elmer Dam total approximately 29 cfs in addition to water storage rights for another 298 acre-feet. Pump capacity likely limits withdrawals to less than 20 cfs, which is further reduced later in the summer (Hattan 2011). The water rights are enough to completely and regularly dry Catherine Creek below the dam during the irrigation season. The dam itself has multiple effects on the creek: it acts as an artificial grade control structure preventing vertical migration of the channel, it develops a backwater pool, and it disconnects upstream and downstream movement of aquatic species, nutrients, and detritus that form the food base for salmonids. The backwater area upstream has a reduced ability to carry sediment due to the reduced slope and has aggraded in response to the artificial grade control imposed by the structure. This has caused any natural pools to fill with sediment. Multiple delta deposits of fine-grained sediment were observed during the summer of 2010 in the backwater areas of Elmer Dam, which further indicates that the reservoir area has limited sediment transport capacity.

Another effect of the structure is the documented thermal stratification of the water column in the backwater of the structure (Watershed Sciences 2000). The stratification results in the warmest water being at or near the water surface and this is the water that flows into the fish ladder. This may increase the potential for the development of a thermal barrier for upstream migrating fish. While most of the adults have already passed upstream before this temperature gradient would become a problem, it is possible that late returning adults would encounter these conditions.

Figure 25. View looking upsteam at Elmer Dam located at RM 13.1 used for irrigation water storage and diversion – Catherine Creek, Grande Ronde Subbasin. (Reclamation photograph by D. Stelma – July 9, 2010).

A reduction in habitat quantity and diversity likely began with the modifications that took place beginning soon after the settlement of the valley and continued until as recent as the mid-1970s. Noted large-scale modifications within reach 1 include levee construction, road construction, placement of bridges, introduction of exotic plants and animals, and diversion and capture of multiple unnamed springs emanating from the eastern edge of the Grande Ronde Valley that historically entered Catherine Creek throughout this reach between RM 3 and 19. Modifications to the main channel include 19 plugs across the entrances and exits of historic main and side channels (oxbows). The main channel may have also been excavated in some sections to provide the material required to build the levees that are currently located along both banks. There was likely an effort to clear wood and other debris from the channel to convey water as well (USACE 1950). Bank protection in the form of riprap comprised of concrete blocks, rock cobbles, and boulders was noted, but overall covers less than 1 percent of both banks.

Levees

Extensive sections of one or both sides of Catherine Creek in reach 1 have been altered with levee construction. Levees occupy 48 percent of the total length of the banks in reach 1, and are typically of two types; large levees that may be up to 30 feet tall and a smaller type that may be only a few feet tall . Some of the smaller levees may be a natural result of out of bank flood processes. In addition to the levees, over 47,000 linear feet of paved highway, gravel, and private roads with bed elevations raised above the floodplain may act as either dams or levees during flooding but the extent of which is not currently understood (Appendix C). Based upon hydraulic modeling in Appendix D, the levees in reach 1 are overtopped at the greatest frequency in the study area, with more than 80 percent experiencing overtopping at discharges of 10-year recurrence interval or less.

Hydraulics

Reach 1 is in a wide, unconfined valley with an average slope of approximately 0.006 percent (Figure 24). The section of the reach below Elmer Dam has a slope of approximately 0.004 percent (Appendix D). Water surface elevations within reach 1 are strongly influenced by downstream factors including Rhinehart Gap and flows on the Grande Ronde River. The geologic constriction at Rhinehart Gap has a strong influence on the lower valley including Catherine Creek within reach 1.

Rhinehart Gap is located on the Grande Ronde River between Elgin and Imbler, Oregon. The narrow canyon, formed by geologic features, creates a backwater effect upstream for nearly all flows at and above approximately 1,000 cfs at this location (USACE 1996). The 1996 USACE study focused on potential upstream flood reduction resulting from excavation at this location. The study determined that a major excavation of the “gap” which would require removing the existing road (old Highway 82) and moving the Union Pacific Railroad, would reduce the water surface of the Grande Ronde River at this location by over 3-feet for the 2-year event that was modeled (4,490 cfs) and by over 4-feet for the 100-year event that was modeled (11,000 cfs) (USACE 1996). This study showed the extent of influence that Rhinehart Gap has on water surface elevations upstream. As the water surface elevation changes in the Grande Ronde River at Rhinehart Gap, the base level, which controls water surface elevations in Catherine Creek, also changes. Therefore, the water surface elevation in reach 1 may increase due to backwater effects from Rhinehart Gap and flow from State Ditch, even though the discharge in Catherine Creek may not have increased.

Hydrologic conditions in the Grande Ronde River watershed and the Catherine Creek watershed are variable. This results in differences in timing of peak runoff between the two streams, and can have an effect on flow conditions within reach 1. For this assessment, a one-dimensional “steady-state” hydraulic model was developed (Appendix D) which means that only a single discharge event was run at any one time (a “snapshot” in time). For example, a simultaneous 2-year peak flow event was simulated in Catherine Creek and the Grande Ronde River. It is not, however, the typical case that a peak event of the same recurrence interval would occur at the exact same time on both the Grande Ronde River and Catherine Creek. In fact, the Grande Ronde River average spring peak occurs seven days earlier than on Catherine Creek, and can occur months earlier because of the lower relative elevation of the Upper Grande Ronde River watershed. Due to the varied timing of runoff and downstream boundary impacts, a range of discharges may result in filling the channel to its capacity in reach 1.

The steady-state results indicate that most locations along reach 1 exhibit bankfull (maximum channel capacity) conditions at flows between the 1.5- to 2-year discharges. While channel-forming flows in most streams in this area are typically 1.5- to 2-year discharges, the channel dimensions and form of this reach of Catherine Creek (and formerly the Grande Ronde River) may be more influenced by the complex relationships between the backwater effects and the interaction of flow regimes in both rivers. Approximately 40 percent of the historic 1.5 to 2 year discharge currently flows through this reach and the approximate dimensions are the same. The hydraulics within reach 1 are not typical of a mountain stream. The historic information collected indicates this reach acted as an ephemeral lake or estuary. Therefore, typical values of geomorphic properties such as the width-to-depth ratio and bankfull flow values do not apply well in reach 1. It is possible that the reach was more frequently flooded historically and although less flow is conveyed through this reach today, the capacity is still only a 1.5-2 year flood. The physical characteristics of this reach are dominated by backwater effects from Rhinehart Gap. This means that processes of sediment and water movement through this reach are dominated by hydrograph timing and magnitude of both Catherine Creek and the Grande Ronde River, not Catherine Creek alone.

The steady state model indicated that average in-channel velocities are very low and are typically around 1.3 feet per second (ft/s) at discharges with recurrence intervals between

1.5 and 100 years. Similarly, shear stresses are very low, indicating the potential to transport only sand size sediment under flood conditions. Levees are present along most of the reach, limiting floodplain access. In most locations, levees are overtopped at flows equal to or less than the 10-year discharge. There are four disconnected oxbows (RM 10.2, 14, 16.3, and 17.5) in this reach where the levee is overtopped at less than a 5-year flood. The most notable hydraulic controls in this reach are Elmer Dam at RM 13.1 and the “Old” Grande Ronde River (the historic Grande Ronde River channel before redirection into State Ditch), which is located in the upstream extent of the reach at RM 22.5. Bridges within the reach, including Booth Lane, Market Lane, and Highway 237, exert local controls at flows exceeding the 100-year discharge but do not appear significant at lower discharges.

Within reach 1, the bed slope can be divided into three sections. The slope of the bed is constant, 0.004 percent from the mouth to Elmer Dam at RM 13.1. There is a flat slope section behind Elmer Dam until Booth Lane, which is likely due to sediment deposition upstream of the dam (Appendix D). From Booth Lane until the Old Grande Ronde River confluence at RM 22.5, the slope is nearly constant at approximately 0.01 percent, which is steeper than in the other two sections (Figure 26). The historic confluence of the Old Grande Ronde River and Catherine Creek is a slope break between the reaches. The slope steepens upstream of the confluence in reach 2 (Appendix D).

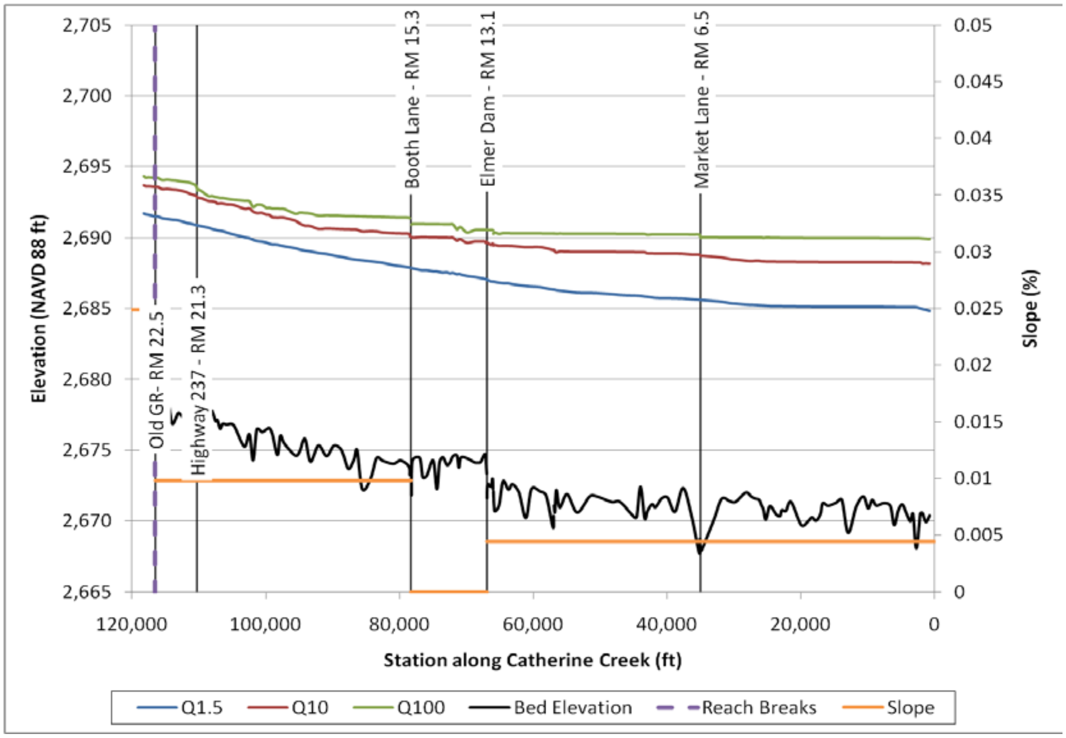


Figure 26. **Computed water surface elevations along on Catherine Creek (Appendix D).**

Geomorphic Properties

Today, only Catherine Creek flows through reach 1 but the dimensions of the channel are assumed to be similar to that of the historic channel that once also contained the waters of the Grande Ronde River. As a result, the channel is oversized for the amount of discharge that Catherine Creek provides. Although not determinable from the results of the steady-state hydraulic model used in this assessment, it may be the case that there has been a reduction in flooding, water velocities, and stream power, which has led to a reduction in stream and floodplain interactions. The ultimate result may be that this section of Catherine Creek has less power to induce the geomorphic change necessary to create complex habitat because the stream energy is no longer available to cause differential erosion and deposition. Without this, there is little opportunity for the creek to develop overflow channels, side channels, pools, and islands. Additionally, the interaction and disturbance of floodplain vegetation and soils that would otherwise help provide LWD to the floodplain and stream does not occur to the extent it would have historically. While this was likely not a very active section of the Grande Ronde River in the past, the little habitat complexity and woody debris that would have developed no longer exists.

Reach 1 has been shortened through channel straightening by cutting off meander bends. Shortening the channel has reduced channel sinuosity and increased the stream gradient locally. The channel length was reduced by approximately 28,800 feet resulting in a decrease in sinuosity from 3.0 in 1937 to 2.4 in 2009. Alterations were already largely present in 1937 and sinuosity was likely even greater at times prior to 1937. However, due to the naturally low gradient in reach 1, the overall channel gradient in the reach has not been significantly affected. Results from remote analysis using 10-meter digital elevation models (DEM) indicate that reach 1 has an average stream gradient of 0.006 percent with a valley gradient of 0.03 percent and an average width-to-depth ratio of 10:1.

Floodplain

The floodplain is generally wide, with subtle terrace rises (Figure 27). This figure shows the depths of potential flooding within the bounds of the modeled cross sections for the 100-year discharge. More details on how these depths were developed and their limitations are provided in Appendix D. The connection of the creek to the floodplain may be less than the historic condition; however, the extent to which that has changed was not determined in this assessment. Results appear to indicate that the connection may not be as poor as would be expected based on the redirection of the Grande Ronde River. Flooding occurs with surface water ponding within historic oxbows and topographic lows on the floodplain and in very low gradient channels. The floodplain area between the bank and the levee toe is typically a flat elongated bench where LWD and flood deposits accumulate. Materials include silts and fine sands inter-bedded with clay. Within the floodplain, there are relict channel scars visible in aerial photography and LiDAR data. These relict scars often contain slightly coarser material with higher porosity that interacts with the less permeable layers described above and may provide a conduit to return shallow groundwater back to the current active channel. Vegetation has also been highly altered within the floodplain. Although some willow and large cottonwood trees exist along the immediate bank, there are likely fewer today than the historic condition. In the floodplain areas away from the channel bank, native vegetation that likely consisted of sedges, grasses, and shrubs has been almost completely replaced by commercial crops and pasture grass.

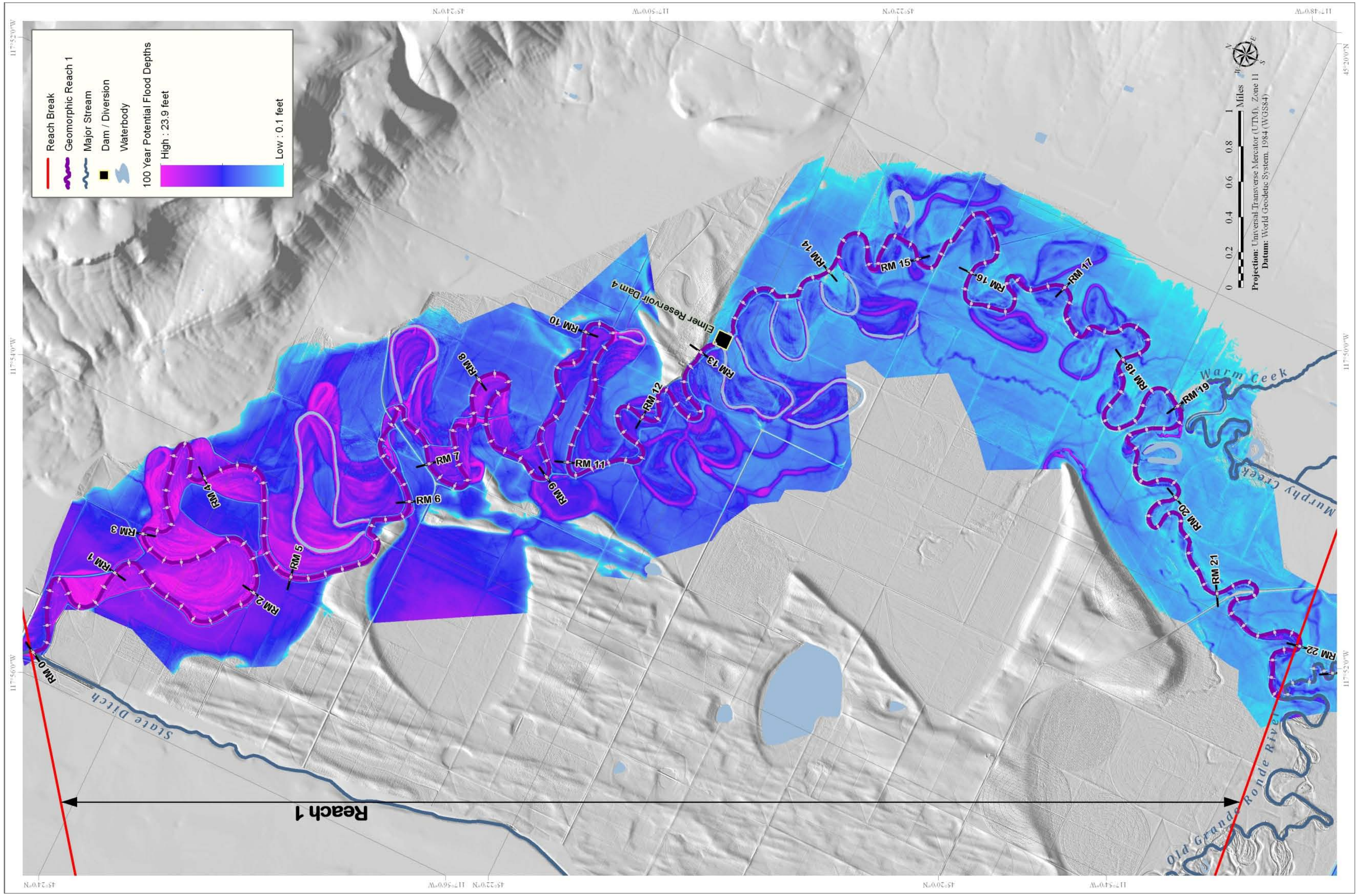


Figure 27. The 100-year floodplain depths of potential flooding within the bounds of the modeled cross sections for the 100-year discharge in reach 1.

Sediments

This reach is primarily located within alluvial and fluvial lacustrine sediments with gently sloping to vertical streambanks. Bank material consists of inter-bedded and indurated fine sands with dense, cohesive silts, and clays. The denser materials may act as groundwater infiltration barriers (aquatards) to some degree, reducing vertical infiltration. In this reach, Catherine Creek meanders into a higher terrace along the left bank from about RM 5.2 to 5.8 and along the right bank at RM 13.0 and again from RM 2.9 to RM 3. At RM 3.7, the creek meanders against the toe of a bajada that forms the toe slopes at the base of the Wallowa Mountains along the right bank (Appendix C). Materials in the banks developed in higher terraces and the bajada and consist of indurated fine sands and cohesive silts and clays similar to the alluvial and fluvio-lacustrine valley fill. Pebble counts were not done in this reach because both bank and bed materials were visually estimated to be medium sand and smaller in size.

The streambanks are devoid of vegetation in many areas. Shear stresses are low and may only be causing minor erosion that adds to the fine sediment problem. Some localized bank failure may be occurring due to saturated soil in the banks that cannot support themselves when the high water levels from spring floods recede. These saturated banks fail by slumping into the channel.

Water Flow

Water quantity is a limiting factor in this reach. Water quantity is compromised due to upstream and local withdrawals during low summer flows from July to October (Figure 28). Instream flows into reach 1 can be reduced by 90 to 95 percent and occasionally Catherine Creek is completely dewatered. Minimal flow combined with elevated summer water temperatures can limit rearing and access by later returning (NOAA Fisheries 2008a).

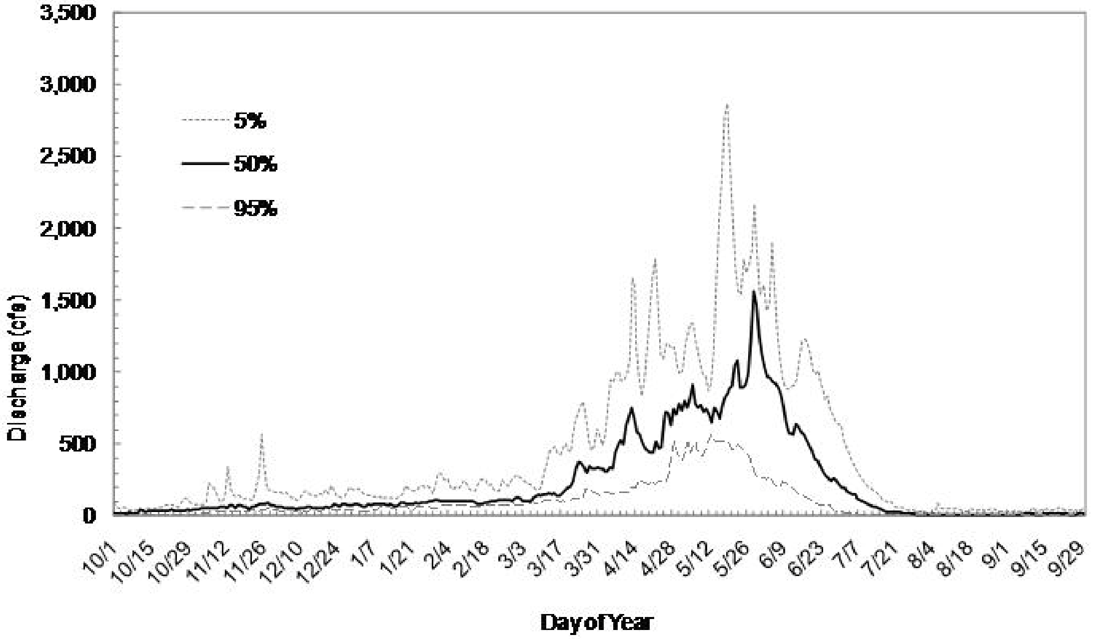


Figure 28. Estimated mean daily flow percent exceedance values for reach 1 using data extrapolated from the Catherine Creek at Union, Oregon stream gage. The 50 percent values indicate the average annual hydrograph.

Reach 1 is at the downstream end of the Catherine Creek watershed and is affected by all physical and meteorologic changes that have occurred throughout the watershed. Locally, direct changes to hydrology have mostly occurred due to the land use changes in the lower valley. The current land use in reach 1 illustrates the extent of urbanization and agriculture adjacent to the reach (Figure 29). Reach 1 was historically fed by multiple springs, which have been altered through diversion and capture. Additionally, alterations to the Grande Ronde Valley including reach 1 have significantly changed the baseflow conditions that would have occurred through storage within the shallow surface layer with slow long-term recharge to the creek. Upstream, the draining of wetlands and lakes has increased the delivery rate of water downstream that would have otherwise been, at least temporarily, stored in the valley bottom. Within the valley, tile drains further expedite water transport out of the valley along with roadside ditches and channelized portions of creek. The extensive network of levees within reach 1, as well as upstream, further advance water through the valley because of the reduced floodplain access and soil storage that result. While seasonal flooding and ponding associated with springtime runoff still occurs, it is not as widespread or long lasting as it is hypothesized to have been prior to settlement of the valley. Finally, pumped withdrawals throughout this reach deplete summer low flows to irrigate crops and provide stock water. Hydrologic stream gages were placed in the fall of

2010 near this reach along the Grande Ronde River at Rhinehart Road Bridge, Alicel Road Bridge, and Pierce Road Bridge and along Catherine Creek at Gekeler Road (RM 24.7) (Figure 30). Each gage measures stage and temperature on an hourly basis. Initial data analysis was beyond the scope of this assessment, but will be used to further refine understanding of hydrology, groundwater influences, and hydraulics and will be included in any future assessment of this area.

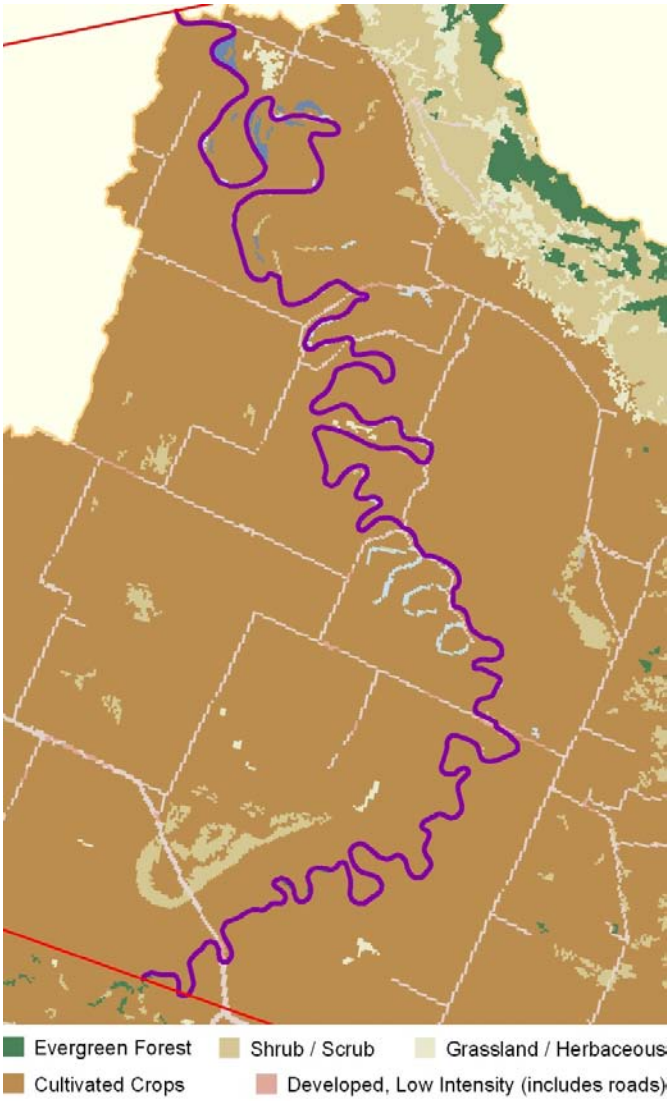


Figure 29. Land use in reach 1 from the 30-meter resolution National Landcover Database (NLCD).

Figure 30. Stream gages located in or near reach 1.

There has been a substantial amount of indirect change to the local hydrology. Analysis of the NLCD indicates that approximately 5.5 percent of the watershed area is now covered with impervious surface (e.g., buildings and roads) and the conversion of grasslands, wetlands, riparian areas, and other types of natural features has measureable changes to evapotranspiration, infiltration, interception, and surface runoff. Forestry practices, including road building, harvesting, planting, and forest fuels management may also have substantial effects on hydrology even though they occur further upstream.

Water Quality

Reach 1 has significant water quality problems with several parameters exceeding ODEQ's Section 303(d) list for violation of water quality standards: temperature; aquatic weeds (or algae); dissolved oxygen; nutrients; and pH (ODEQ 2000). All of these parameters can be associated with flow and habitat modifications to the stream both upstream and within reach 1. The Catherine Creek TMDL (ODEQ 2000) reported several issues within reach 1 that contribute to poor water quality that include substandard riparian conditions, low summer flows, high summer temperatures, limited dilution, and streambank erosion. Severely reduced summer flows together with reduced riparian shading and the overly wide channel relative to low flows exacerbate high water temperatures in the summer.

Habitat

A habitat survey conducted in the summer and fall of 2011 for this assessment by ODFW concluded that this reach is homogenous, thick with suspended sediment, and contained little defined habitat (Appendix G). Overall, the habitat quality rating for summer and winter juvenile rearing Chinook was fair, and poor for steelhead (Appendix G). The substrate and streambanks are primarily fine sediment (hardpan clay, silt, some sand).

Vegetation on the face of the banks within reach 1 includes grasses, shrubs, and willows, with occasional small trees, such as cottonwoods. There are large areas of the banks that are bare with little or no vegetation. Vegetation along the tops of the banks is predominantly grasses and shrubs with willows and sapling trees; however, some mature deciduous trees are present.

The potential for large wood – defined as 21- to 32-inch diameter at breast height (USFS 2006) recruitment – an important process for developing complexity in stream habitat, is low in this reach. The recruitment rate would naturally be low in this reach due to the relatively stable planform, lack of significant stream power to create and continue active lateral migration, and few large trees in and adjacent to the creek that would typically be the source of such material during events that would have disturbed the riparian area. Based on the very fine grained and seasonally saturated soils in the riparian zone and floodplain, it is unlikely that this area supported sizeable tracts of large trees. Although woody debris is transported into and through the reach during high flow events, it is unlikely that a significant volume of large wood is imported to this reach from upstream. Very little large wood (as defined above) or woody debris was observed in the channel or on the banks in reach 1. Most of the wood, regardless of size, that is transported into the reach would likely be deposited on the floodplain as the back waters recede, or transported further downstream rather than depositing within the active channel due to the lack of in-channel roughness. ODFW observed and documented only 0.2 pieces of LWD for every 100 meters of channel (Appendix G).

Beaver

Currently, there appears to be little use of this reach by beaver, which were once common in the area.

Fish Use

Reach 1 supports adult migrating spring Chinook salmon and steelhead, out-migrating juveniles, and may provide some limited juvenile rearing in winter. However, it appears that the existing habitat is of poorer quality than that provided historically both spatially and temporally. Current limiting factors in this reach include low flows, restricted passage for adults, and poor water quality (elevated summer temperatures and low dissolved oxygen levels) which are related to and influenced by cumulative effects of changes upstream, downstream, and within the reach that include a lack of shading, lack of wetlands, and artificially stored water for agricultural purposes. Excess fine sediment, substandard streambank and riparian conditions, and a lack of habitat diversity are also significant limiting factors (Huntington 1994; GRMW 1995; Nowak 2004). The *Draft Conservation and Recovery Plan* (NOAA Fisheries 2008b), also lists fish passage as a limiting factor which may be a result of Elmer Dam not meeting current fish passage criteria, as well as poor instream conditions. The combination of seasonal low flows and water withdrawals may leave so little water in the channel that a physical barrier develops.

Elevated summer water temperatures due to thermal stratification in the backwater areas of diversion dams and the low flow conditions may also increase the potential to limit access of returning adults (NOAA Fisheries 2008a). In addition, out-migrating juvenile Chinook salmon may also be delayed through this reach because of high spring runoff flows in the Grande Ronde River backing up Catherine Creek, which would reduce average downstream velocities and can cause reverse flows downstream of Elmer Dam within this reach. Levees and unscreened but hydraulically connected oxbows may also be causing delayed outmigration or even stranding juveniles as flows recede.

Reach 1 does not appear to provide significant habitat for overwinter rearing of spring Chinook juvenile salmon. Results from the winter period of 2009 to 2010 in the ODFW fish tracking study for overwintering juvenile spring Chinook salmon, show little use of this reach by radio-tracked fish with more use found in upstream reaches (Appendix H). Figure 31 shows observations by river mile and date of radio-tagged juvenile salmon throughout the lower valley within Catherine Creek during the fall and winter of 2009 and 2010. Observations indicate a high usage of reach 3, followed by limited usage of portions of reach 2 and very little to no usage of reach 1 for winter rearing. Preliminary results from the 2010 to 2011 winter study indicate that the most significant difference between this and the previous winter study was that a small percentage of the fish moved greater distances during the same period (Favrot 2011).

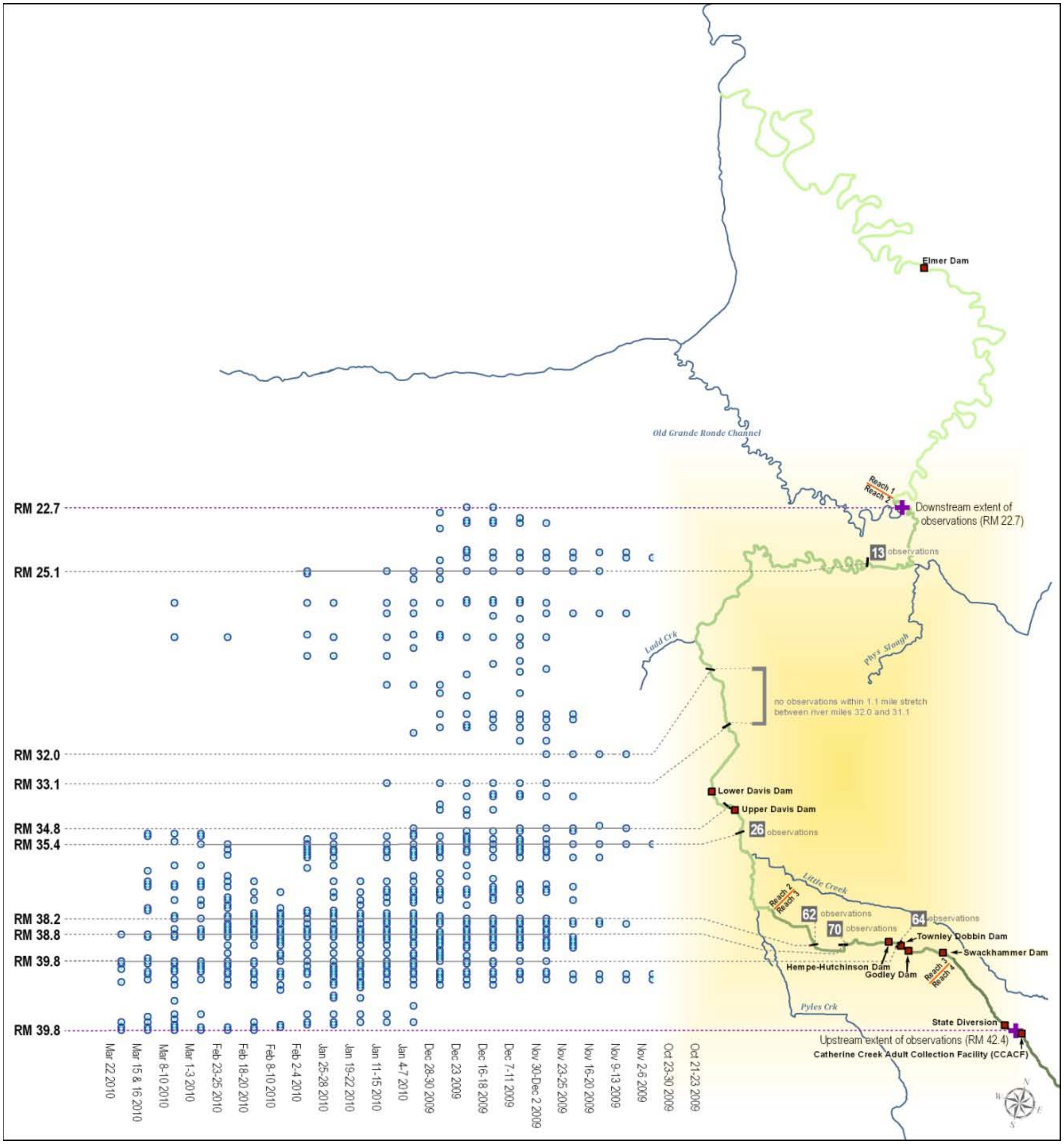


Figure 31. Overwinter fish tracking study results during the winter of 2009 to 2010. (Figure developed from data found in Appendix H).

Invasive Species and Predators

Introduction of invasive species including reed canary grass, Asian carp, smallmouth bass, largemouth bass, and brown bullhead have likely created additional problems for salmonids beyond the hydrologic and geomorphic changes within reach 1. Predation may be occurring in reach 1 by native (northern pikeminnow, Great Blue Heron, Cormorant, North American river otter, and Mergansers) or even introduced species but it is unknown if this is an issue or to what extent. The altered environment within reach 1 favors the survival of some introduced fish species, which can cause water quality, competition, and predation issues for native species. Predation is likely exacerbated by lack of complex refugia including riparian cover, pools, LWD, and other physical structures in addition to the physiological stresses associated with poor water quantity and quality. Predation may also be aggravated due to loss of flow from the Grande Ronde River, which has likely resulted in longer outmigration travel times and more opportunities for predation than under historic conditions.

11.2 Reach 2 (RM 22.5 to 37.2)

11.2.1 General Location and Description

Centered in the lower Grande Ronde Valley, reach 2 spans the section of Catherine Creek between Pyles Creek at RM 37.2 and the historic confluence with the former Grande Ronde River at RM 22.5 (Figure 32). This reach is highly influenced by tributary inflows. Nearly all major tributaries that drain the Grande Ronde Valley and surrounding hills enter Catherine Creek within this reach. Reach 2 is significantly altered from its historic condition with the draining of wetlands and a very large perennial lake to form the channelized reach that is present today. The reach is marked by levees to control floodwaters from inundating agricultural fields. Similar to reach 1, reach 2 has a history of flooding, with fine soils laid down as a result of annual flooding.

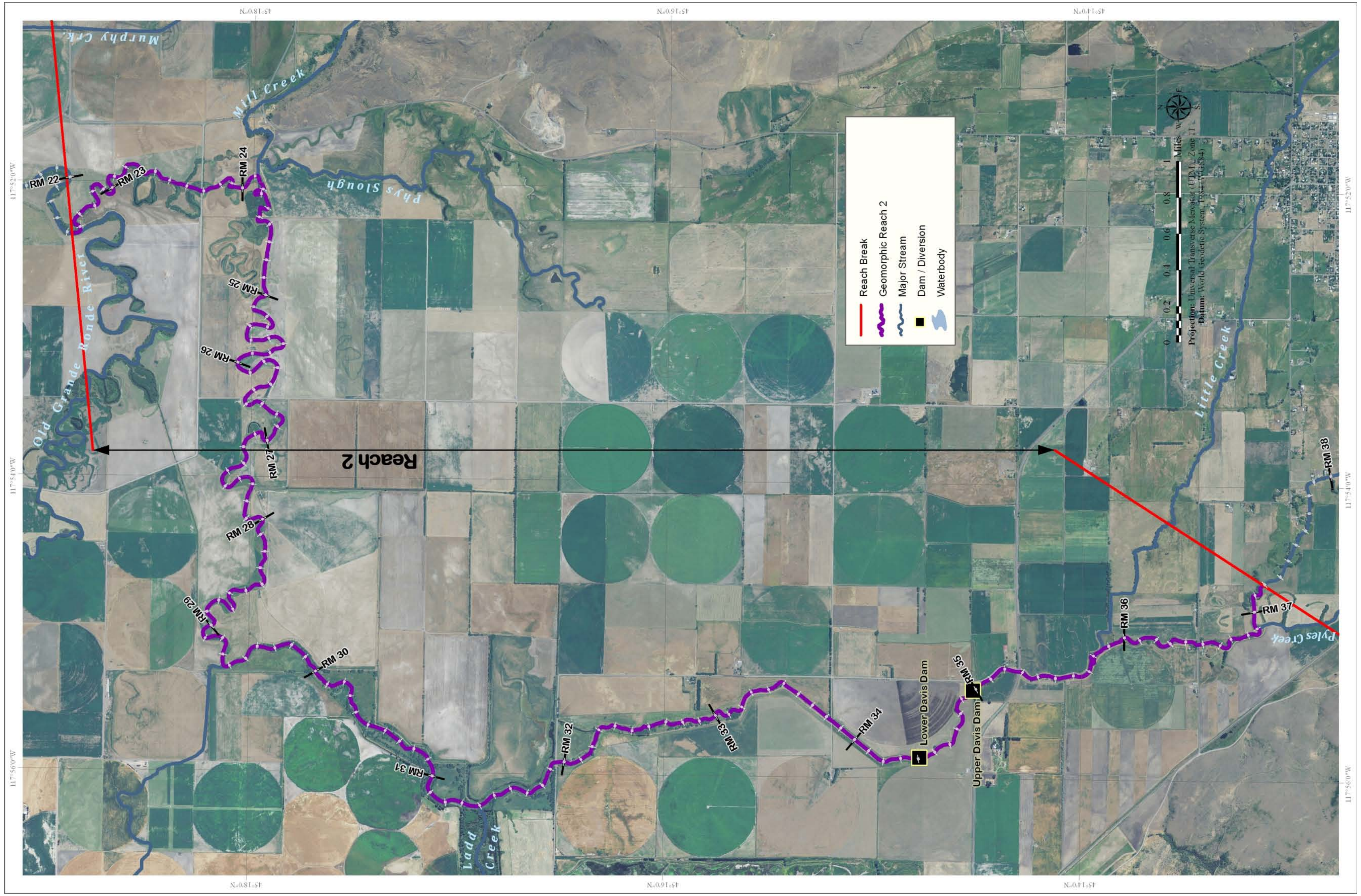


Figure 32. Extent of reach 2. The upstream boundary is the transition from an alluvial fan to fluviolacustrine sediments with a corresponding break in slope. The downstream boundary is the historic confluence of Catherine Creek and the Grande Ronde River.

Several of Catherine Creek's largest tributaries enter within this reach. Mill Creek, a steep mountain stream with a drainage area of 26 mi^2, enters Catherine Creek from the east at RM 24.1. McCallister slough, a flat, valley-bottom drainage with a drainage area of 10 mi^2, enters Catherine Creek from the west at RM 29.4. Ladd Creek, a steep mountain stream that drains the southern valley through a large wetland complex with a drainage area of 86 mi^2, enters Catherine Creek at RM 31.4. Little Creek, a large tributary also draining from the mountains with a drainage area of 38 mi^2, enters Catherine Creek from the east at RM 35.9. Finally, Pyles Creek, a small mountain stream with a drainage area of 28 mi^2, enters from the south at the upper end of reach 2 at RM 36.9.

11.2.2 Historical Conditions

Historical Physical Conditions

In addition to historic accounts, physical evidence of historic channel meander scars, fine sediment layers, topography, and vegetation provide clues to the historic conditions that may have existed within this reach (Figure 33). Reach 2 was likely very similar to reach 1 as a low gradient stream with a strong influence of depositional floods and a wetland environment. A difference between reaches 1 and 2 is the interconnectedness that reach 2 likely had with several tributaries including Pyles, Ladd, and Little creeks. These three tributaries show physical evidence of historic channel meander scars, which created a broad and diverse channel network within this reach including ample habitat opportunities. The historic Grande Ronde River also met Catherine Creek in this reach adding to the natural habitat diversity, as tributary junctions tend to be biologically favorable because they provide more diverse conditions and habitat options over a small area. The backwater effect that the Grande Ronde River currently imposes on Catherine Creek would have occurred at the historic confluence but it would not have been as extensive due to the relatively higher channel slope of reach 2. Reach 2 is not only slightly steeper, but it also contained a large shallow lake (Tule Lake) that Catherine Creek flowed through.

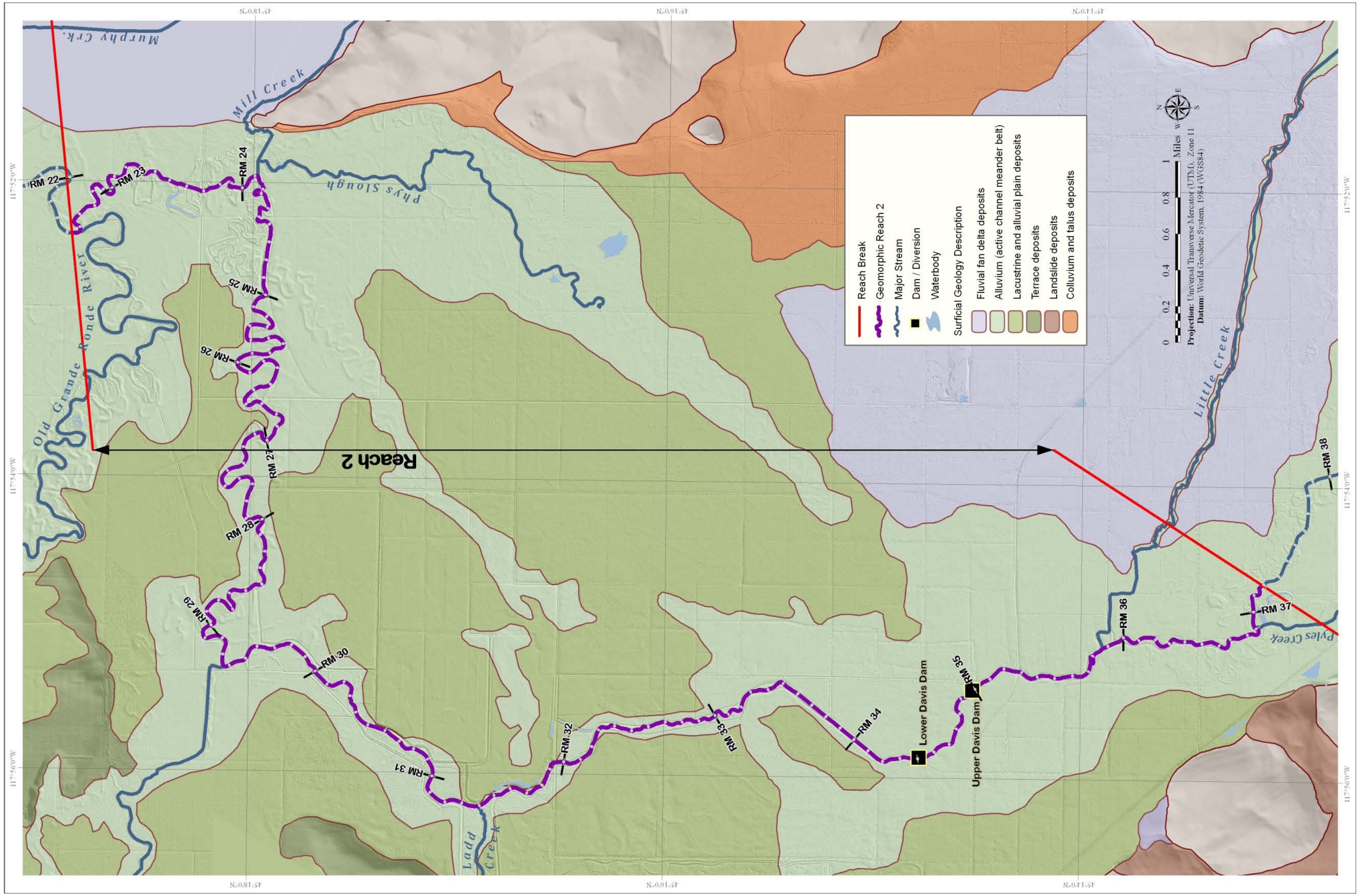


Figure 33. Surficial geologic deposits and "bare earth" hillshade topography in reach 2. This reach includes three substantial tributary confluences: Ladd Creek, Little Creek, and Mill Creek as well as two diversion dams.

Historical Descriptions

Historical descriptions compiled from the journals of pioneers describe the valley floor as having numerous small creeks and rivulets running through all parts. Tule Lake existed within reach 2 at the south-central valley floor, was fed by runoff and overflows from Catherine Creek and the Grande Ronde River, and drained back into both (Duncan 1998). Catherine Creek flowed into the lake at its southeastern end and flowed out on its northeastern side. The reported size of the lake varies from 2,300 acres (Beckham 1995) up to 20,000 acres (Duncan 1998). In addition, Hot Lake was a spring fed lake in the same area. Historical accounts describe the valley floor conditions as wet and marshy. Duncan (1998) reports that an estimated 72,000 acres in the middle valley were subject to flooding, and that up to 60 percent of the valley floor might be inundated for as long as 5 months. Another historical account described the area from La Grande, across the valley to Union and Cove as big cattail swamps (Duncan 1998). Vegetation on the floodplain was noted to be Camas root, red clover, Rye grass and other grasses (Beckham 1995; Duncan 1998). The banks of Catherine Creek (and the Grande Ronde) were noted to be high and muddy, covered with cottonwoods, willows and other underbrush (Beckham 1995; Duncan 1998). Duncan (1998) noted that the Native Americans in this area (Umatilla Tribe) named the valley cop-copi for the large, dense black cottonwood trees that lined the riverbanks. Noted wildlife included numerous inhabitants from the otter family, along with deer, raccoon, elk, and beaver (Beckham 1995) (Appendix C).

Historical Fish Presence

Historically, reach 2 likely had complex aquatic habitat that would have provided opportunities for rearing juvenile salmonids as a result of the wetlands, beaver complexes, and lakes. This reach would have also functioned as a migration corridor for returning adults and out-migrating smolts. Because of the extremely low gradient, and subsequent low energy, the substrate would not have been suitable for supporting Chinook or steelhead spawning.

Beaver were common in this reach before being trapped in excess (ISG 2000; Beckham 1995).

The stored flow as a result of the beaver complexes would have likely provided abundant and diverse cool water habitat throughout the warm summer in the wetlands and lakes and the higher baseflows would have supplied better instream habitat and fish passage throughout summer and fall.

11.2.3 Present Conditions

Modifications

A reduction in habitat quantity and diversity likely began with the modifications that took place beginning soon after the settlement of the valley and continued until as recent as the mid-1970s. The channel bed, banks, and adjacent floodplain areas have experienced significant anthropogenic manipulations, which include road construction, bridges, levees, alteration to floodplain and bank vegetation, surface water withdrawal, and channel relocation, clearing, and dredging. There are nine plugs across the entrances and exits of historic main and side channels within reach 2. Shortening the channel has reduced channel sinuosity and increased the stream gradient locally within the confines of grade control provided by diversion dams.

In reach 2, one of the earliest modifications to the channel planform of Catherine Creek was the draining of Tule Lake in 1870 (Beckham 1995). This action entailed the re-routing and channelization of Catherine Creek around the lake on the east side in a constructed channel. The comparison of the GLO maps (circa 1864-1876) to the current channel alignment in ortho-rectified aerial photographs suggests that the location of the main channel was altered beginning around RM 34.4 and continuing downstream to about RM 31.4. Other stream channel manipulations include the reduction of overall channel length by nearly 3 miles since 1937. This has been accomplished by cutting off individual sections of channel meanders. Some of the meanders that have been disconnected since 1937 now function as off-channel storage ponds that are filled by spring melt of valley floor snow as well as groundwater and overbank inundation from Catherine Creek in the spring. Other historic oxbows have been filled in and converted to agricultural use. From analysis of aerial photographs dating back to 1937, it is apparent that the cut-off sections are concentrated in the downstream half of the reach between RM 23.5 to 30.0 and within a short upstream section from RM 35.8 to 37.8. Additional manipulations to Catherine Creek in reach 2 include placed anthropogenic features such as levees, diversion dams, roads, and bridges. Levees have been constructed essentially through the entire reach and are generally located along the edges of the meander belt-width. This means that the majority of the reach is enclosed within levees even though the total length in feet of levees in reach 2 is a much lower figure than the total length of channel and banks (Appendix C). Catherine Creek meanders within a wide band of area between two relatively straight levees.

There are two diversion dams within reach 2 located above the mouth of Ladd Creek and below Little Creek. The “Davis Dam complex” consists of Lower Davis Dam at RM 34.4 and Upper Davis Dam at RM 35.0. The two dams are used for both surface and pumped diversions and can create a backwater for over 2 miles upstream, to near the mouth of Pyles Creek. The water rights associated with Lower and Upper Davis dams total approximately

47 cfs and 60 cfs, respectively, however, the associated ditches have capacities for only about 25 cfs each. Both dams have guides and flashboards for headwater manipulation and fish ladders for passage. Both dams were completely reconstructed in 2011 and are equipped with radial gates and vertical slot fish ladders. The dams have multiple effects on the creek: they act as artificial grade-control structures preventing vertical migration of the channel and the backwater pool upstream has a reduced ability to carry sediment and becomes a depositional reach, filling pools and covering the streambed with sediment. Bathymetric survey data shows a break in slope upstream of the Davis Dam complex, which would be caused by deposition in response to the artificial grade imposed by the structures. Other diversion dams and culverts exist near the mouths of large tributaries within this reach including Pyles, Little, and Ladd creeks, which have likely created both physical and flow barriers to these tributaries; however, further discussion of these tributaries is beyond the scope of this assessment.

There are six bridges within reach 2 and approximately 23,000 feet of roads with elevated surfaces that run both parallel and perpendicular to the floodway and alter floodplain connections. Additionally, there are multiple culverts throughout this area, which act as overflows for flood passage. In addition to surface diversions, there are three pumps near the Davis Dam complex; one just above the lower dam and two upstream just below the highway bridge crossing Catherine Creek at RM 35.23. There are two additional pumps further upstream, but it is no known if they pump from the Davis backwater (GRMW 2011). There are also numerous large diversion ditches within the reach that feeds the Ladd Marsh wetland complex and carry storage water to off-channel storage sites, including the lower end of the Old Grande Ronde River when flows are high in Catherine Creek. Some of the ditches that convey water to storage sites such as the Old Grande Ronde River are not screened and may strand fish, as it provides no egress outside of the inflow ditch except when the creek is overtopping.

Levees

A significant levee system controls flooding within most of reach 2. Construction of levees within this reach has been ongoing since channelization of Tule Lake in the late 19th century. An extensive levee and channel enlargement project was authorized to be constructed as part of the 1950 Flood Control Act (USACE 1950). The project was deauthorized in 1986 before being constructed (USACE 2011); however, some emergency protection measures were constructed in 1949, 1950, and 1951 (USACE 2011). The Catherine Creek Corridor Improvement District was formed in the early 1980s to enter into the USACE levee program. The levee district spans the reach between Lower Davis Dam and Godley Bridge, but levees of some magnitude generally occur throughout the entire reach. The USACE levee program places stringent requirements on levee maintenance that include removing vegetation and controlling burrowing animals. There are approximately

91,000 feet of levees within reach 2. Hydraulic modeling indicated that levees within reach 2 tend to be overtopped at less frequent recurrence intervals than within reach 1. Modeling suggests less than 40 percent of the levees overtop at flows equal to or less than the 10-year discharge and nearly 50 percent of the levees are not overtopped until flows exceed the 100-year discharge. In general, leveed areas upstream of Ladd Creek (RM 31.4) require smaller discharges to overtop their associated levees.

Hydraulics

The 1D model was also used to understand the hydraulics of reach 2 (Appendix D). Reach 2 is a wide, unconfined valley with an average slope of approximately 0.04 percent (Figure 34). A break in slope occurs at the confluence of Ladd Creek near RM 31.4, which coincides with changes in hydraulic properties. Channel capacity throughout the reach is variable, with bankfull conditions occurring in most cross sections around 1.5 to 2-year discharges. In-channel velocities below Ladd Creek are generally around 1.7ft/sand upstream they average 3.1 fps. Shear stresses in reach 2 are slightly higher than those in reach 1 with reach averages ranging from approximately 0.10 to 0.17 lb/ft^2 for discharges between the 1.5- and 100-year recurrence intervals. Levees within reach 2 are overtopped less frequently than reach 1 with 50 percent of the levee reach indicating overtopping only at flows exceeding the 100-year discharge. Notable hydraulic controls in this reach include Upper and Lower Davis dams, Ladd Creek, Wilkinson Lane Bridge, and a 2010 beaver dam located at RM 24.9. Similar to Reach 1, most bridges in the reach impart some hydraulic control at the 100-year discharge, but their influence appears to be localized (Appendix D).

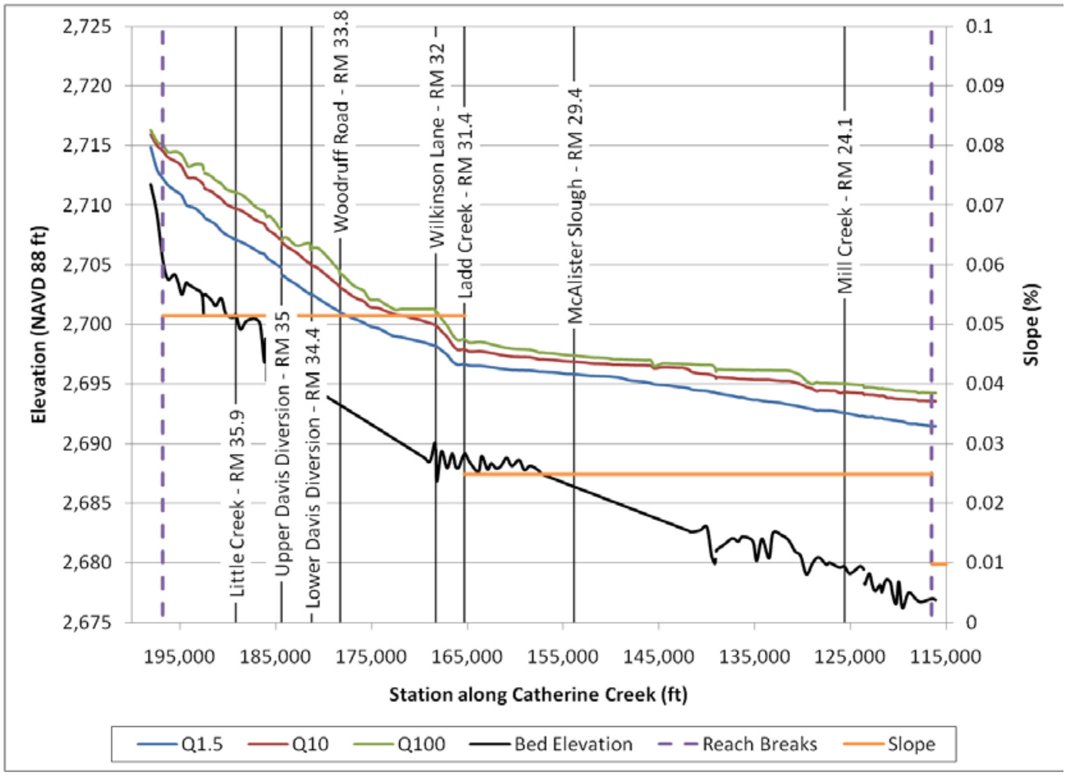


Figure 34. **Computed water surface elevations along reach 2.**

The bed slope below Ladd Creek is approximately 0.02 percent, (where data was collected) and there may be controls in this area, such as McAlister Slough, that are not included in the bed profile. Upstream of Wilkinson Lane Bridge, the bed slope steepens until reach 3 to 0.05 percent. Sediment deposition upstream of Lower Davis Dam was notable in the bed profile (Appendix D).

Geomorphic Properties

The channel in reach 2 has been shortened by nearly 12,500 feet since 1937 with the intention of reducing flooding. This equates to a decrease in sinuosity from approximately 1.61 in 1937 to 1.40 in 2009. A lower sinuosity can lead to higher stream power and increased sediment transport capacity. However, reach 2 has a natural low gradient and the overall channel gradient in reach 2 was not affected significantly by straightening.

Results from field measurements indicate that the average width-to-depth ratio in reach 2 is approximately 10:1 with an average valley gradient of 0.04 percent. A reduced sinuosity within reach 2 relative to reach 1 corresponds to the significant channelization and straightening efforts that have taken place along with the naturally slightly steeper slope.

Floodplain

The historic creek-to-floodplain connectivity in areas outside the levees has been reduced but the floodplain is generally wide, with subtle terrace rises (Figure 35). Flooding occurs with surface water ponding within historic oxbows and topographic lows on the floodplain and in very low gradient channels. The floodplain area between the bank and the levee toe is typically a flat elongate bench that is connected to the creek and where LWD and flood deposits accumulate. Materials include silts and fine sands inter-bedded with clay. Within the floodplain, there are relict channel scars visible in the LiDAR data. These relict scars often contain slightly coarser material with higher porosity that interacts with the less permeable layers described above and may provide a conduit to return shallow groundwater back to the current active channel.

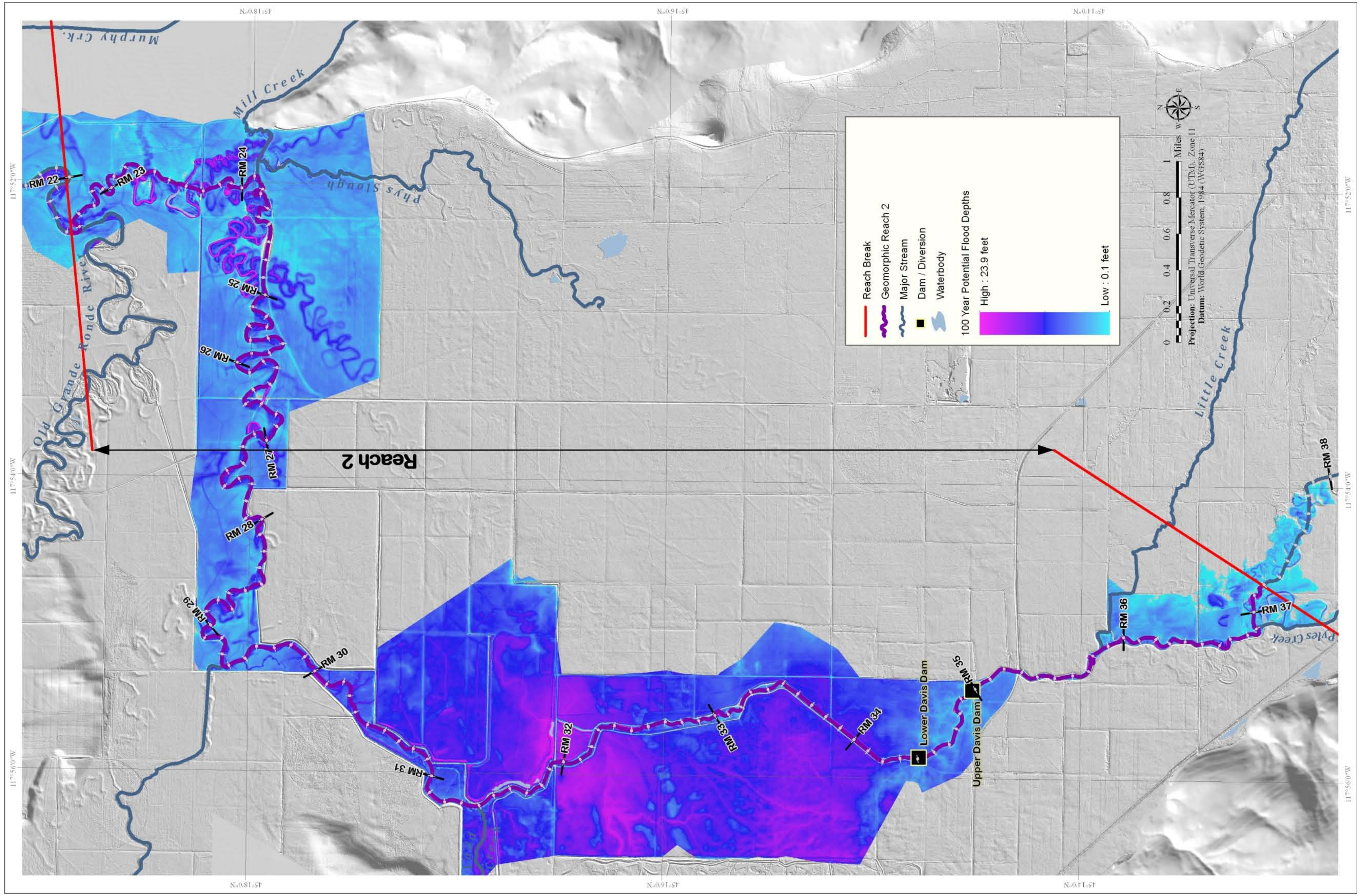


Figure 35. **The depths of potential flooding within the bounds of the modeled cross sections for the 100-year discharge along reach 2.**

Sediments

This reach is primarily located within alluvial and fluvial lacustrine sediments with gently sloping to vertical streambanks. Bank material is inter-bedded indurated fine sands with dense, cohesive silts, clays, and ash. The denser materials may act as a groundwater barrier to some degree, reducing vertical infiltration. Within reach 1, the creek has eroded through multiple "hardpan" layers. Within reach 2, these dense layers are noted at the toe of the banks and they extend across the channel bottom. In some locations, it has been scoured through to form a pool.

Excess fine sediment has been indicated as a limiting factor in this reach (NOAA Fisheries 2008a). The streambanks and bed are comprised of fine sediments throughout the reach. The streambanks are devoid of vegetation in many areas. Shear stresses are generally low and may only be causing minor erosion that adds to the fine sediment problem.

Evidence of slight lateral migration that include bank slumping, slight erosion of the bank on the outside of meander bends, and occasional bar formation on the inside of meander bends was noted in small localized areas within reach 2. In non-backwatered sections of the valley, the in-channel substrate was observed to be medium sand (2 mm or less, using the USCS) that is mobile at low flows, forming dune-ripple and delta-type structures in the wetted channel. Based on these observations, it is assumed that the in-channel substrate is mobilized and transported during channel-forming flow (approximately the 1.5 to 2 year recurrence event). Finer particles (silt and clay) are assumed to be transported as suspended sediment at a wide range of flows. Bank protection in the form of riprap comprised of both concrete blocks and rock cobbles and boulders was noted within reach 2, but overall covered less than 1 percent of both banks.

Water Flow

Water quantity is listed as a limiting factor in reach 2. Water quantity is compromised due to substantial water withdrawals combined with low summer flows from July to October (Figure 36). Instream flows within sections of reach 2 are commonly reduced by 90 to 95 percent and occasionally dewater Catherine Creek, particularly in the section directly downstream from Lower Davis Dam. The potential affects are the same as those previously described for reach 1.

Hydrologic inputs within reach 2 have been altered by multiple causes. All significant tributaries entering reach 2 have been over allocated creating little to no net surface water inputs to this reach. Surface waters are diverted to irrigate adjacent fields and the runoff is then captured within ditches that are often routed to storage reservoirs and re-used. It is not known how much flow returns to reach 2 through groundwater seepage.

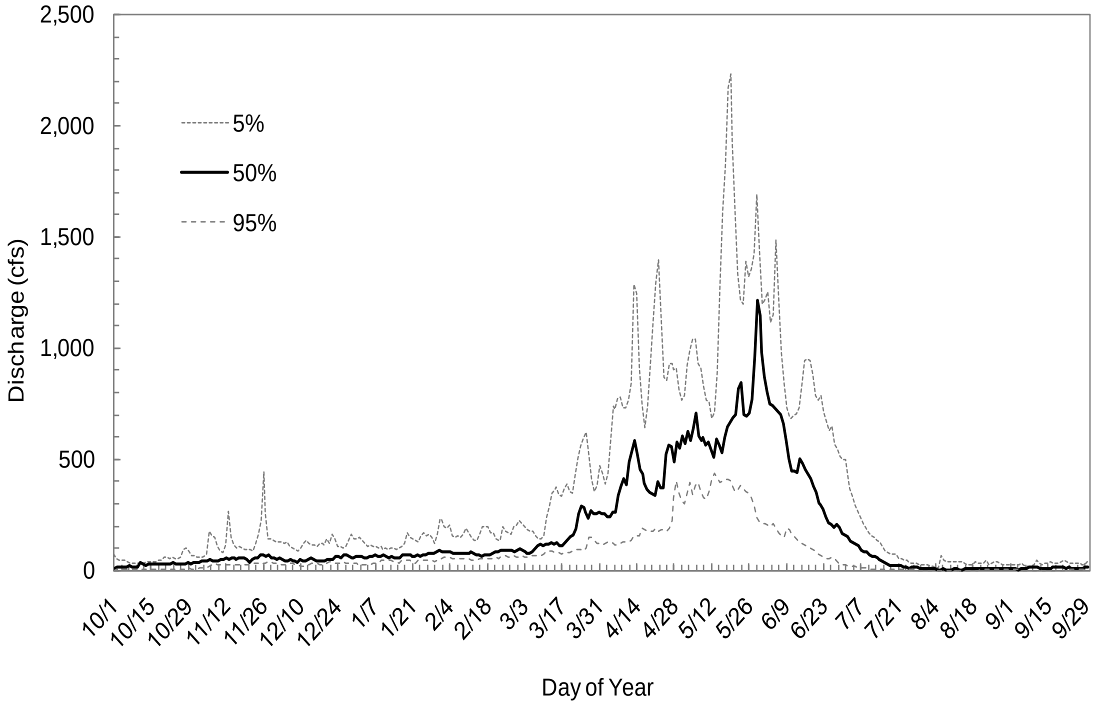


Figure 36. Estimated mean daily flow percent exceedance values for reach 2 using data extrapolated from the Catherine Creek at Union, Oregon stream gage. The 50 percent values indicate the average annual hydrograph.

Cumulative effects of upstream and adjacent floodplain practices have likely altered the flow hydrograph within this reach. The conversion of grasslands, wetlands, riparian areas, and other types of natural features to urban and agriculture uses has resulted in measureable changes to evapotranspiration rates, infiltration, interception, and surface runoff. Forestry practices, including road building, harvesting, planting, and forest fuels management also have substantial effects on hydrology even though these practices occur far upstream. Direct changes to hydrology have also occurred due to land use changes in the lower valley. The current land use map of reach 2 illustrates the extent of urbanization and agriculture land use conversion adjacent to the reach (Figure 37). The draining of wetlands and lakes has likely increased the delivery rate of water downstream that would have otherwise been, at least temporarily, stored in the valley. Ditches further expedite water transport out of the valley, as do the many roadside ditches and channelized portions of creek. An extensive network of levees in the lower reaches further advance water through the valley by reducing floodplain and soil storage. Finally, water diversions and pumps throughout the valley deplete summer low flows to irrigate crops and provide stock water. Hydrologic stream gages were placed in the fall of 2010 within this reach at Wilkinson Lane, Godley Lane, and Gekeler Road crossings to measure stream stage, flow, and temperature. Data collected at these stream gages will be included in any additional assessment completed in this area.

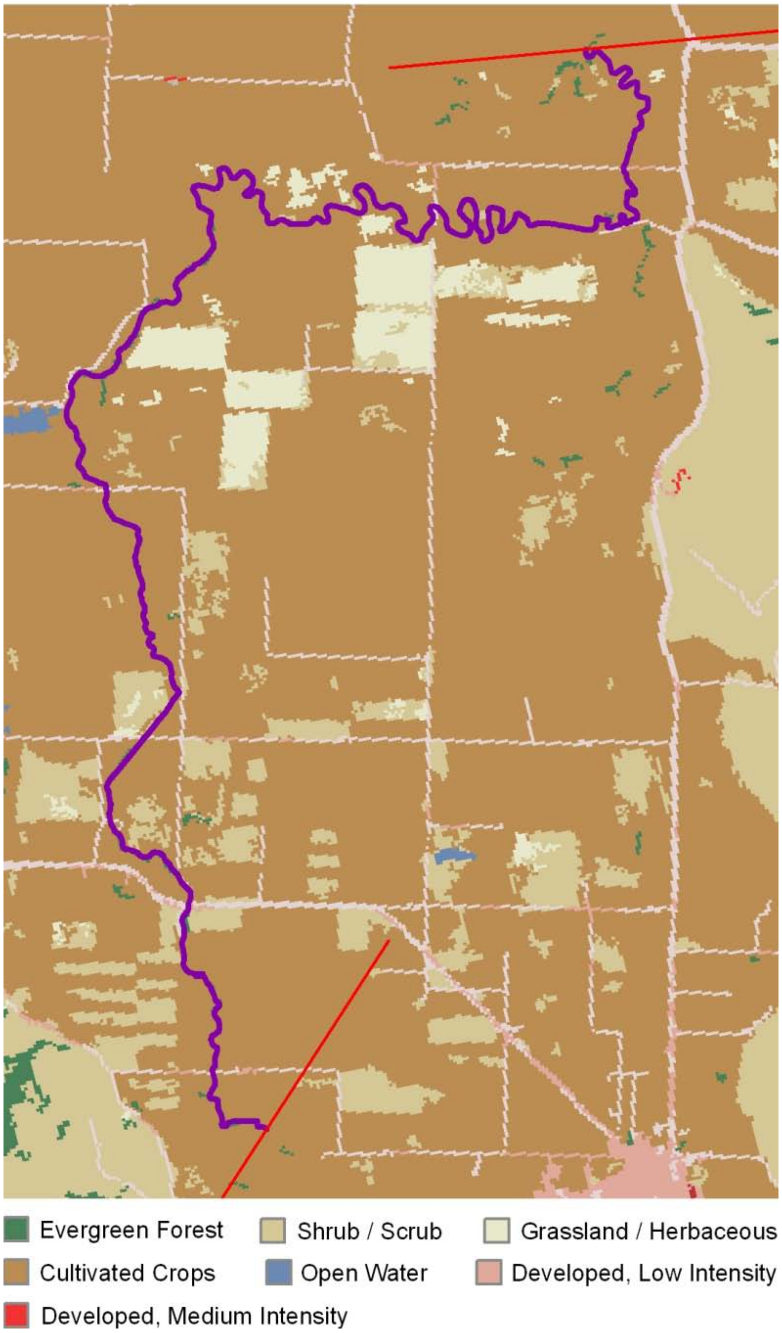


Figure 37. Current land use (land cover types) in reach 2 from the 30-meter resolution NLCD.

Water Quality

Reach 2 has significant water quality problems with several parameters exceeding water quality standards. This reach is listed on the 303(d) list for temperature, aquatic weeds (or algae), dissolved oxygen, nutrients, and pH (ODEQ 2000). All of these parameters can be associated with significant flow and habitat modifications to the stream both upstream and within reach 2. The Grande Ronde TMDL (ODEQ 2000) reported several issues within Catherine Creek that contribute to poor water quality within reach 2: substandard riparian conditions, low summer flows, high summer temperatures, limited dilution, and streambank erosion.

Elevated temperatures can occur in the summer months throughout reach 2 and were documented as being within the lethal range for salmonids during the summer 2010 FLIR flight that was produced for the TMDL (Figure 38). Reach 2 is a slow water section with a large surface area of ponded water and reduced riparian vegetation that likely leads to high water temperatures creating a thermal barrier for both returning adults and migrating juvenile Chinook salmon.

Most sections of reach 2 would have naturally low water velocities due to the extremely low gradient. The combination of a large surface area of low velocity ponded water and reduced riparian vegetation has the potential to create thermal stratification of the water column. Thermal stratification was documented from just downstream of the Davis Dam complex by Watershed Sciences during FLIR data collection in 2000. This is turn can increase the potential to create thermal barriers as described previously in reach 1.

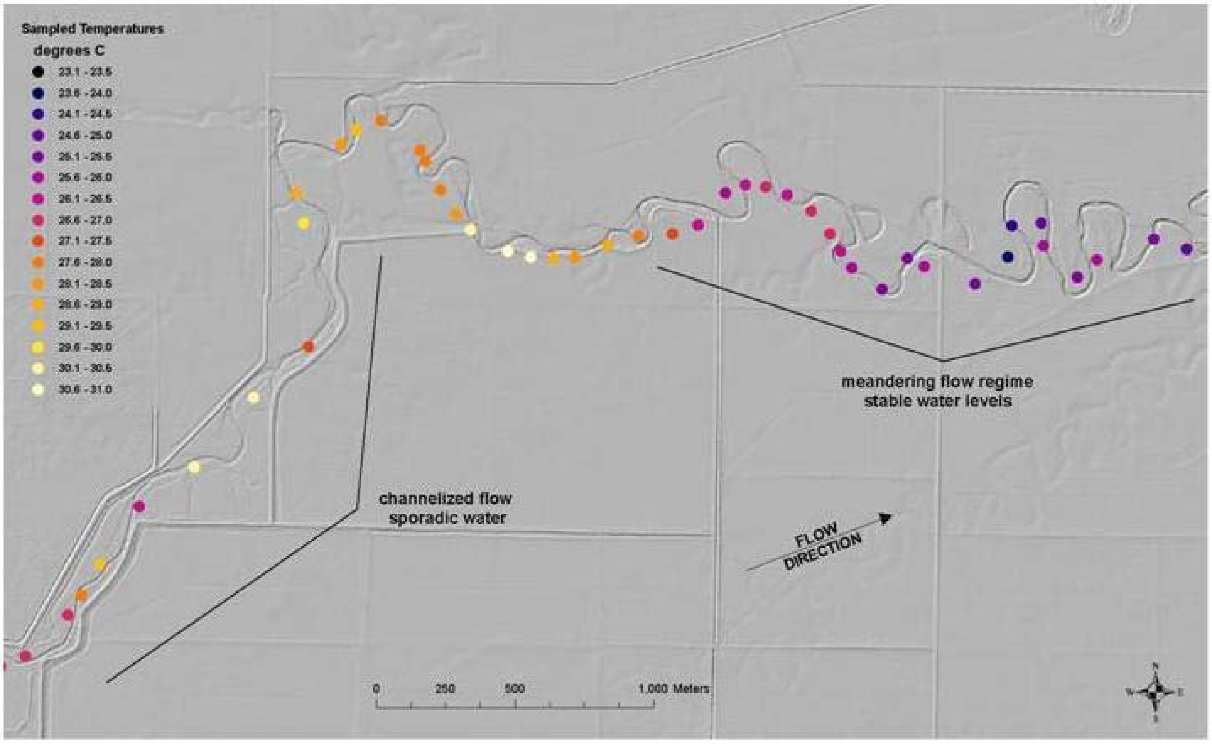


Figure 38. **Hillshade of "bare earth" LiDAR data showing sampled temperatures along the lower section of reach 2.**

Habitat

The habitat assessment produced for this TA concluded that this reach is homogenous, thick with suspended sediment, and contained little defined habitat (Appendix G). Overall, the habitat quality rating for summer and winter juvenile rearing Chinook was fair, and poor for steelhead. The substrate and streambanks are primarily fine sediment (hardpan clay, silt, some sand) and the riparian areas generally only contained hawthorn, willow, dogwood, and grasses. Few large trees are present to provide shade or woody structure.

Vegetation, when present on the face of the bank includes grasses, shrubs, and willows, with occasional small trees, such as cottonwoods. Vegetation along the tops of the banks is predominantly grasses and shrubs with willows and sapling trees; however, some mature deciduous trees are present. The potential for LWD recruitment, an important process for developing complex in stream habitat, is low in this reach. There are very few large trees in and adjacent to the creek that would typically be the source of such material; however, due to the very fine, predominantly wet soils in the riparian and floodplain area, sizeable tracts of large trees should not be expected. It is unlikely that a significant volume of LWD could be imported from upstream due to instream structures at the Davis Dam complex, width of the creek, gradient, and distance over which the debris would have to travel. ODFW staff observed and documented few pieces of large wood in the channel (Appendix G).

Fish Use

Reach 2 supports adult migrating Chinook salmon and steelhead, out-migrating juveniles, and provides juvenile rearing habitat. However, the habitat is of poorer quality than that provided historically. In 2009 and 2010, ODFW documented juvenile spring Chinook utilizing portions of reach 2 for winter rearing (Figure 39) (Appendix H). Tributaries have been blocked for fish access in many locations. Spring Chinook have been documented using the lower 2 to 3 miles of Gekeler Slough for winter rearing (StreamNet 2006) and lower Little Creek for rearing (Appendix H). Current limiting factors in this reach include low flows, restricted passage for adults, and poor water quality (elevated summer temperatures and low dissolved oxygen levels) which are related to, and influenced by, cumulative effects of changes upstream, downstream, and within the reach that include a lack of shading, lack of wetlands, and ponded water for agricultural purposes. Excess fine sediment, substandard streambank and riparian conditions, and a lack of habitat diversity are also significant limiting factors (Huntington 1994; GRMW 1995; Nowak 2004).

The *Draft Conservation and Recovery Plan* (NOAA Fisheries 2008b) also lists fish passage as a limiting factor. The combination of seasonal low flows and water withdrawals may leave so little water in the channel as to present a barrier. Elevated summer water temperatures due to possible thermal stratification in the low backwater velocity areas and the low flow conditions may also increase the potential to limit access of returning adults (NOAA Fisheries 2008b). In addition, of the limiting factors indicated above, poor water quality, low abundance of pool habitat, and lack of protective cover limit winter rearing for juvenile Chinook.

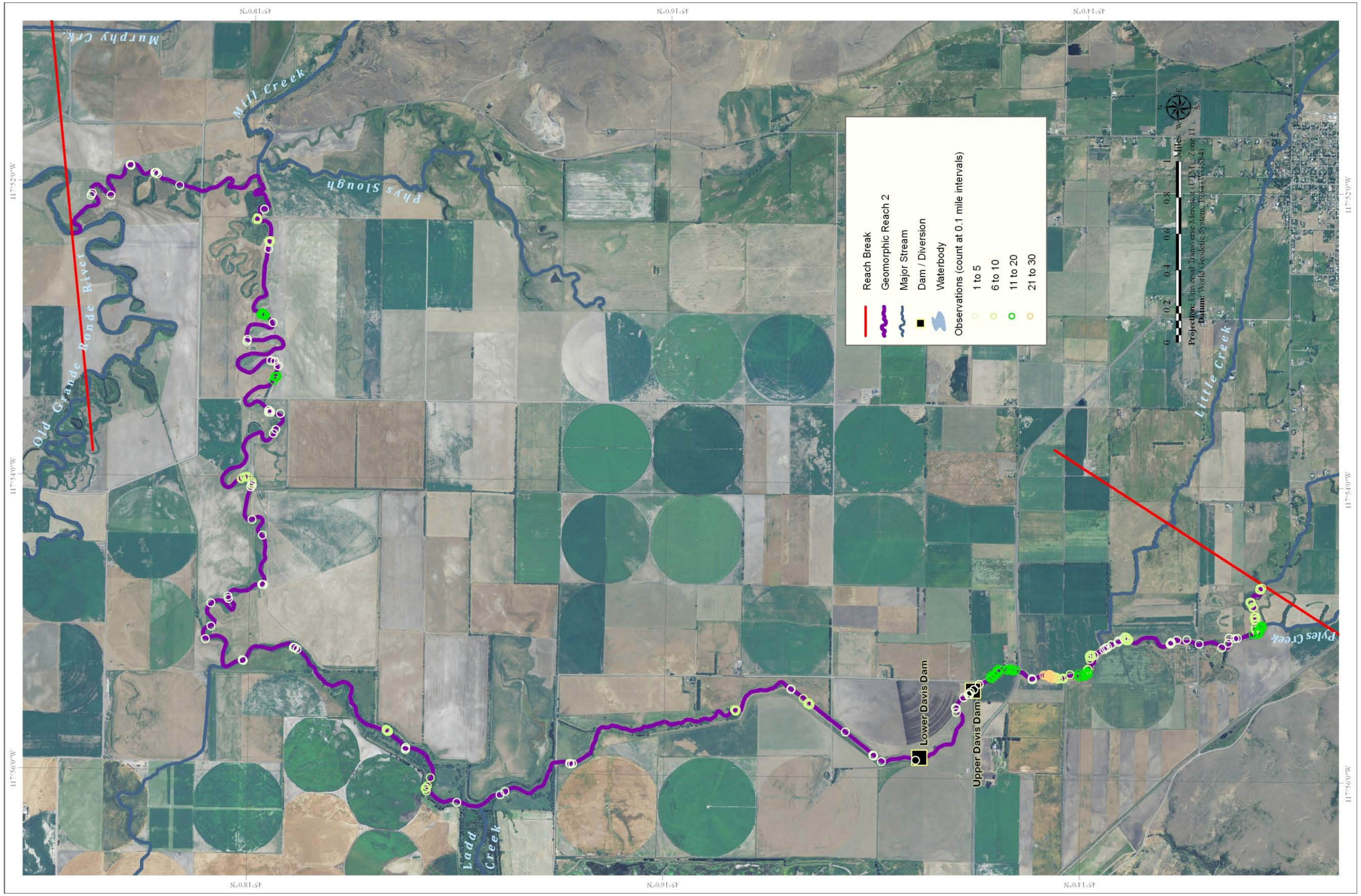


Figure 39. **Overwinter fish tracking study results along reach 2 during the winter of 2009 to 2010.**

Invasive Species and Predators

Invasive species within this reach include reed canary grass, Asian carp, smallmouth bass, largemouth bass, and brown bullhead. Predation may be occurring in reach 2 by native (northern pikeminnow, Great Blue Heron, cormorant) or even introduced species but it is unknown if this is a significant issue or to what extent. A large cormorant and heron rookery is located within reach 2 near RM 31. Numerous PIT tags from hatchery and natural smolts released in Catherine Creek have been found on the ground below the nests (Hoffnagle 2011). Predation is likely exacerbated by a lack of complex refugia including riparian cover, pools, LWD, root mats, and other physical structures in addition to the physiological stresses associated with poor water quantity and quality.

11.3 Reach 3 (RM 37.2 to 40.78)

11.3.1 General Location and Description

Reach 3 spans the length of the Catherine Creek alluvial fan. The reach ends just upstream of the current Catherine Creek and Pyles Creek confluence and extends upstream through the town of Union, Oregon to where Catherine Creek transitions from an alluvial valley to the alluvial fan near Swackhammer Dam (Figure 40). This is the only reach on Catherine Creek that flows directly through an urban area. This reach is naturally unconfined with a broad floodplain that has developed through alluvial processes (Figure 41). This floodplain functions differently than a typical fluvial floodplain such as exists in reaches 1 and 2. Being on an alluvial fan, this reach was historically dynamic with sedimentation processes being a significant driver of channel form and habitat. Bedload transported from upstream would have been deposited in this reach, at times filling the channel, and causing avulsion and development of multiple channels across the fan surface. Flow would have switched between channels regularly in response to deposition and out-of-bank flows at the apex or upstream end of the alluvial fan near RM 40.8. Flooding would have spread out across the sloping fan surface as sheet and distributary flow rather than in a discreet floodplain, and fine-sediment deposition would have been dispersed without building a typical depositional floodplain surface. These described processes were most active in pre-historic times during the Pliestocene (glacial) runoff and subsequent modern valley and stream development, but still remain somewhat active today. The lower third of the reach has a developed floodplain due to a lower gradient with finer sediment than the upstream two-thirds of the reach. Reach 3 supports all life stages of anadromous fish including spawning, rearing, and migration.

No tributaries enter this reach. Four surface irrigation diversion dams are located within reach 3 that collectively alter the transport of sediment and contribute to low instream flow during irrigation season and subsequent water quality and habitat impacts. An undocumented number of pumps and a sewage return are also present. Channelization has also occurred to a significant extent within reach 3.

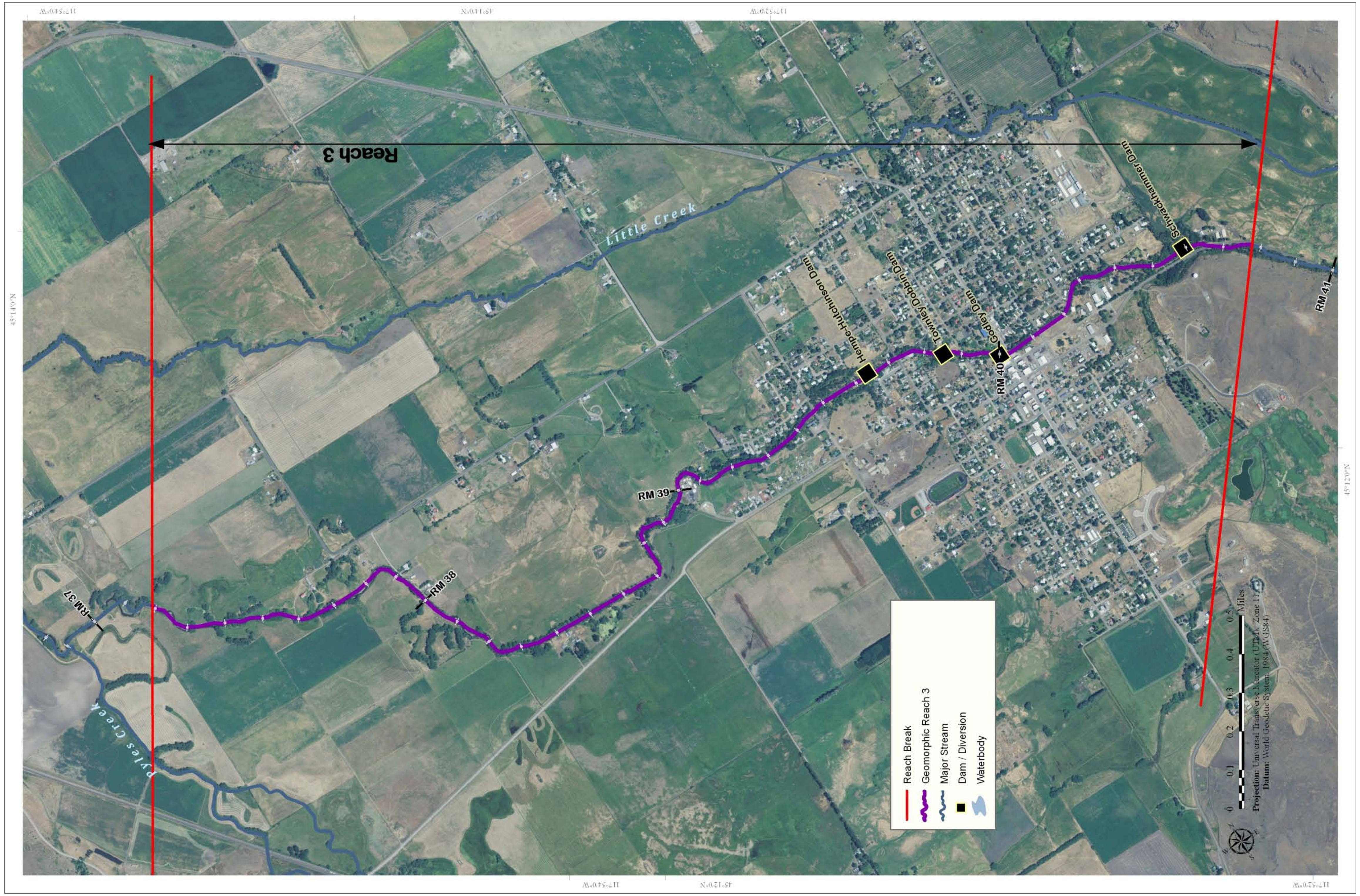


Figure 40. **Reach 3 general reach map.**

11.3.2 Historical Conditions

Historical Physical Conditions

Visible channel swales in the 1937 aerial photographs (Figure 41) and matching depressions in the 2008/2009 LiDAR indicate that at some point prior to settlement, multiple channels conveyed water in a southwest direction as the flow ran onto the apex or top of the alluvial fan structure from upstream (Figure 42). A comparison of the 1937 aerial photographs and the 2009 NAIP imagery shows local areas of both improvement and degradation in vegetation along reach 3. Overall, the vegetation appears to have successively decreased in reach 3 as seen in the 1937, 1964, 1965, and 1971 aerial photographs. A comparison of the 1971 and the 2008 aerial photograph show an overall improvement in the riparian vegetation abundance; however, it is much less substantial and diverse than natural historic conditions.

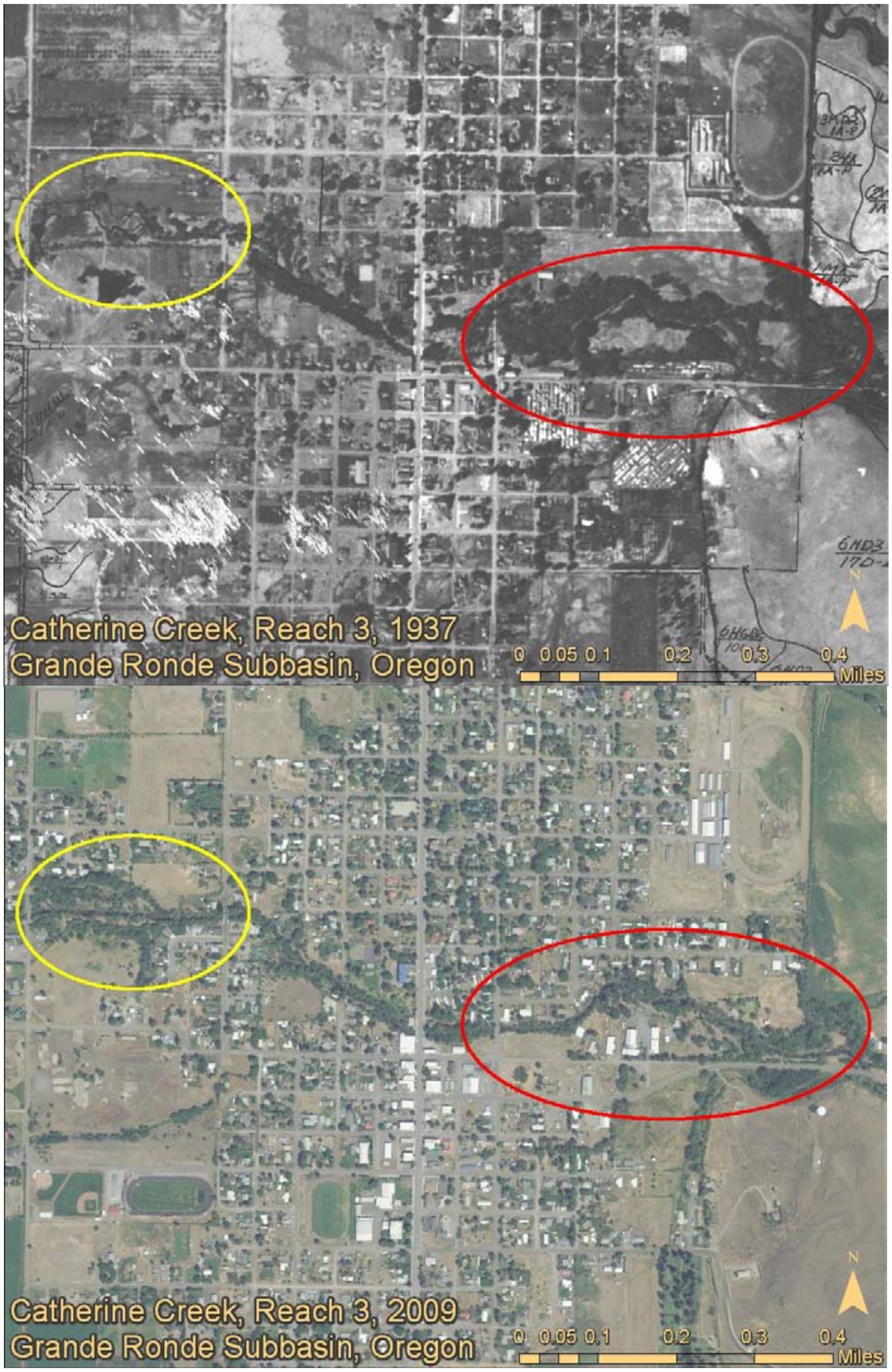


Figure 41. **A comparison of areas along Catherine Creek in Union between 1937 and 2009. The yellow oval indicates an area where vegetation along the bank has increased and the red oval indicates an area where the vegetation has decreased since 1937.**

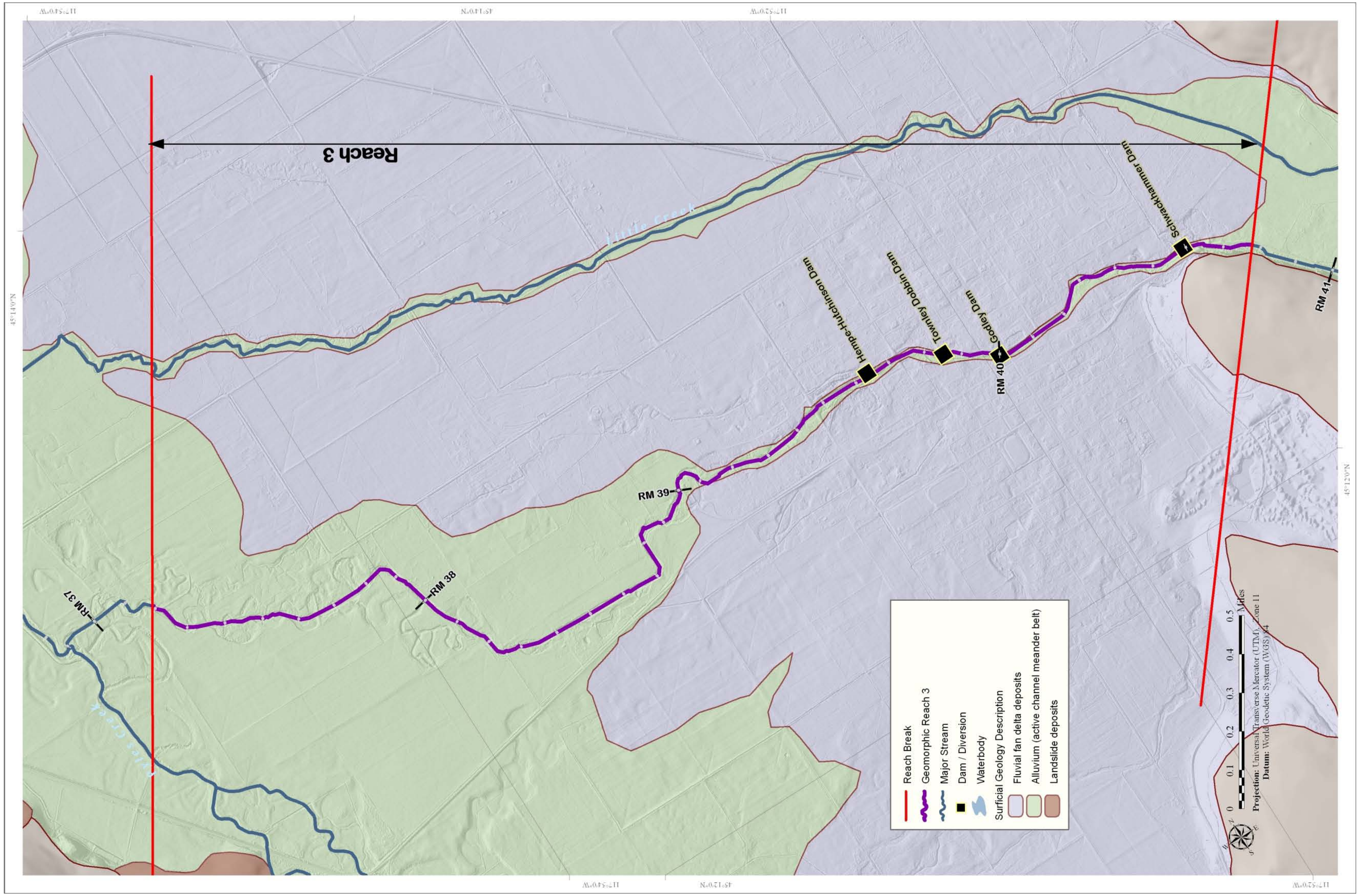


Figure 42. **Surficial geologic deposits and “bare earth” hillshade topography in reach 3. This reach emcompasses the Catherine Creek alluvial fan, Union, Oregon, and four diversion dams.**

Historical Descriptions

Traveler's accounts of historic conditions in the Catherine Creek area collected by Beckham (1995) include descriptions of vegetation describing various grasses in the floodplain, and willows and cottonwoods along the banks that likely apply to this reach. The descriptions citing numerous small creeks and rivulets of Catherine Creek itself also likely apply since this reach encompasses a large remnant alluvial fan structure that would typically exhibit multiple channels.

Historical Fish Presence

Historically, this reach would have likely been good habitat for all freshwater life stages of spring Chinook salmon. LWD, beaver pools, and wetlands would have existed in the lower third of the reach. Available instream gravels combined with hyporheic flows from the alluvial fan structure and materials would have contributed to good quality spawning and egg incubation conditions for salmonids. This would have resulted in a good quality spawning reach with good juvenile rearing habitat in the downstream portion throughout the year.

11.3.3 Present Conditions

Modifications

The active channel, banks, and adjacent floodplain areas within reach 3 on Catherine Creek have experienced a number of significant anthropogenic manipulations. Manipulations generally include road and bridge construction, bank protection measures, alteration to floodplain and bank vegetation, surface water diversion dams, and channelization through the construction of levees and the "raising and revetting" of banks as noted in USACE documents. In addition, development in Union has covered the floodplain with roads, buildings, and parking lots. Along the banks, protection measures including rock riprap, concrete walls, and constructed levees are also present. Five bridges occur within reach 3, mostly within the town of Union. Outside of Union, floodplain impacts include conversion of remnant channels and wetlands to agriculture with associated levees and channelization. Approximately 1,900 feet of levee were noted within reach 3, generally occurring in the lower portions of the reach. Bank protection measures were also noted including rock and concrete over a length of approximately 6,335-feet. All of the above-mentioned anthropogenic features act to confine the channel and limit lateral migration and avulsion throughout the reach, but particularly in Union.

Reach 3 contains four diversion dams. Swackhammer diversion located at RM 40.6 was reconstructed in 1995 for improved fish passage and further modified in 2005. The water rights associated with it are approximately 30.5 cfs, but the ditches have a limited capacity of less than 24 cfs (Hattan 2011). The Godley diversion located at RM 40 was originally constructed in 1950 with modifications made in 1990 for improved fish passage. Previous to the 1950s, and as far back as the 1870s, the diversion may have been a push-up dam. In the fall of 2011, GRMW added a step-pool fishway. Currently, there is a total water right of just over 17 cfs associated with the Godley diversion. The Townley-Dobbin diversion located at RM 39.9 was completely reconstructed in 2010 to include a step-pool fishway and has a water right of approximately 4.5 cfs. The Hempe-Hutchinson Diversion located at RM 39.6 was partially reconstructed in 1994 and retained a previously built fishway. It has a water right of approximately 31 cfs but may only have the capacity to divert about 15 cfs (Hattan 2011). In addition to the diversion structures, a wastewater treatment plant exists along Catherine Creek for the town of Union. The plant discharges effluent into Catherine Creek at approximately RM 39.0.

Levees

The levees in reach 3 are found in small discontinuous sections in the lower third of the reach. Within reach 3, levees are typically not overtopped at flows less than 50-year discharge. More than 70 percent of the levees do not experience overtopping at flows less than the 500-year discharge, further indicating an underfit stream due to the reduction of flow volume that carved the channel. A comparison of reach 3 levee elevations and water surface elevations is shown in Figure 43.

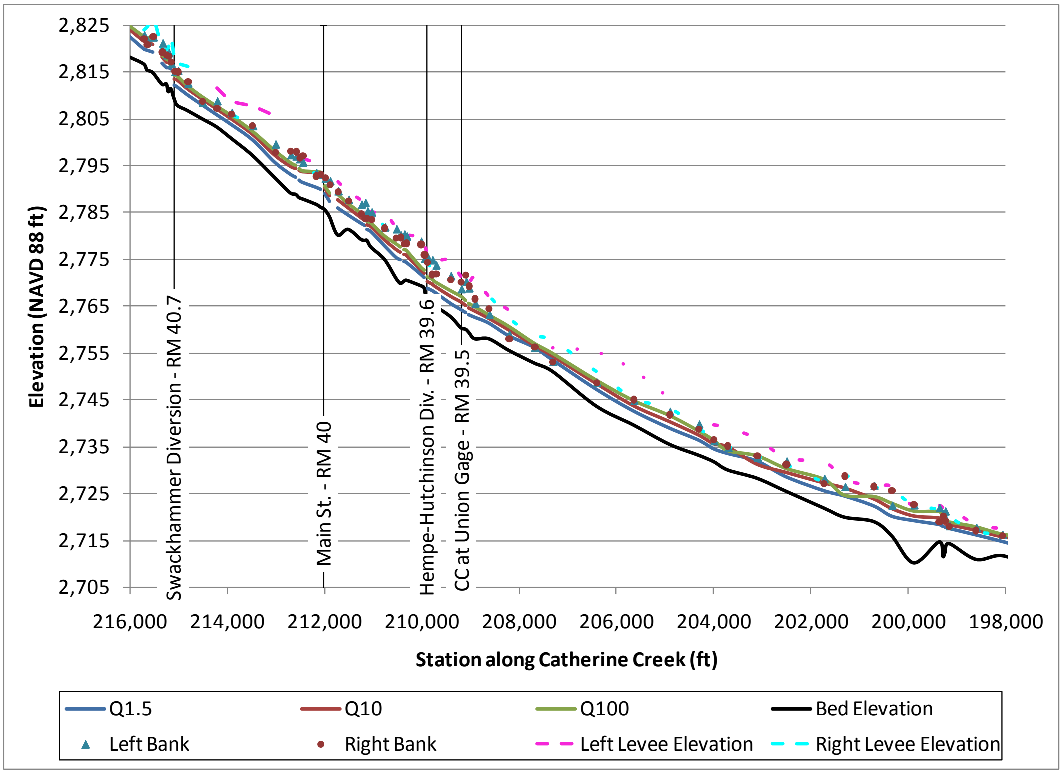


Figure 43. **Reach 3 water surface profiles and levee elevations (Appendix D).**

Hydraulics

The downstream end of reach 3 is located at a hydraulic transition zone at the base of the Catherine Creek alluvial fan. The confinement of the valley within reaches 3 increases from downstream to upstream. Average bed slope within this reach is 0.59 percent. Channel capacity in this reach is high compared to downstream reaches 1 and 2 and upstream reach 4. Over 60 percent of the reach required a flow of 100-year recurrence interval or greater to exceed the channel banks (Appendix D). Reach-averaged channel velocities are also much higher within reach 3 than downstream and range from 4.6 ft/s for the 1.5-year flood to 6.6 ft/s for the 100-year flood. Because the flow is contained in the channel at greater discharges, the local instream velocities are increasing with greater discharges. Shear stresses in the reach, which correlate with stream power and erosive processes, range from about 1 lb/ft^2 for a 1.5-year discharge to 1.75 lb/ft^2 for a 100-year discharge, indicating some potential to mobilize gravels at higher discharges. Hydraulic modeling indicates overtopping of less than 30 percent of the leveed reach for flows less than a 500-year discharge.

Reach 3 is in the upstream section of Grande Ronde Valley. The average slope in this reach, 0.59 percent, is steeper than in reach 1 or reach 2. However, variation in the slope throughout the reach is visible (Figure 44). Several of the bridges, such as Main Street Bridge at RM 40 exert hydraulic control on the larger flood flows (Appendix D). Within reach 3 of Catherine Creek, the greatest known impacts to river hydraulics results from channelization, the presence of low-head diversion structures, and bridges. However, the effects of the structures on floodplain access are minimal since the floodplain extent is much narrower when compared with downstream reaches.

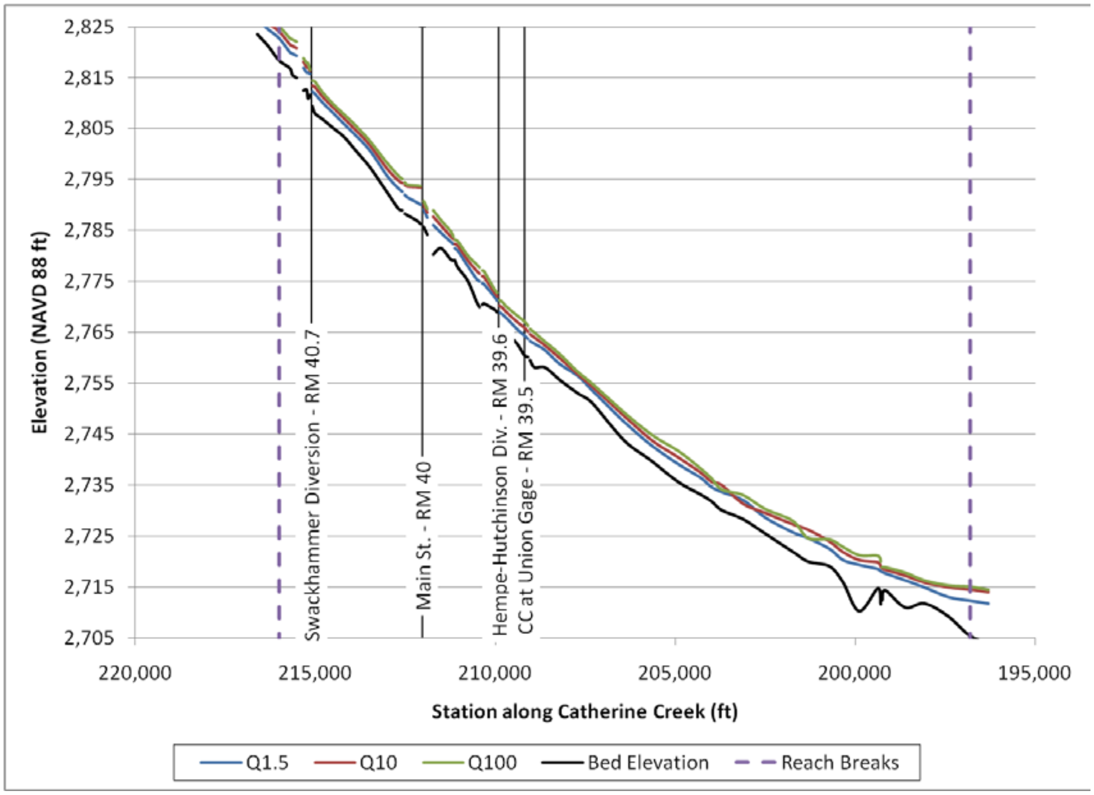


Figure 44. **Computed water surface elevation for reach 3 of Catherine Creek (Appendix D).**

Within reach 3, bankfull channel capacity at most cross sections is not reached until flows become equal to or exceed the 100-year discharge. Bankfull channel capacity is reached in less than 30 percent of the reach for flows up to the 10-year discharge, and less than 40 percent for flows up to the 50-year discharge. A large portion of this reach is highly confined between artificial levees and natural high banks. In addition, the channel banks are coincident with the tops of levees in many of these cross sections, resulting in similarities between the channel and levee capacity (Appendix D).

Geomorphic Properties

Reach 3 represents a substantial transition zone from the steeper, more confined, higher energy channel upstream, to the gentle, open, and low energy channels of the Grande Ronde Valley. Sediments are deposited as the channel energy decreases through this reach. Aerial photographs from 1937 show numerous channels scars and indicate that the confluence with Pyles Creek may have moved by several miles due to channel evulsions or reoccupation of older channel paths associated with alluvial fan building process. Comparison of historic aerial photographs shows a decrease in the density of riparian vegetation when comparing the 1937, 1956, and 1971 aerial photographs; however, local sections of improvement can be detected when comparing the 1971 and 2008 aerial photographs. Overall, there is a decrease in abundance from natural riparian vegetation conditions, with the most significant alterations occurring in the 1800s as the area was being settled.

Channelization has occurred in the reach and has resulted in a single homogenous creek, possible channel incision, few pools, and localized bank failures. The sinuosity has been reduced locally and the slope proportionally increased with a correlated increase in stream energy. The channelization and resulting increase in stream energy could increase the potential for localized channel incision. However, the building up of the banks and the change in processes including reduction in flow volume and sediment from those levels that were active during the time that the alluvial fan was actively being built has resulted in an underfit stream. This current condition has further exacerbated poorly connected floodplains and associated processes. The average stream gradient is 0.59 percent, the sinuosity is 1.14, and the width-to-depth ratio is approximately 20:1.

Conditions including sinuosity, width-to-depth ratios, and valley and stream gradient have likely changed because of the manipulations that have been applied to the channel, banks, and floodplain of reach 3. Shortening of the channel by the disconnection of meanders increases the stream gradient by decreasing the length of active stream over the same valley length. Shortening of the channel also decreases sinuosity for the same reason (Appendix C). Changes in the width and depth result from the channel adjusting to the increases in stream power as a consequence from the shortening of the channel or reducing access to the floodplain or the floodplain width. In reach 3, artificial changes to width and depth for flood control and water conveyance may have taken place. Although a considerable amount of development along the banks of Catherine Creek and within the floodplain had occurred by the earliest set of aerial photographs (1937) within reach 3, significant changes to the channel planform can be observed in the 1937 aerial photographs which do not change beyond the 1964 aerial photographs. Approximately 3,637 linear feet of channel was observed to be partially disconnected in the 1937 aerial photographs (Figure 45).

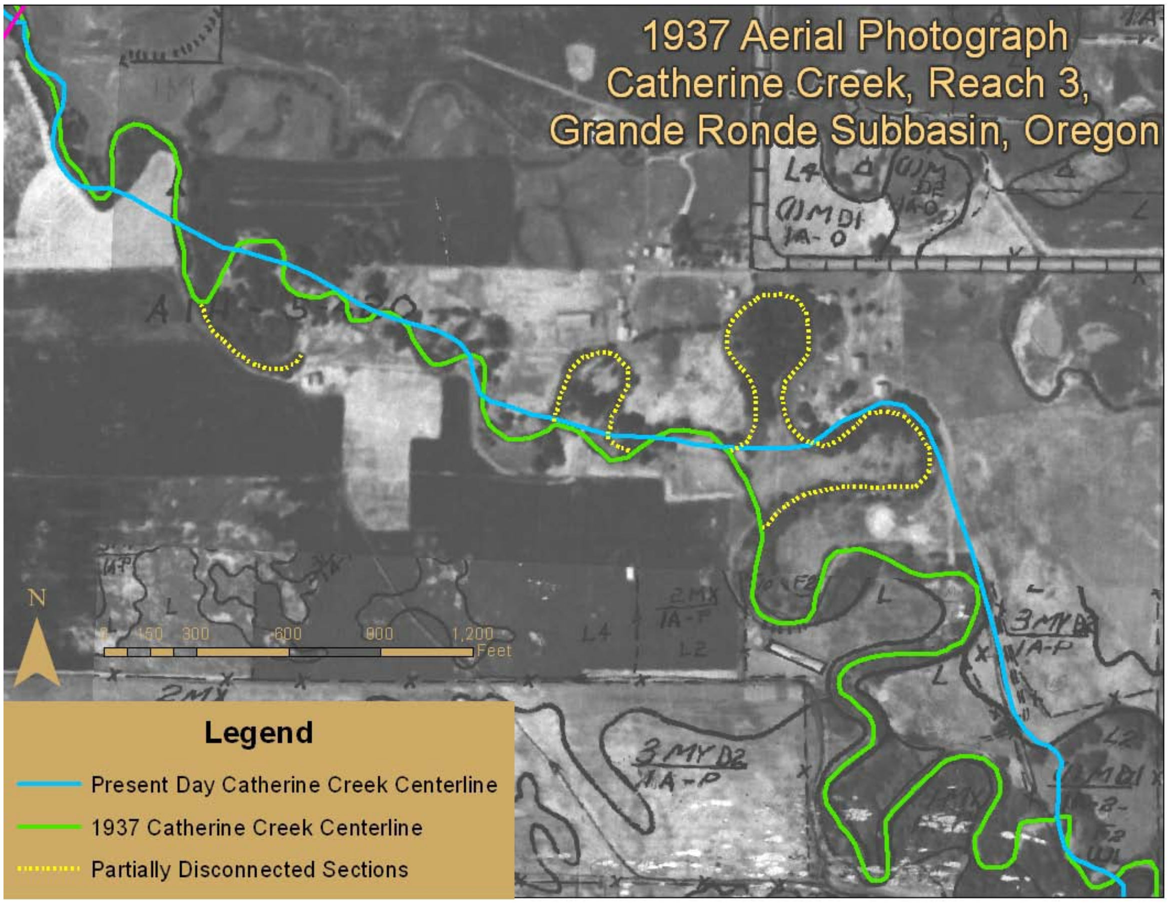


Figure 45. **A 1937 aerial image of reach 3 with the 1937 and present day channel centerlines.**

Pebble counts were conducted in reach 3 in order to develop grain size distribution curves for substrate in the active channel bottom including thalweg and bars. The dominant substrate is cobble and gravel; however, sands and fine material were observed. The D_{50}, (meaning that 50 percent of the material is smaller than that size) measurements for reach 3 range from 42.6 mm to 50.5 mm, with the average D_{50} for reach 3 being 46.9 mm (Appendix C).

Channelization by the construction of levees, as well the reported “raising and revetting” of banks in 1949 by the USACE have resulted in conditions that require a flow of greater than the 500-year recurrence interval to overtop the banks at 70 percent of cross sections within the reach. In addition to the human manipulations, the natural processes responsible for the construction of the fan have changed. Lower flow volumes and sediment load than those that were active when the fan was actively building exist in the system in the present day. The combination of the two factors, anthropogenic manipulation and a change to the fluvial and geomorphic processes, result in an underfit stream with reduced sediment load and flow for the channel that it resides in (Appendix C). Although local sections of vertical banks and some undercutting were observed throughout the reach, overall rates of lateral and vertical migration appear to be lower than would be expected of a channel that is in dynamic equilibrium due to changes in system dynamics and the noted anthropogenic features.

Ice commonly forms on the creek in reach 3 during periods of low flow and extreme low temperatures. Anchor ice (ice that forms on the bed of the stream and freezes upward into the water column) can form at shallow locations such as riffles within reach 3 and in upstream reaches but more typically ice forms on the surface. Ice can be found throughout most of this reach during winter months with especially long periods of below freezing temperatures. When the ice breaks during rising flows, flooding and riparian damage can result as a result of ice flows and jams. In January of 2011, over a month of below freezing temperatures developed a thick layer of ice that extended downstream through the town of Union. As the ice broke up large pieces were carried downstream backing up behind some bridges and culverts causing localized scour and flooding that otherwise would have been unlikely at such discharges.

Floodplain

The floodplain within reach 3 consists of two primary areas, the community of Union spanning the upper reach, and the lower agricultural reach. Significant floodplain alterations have occurred compared to conditions prior to European settlement. Riparian communities of cottonwood and willow were replaced with urban infrastructure and agricultural fields. The lower portions of the reach are mainly agriculture, including livestock grazing, while the upper portions are mainly urban (Figure 46). The riparian areas typically reflect the land use and include grazed grasses, planted landscapes, roads, and buildings.

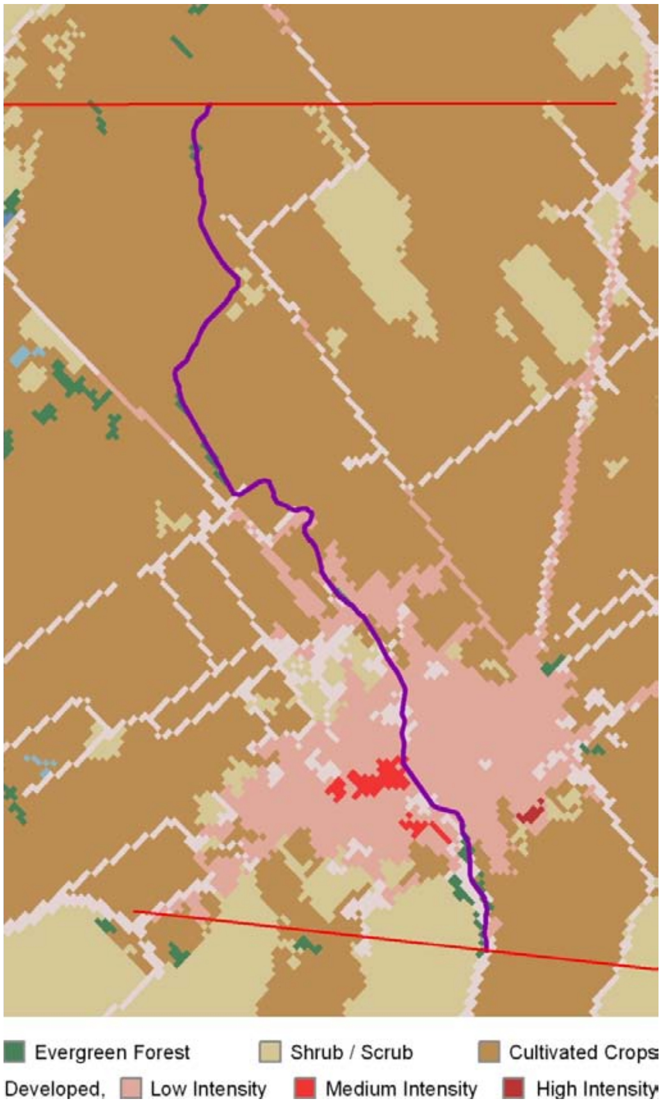


Figure 46. Current land use (land cover types) in reach 3 (30-meter NLCD).

Stream and floodplain interactions are extremely limited within reach 3 (Figure 47). Depths of potential flooding for the 100-year discharge indicates that there are very few areas within this reach that are inundated outside the channel during the 100-year event, which is very different than reach 2 immediately downstream where flooding is widespread. This may further validate the occurrence of channelization and incision in reach 3 in addition to illustrating the geomorphic differences between the two reaches (historic channel processes, slope, substrate size, and geology).

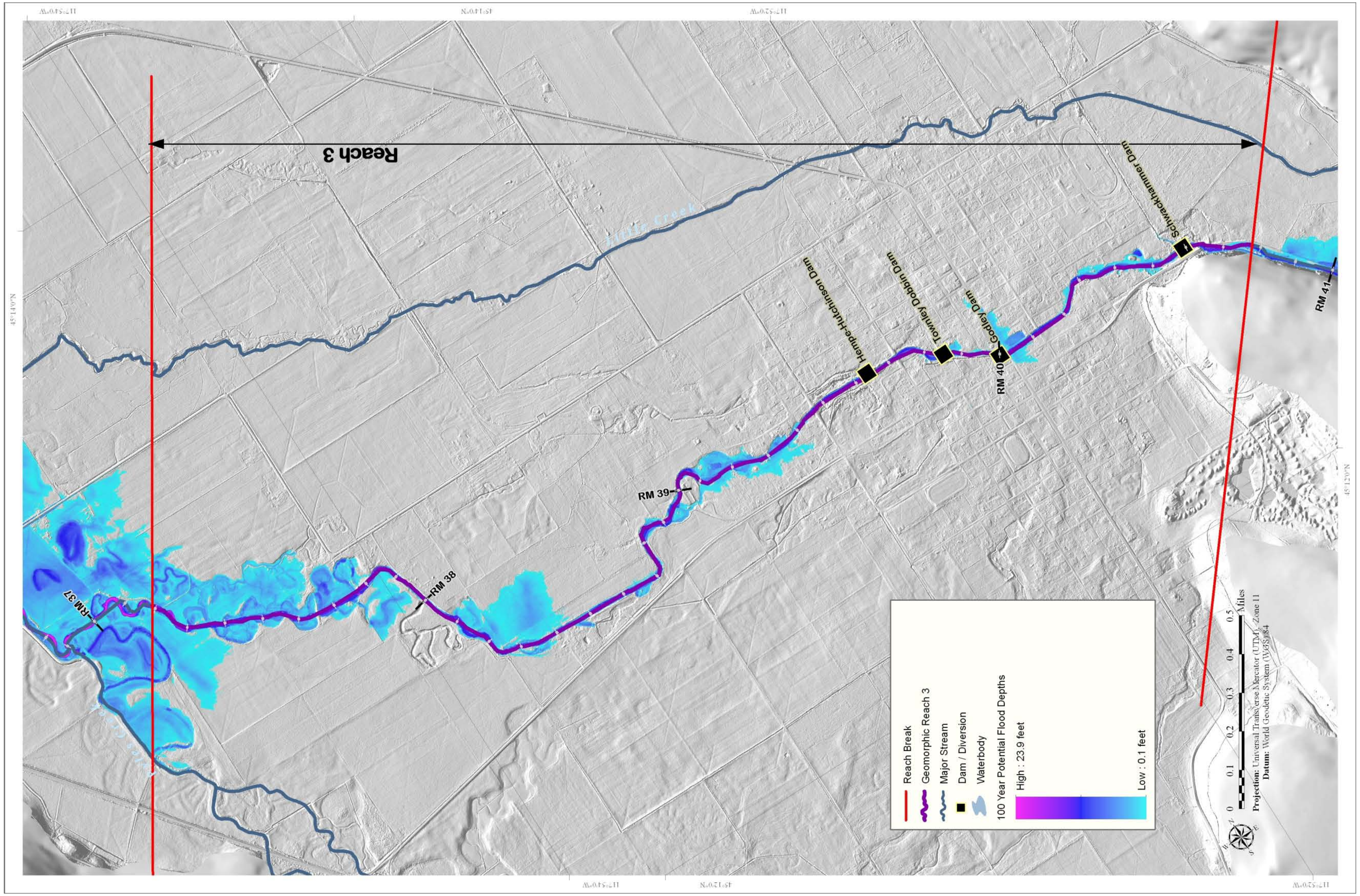


Figure 47. The depths of potential flooding within the bounds of the modeled cross sections for the 100-year discharge in reach 3.

Sediment

Reach 3 is developed on an alluvial fan deposit that extends upstream and downstream from Union, Oregon. It was formed in the Pleistocene and early Holocene (between 2.5 million and 12,000 years ago) and is a gently sloping natural fluvial fan delta that developed through alluvial processes (Ferns et al. 2010). This area was once dynamic with multiple high-flow channels. Sediment was dispersed by sheet and distributary flow on the slope of the fan without building a typical depositional floodplain because overbank flows on this feature tend to flow away from the channel. The lower third of the reach would have had a more developed floodplain due to lower gradient and finer grained sediment more typical of a fluvial floodplain. This fan structure and the processes that formed it are remnants from post-Pliestocene water and sediment discharge during wetter climates. Present day Catherine Creek is “underfit” in that it is superimposed on the old fan surface and channels without having the sediment load, competency, or capacity to continue the physical processes that built the fan. The condition is likely exacerbated by the anthropogenic manipulations that are present in the reach. The upper third to two-thirds is developed within the most recent channel from the alluvial fan processes, without enough flow volume and competency to significantly interact with the floodplains. The lower third has developed into an unconfined alluvial channel with fine-grained banks that can be eroded, allowing the channel to develop a meandering planform and store sediment.

Material directly adjacent to the stream is alluvium and described as “channels locally choked with overbank silt” (Ferns et al. 2010). Material in the floodplain is fluvial fan delta deposits (Ferns et al. 2010). Overall channel bed materials were observed to be predominantly cobbles and gravels with boulders with a trend toward fining in the downstream direction. Bank materials observed in the upper section of the reach were inter-bedded sands, gravel and cobbles, indurated fine sand and oxidized iron with moderately cemented gravel and cobble that graded into fine sand and silt overlying gravel in the downstream end of the reach. Natural lateral and vertical control in the upper third to two-thirds of reach 3 appears to come from a combination of the substrate size and cohesive and/or cemented condition observed. In addition, there is an anthropogenic component to the lateral and vertical control provided by multiple grade control structures consisting of channel spanning concrete diversion dams, along with bank protection, concrete walls along the edge of the channel, and channel straightening with remnant oxbows. Banks range from gently sloping with grass, shrubs, and some mature trees, to banks that are vertical and with some that are artificially constructed. Some instances of bank trampling were observed, particularly in the downstream end of the reach (Appendix C).

Sediment transport calculations using pebble counts and HEC-RAS results show that the average channel shear stress in the reach ranges from 1 lb/ft^2 for the 1.5-year discharge to 1.75

lb/ft^2 for the 100-year discharge, indicating that the bed materials can be mobilized at higher flows (Appendix D). However, there are a wide range of channel slopes, bankfull areas, substrate sizes, and wetted perimeters that are not well indicated by the average values. Overall, the upstream half of reach 3 is a sediment transport section, as indicated by a steeper slope and an in-channel substrate that is slightly coarser. The lower half is a sediment storage section that is evident by the observed increase in developed point bars and finer sediment (Appendix C).

Water Flow

The ODEQ has placed Catherine Creek from RM 42.2 in reach 4 (Union Dam/Catherine Creek Adult Collection Facility [CCACF]) downstream through reach 3 on the Section 303(d) list due to flow modification (ODEQ 2000). Water flow in the summer and late fall is naturally limited in Catherine Creek and diversions located within the reach have the ability to take a substantial amount of water from the creek, exacerbating the problem. A total allotment of approximately 83 cfs exists for the four diversions within Union, but the diversion capacity is likely limited to approximately 61 cfs (Kuchenbecker 2011). A limited amount of flow remains within reach 3 downstream of Union to supply the 37 cfs of senior water rights for Lower Davis Dam downstream at RM 34.4. Reach 3 contains perennial water flow, but it is drastically reduced from historic conditions.

As a result of low summer and early fall flows and four channel-spanning diversion dams within this reach, fish passage is listed as a limiting factor for salmonids. However, three of the four diversions have been updated with improved fish passage facilities in recent years and the fourth is currently being brought to modern fish passage specifications (GRMW 2011).

Upstream from Union, hydrologic alterations are, in part, due to irrigation diversions, roads and associated infrastructure as well as forestry practices, including harvest and forest fuel management. However, while there may be numerous sources of changes to the average hydrograph, the overall changes are likely relatively small with the exception of diversion of substantial volumes of water during the summer low flow periods. Mid-July through September water withdrawals typically reduce instream flows by as much as 90 to 95 percent in this reach (NOAA Fisheries 2008a).

This reach has the most direct hydrologic effects due to urbanization. Hardened surfaces such as roofs, streets, and parking lots reduce infiltration and increase the local discharge during runoff events. Water withdrawals for domestic uses decrease the available water, especially during the summer months when water quantity is already a limiting factor. Local agriculture and a complex system of diversions, drainage ditches, and canals also contribute to altering the local annual hydrograph. The mean daily flow exceedance hydrograph (Figure 48) was developed using the Catherine Creek at Union, Oregon stream gage that has been in operation since 1996. This gage has a limited history so an annual hydrograph was extrapolated using the OWRD-operated Catherine Creek near Union, Oregon stream gage (1911 to present), to better indicate a long-term average. However, the stream gage "at" Union better represents the low flows experienced during the irrigation season.

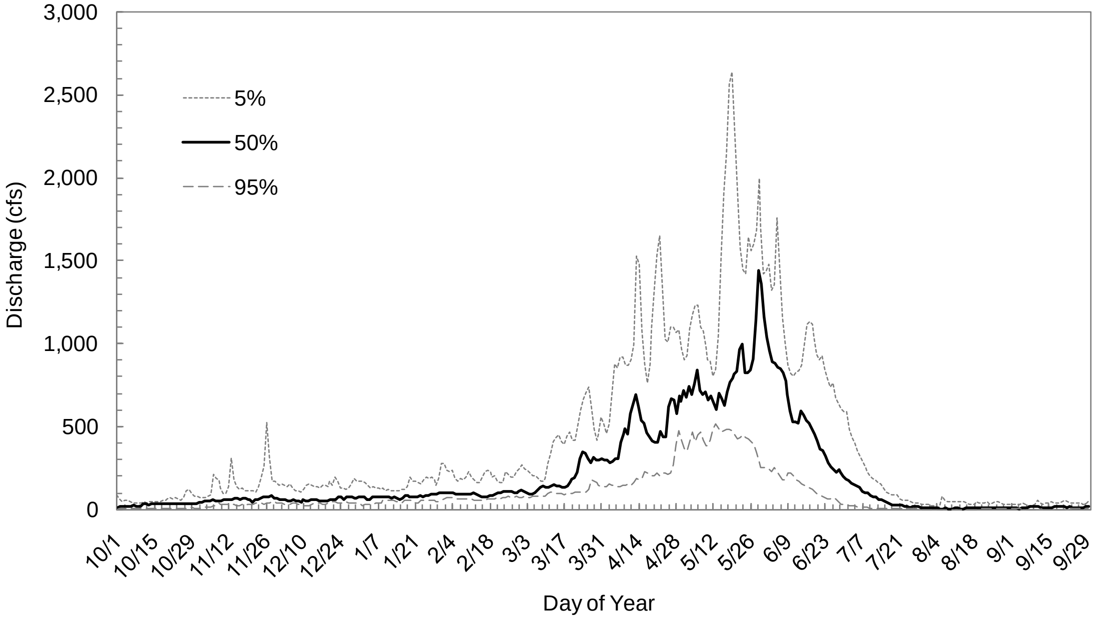


Figure 48. Mean daily flow percent exceedance values for Catherine Creek at Union, Oregon stream gage. This stream gage lies withing reach 3. The 50 percent values indicate the average annual hydrograph.

Water Quality

As a result of land use practices, a number of water quality parameters in Catherine Creek exceed standards established by the ODEQ. Due to water quality standards exceedances, Catherine Creek is included on Oregon's 1998 Section 303(d) list (ODEQ 2000). Temperatures exceed standards throughout the entire stream; however, most of the water quality standard violations occur on the lower reaches of Catherine Creek and extend into reach 3 to Union Dam (also known as CCACF) at RM 42.2. Water quality parameters exceeded in reach 3 include temperature, aquatic weeds (algae), dissolved oxygen, flow modification, habitat modification, nutrients, and pH. A number of factors limiting water quality in Catherine Creek have been identified and include substandard riparian conditions, low summer flows, high summer temperatures, limited dilution flows, excess sediment, and streambank erosion (GRMWP 1994; Nowak 2004; NOAA Fisheries 2008a).

Additionally, the town of Union operates a wastewater treatment plant that discharges effluent in reach 3 at RM 39.0. At the time TMDLs were developed for the Upper Grande Ronde subbasin, the Union Wastewater Treatment Plant (WWTP) was identified by ODEQ as a National Pollutant Discharge Elimination System (NPDES) permitted facility that discharged surface water during critical summertime temperature periods (ODEQ 2000). System potential temperatures and waste load allocations were derived by ODEQ for all point sources. At the time the loading capacities were determined, no data existed for August discharge temperatures at the Union WWTP. A new plant was built in 2001, when the town of Union removed its wastewater discharge during low flows (Ramondo 2011). The current discharge schedule is from October 1 to approximately June 1 to 15. The following specifications must be met in order for the plant to discharge effluent:

- Catherine Creek flows must be at least 17 cfs
- Stream temperatures cannot exceed 57.2^{0}F

These specifications are not always met during the allowable timeframe. For example, in 2010 the creek temperatures and flows did not meet criteria required for the plant to discharge into the creek until November (Ramondo 2011). Union WWTP monitors daily stream temperature about 0.5 miles above the plant.

Continuous and FLIR temperatures collected in August of 1999 correlated well upstream of Davis Dam (reaches 3 through 7) (ODEQ 2000). These data indicated that in the section of Catherine Creek from RM 41.6 (reach 4) to Davis Dam at RM 33.8 (reach 2), which encompasses reach 3, stream temperatures were relatively constant, fluctuating between 67.3 and 70.9^{0}F (Figure 49) (Watershed Sciences 2000). The average median temperature in reach 3 was 69.6^{0}F.

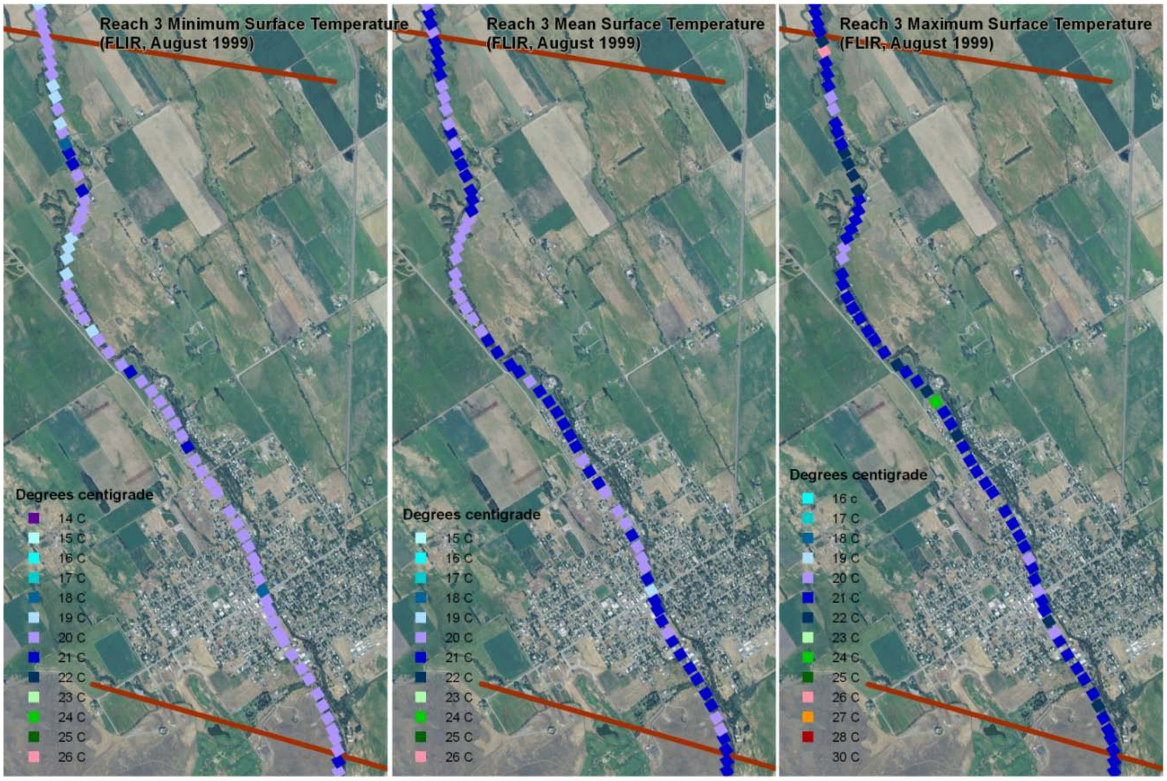


Figure 49. Minimum, mean, and maximum stream temperature results along reach 3 from August 1999 FLIR data.

Temperature data collected in the August 2010 thermal infrared (TIR) surveys showed a gradual increase from the mouth of the North and South Forks (RM 53.8) downstream to RM 39.4 (reach 3) from 59.4°F to 69.4°F (Watershed Sciences 2010; McCullough et al. 2011). At RM 38.8 in reach 3, bulk water temperatures decreased 2.7°F from 69.4°F to 66.7°F over 1.88 miles. It was unclear what causes this decrease in temperatures as the stream flows through Union, Oregon. No significant inflows or outflows, no changes in stream gradient, morphology or vegetation type were identified along this reach. The diversion at RM 39.9 did not appear to have a quantifiable effect on temperatures in Catherine Creek.

Habitat

Observed and documented occurrences of large wood within the active channel were low in reach 3 (Appendix G). Although some large wood (cottonwood and alder) were likely supplied to the stream from the banks of the alluvial fan by beaver activity, blow down or dying and toppling, the main source of large wood was likely from upland forests upstream. Large wood that was incorporated upstream would have been transported into reach 3 during floods, such as rain on snow or intense local rainstorms, but likely did not transport much farther than the toe of the alluvial fan near the bottom of the reach as the stream transitions to a very low-gradient, low energy environment in downstream reaches. The lack of large wood is likely exacerbated by past channel-clearing efforts.

The ODFW habitat report indicates that LWD and the number and complexity of pools is limited in reach 3 (Appendix G). Below the town of Union there was only 60 ft^3 of LWD per 328 feet of channel and 28.2 ft^3 per 328 feet of channel above Union for a total of 208 pieces of LWD (Appendix G). There was only one key piece (>= 39.4 feet long by 2 feet diameter) in all of reach 3 (Appendix G). The lack of LWD may be a result of the historical clearing of LWD to improve floodway efficiency, the simplified hydraulic and increased transport characteristics of the reach, and the simplified riparian area with a limited supply of LWD to contribute to the creek.

The scarcity of LWD further contributes to the low abundance and complexity of habitat because LWD can be an important contributor to pool formation. Meandering is another process that forms pools that is also absent along much of this reach. A meandering channel causes variations in instream flow patterns and velocities that result in localized scour in the channel bed (pool development) along the outside bend of the meanders and concurrent gravel bar deposition on the inside of the bends. This same process results in maintenance of relatively stable areas of higher bed elevation (riffles) between meander bends. It is this varied bed topography and the differences in the size and type of sediment associated with each area that create instream habitat. The riffle areas and associated pool tail-outs upstream of the riffles provide hyporheic flow and loose, clean gravels that provide spawning and egg incubation habitat. These areas also result in macroinvertebrate habitat that helps provide food resources for fish. The adjacent pools provide hiding, holding, and resting habitat for adults and juveniles. The shallow point bars provide high-water refugia for juveniles and habitat for the macroinvertebrates that provide a significant food source to juveniles and adults. While the upstream two-thirds of reach 3 likely did not meander even in undisturbed conditions, the lower third of reach 3 has been straightened over most of its length resulting in a sinuosity of 1.14. With few meander bends remaining and little LWD, there are few formative processes available to develop and maintain numerous, deep, or complex pools. Based upon an inventory of pools conducted by ODFW (Appendix G), there are 39 pools (1 per mile) below Union in reach 3, 23 of which are greater than or equal to 3.28 feet deep (Appendix G). Above Union there are 14 pools (3.1 per mile) and 3 pools which are greater than or equal to 3.28 feet deep (Appendix G). This upstream section would not have included many deep pools naturally due to the channel type (straight, plane bed).

Substrate below Union is mostly gravel with some cobbles and sand and few boulders and bedrock. Above Union, cobbles are the most common bed material with substantial gravel size materials and some boulders.

Fish Use

Reach 3 supports all freshwater life stages of spring Chinook salmon and steelhead. This is the furthest downstream reach of Catherine Creek that contains a geomorphic setting that provides spawning gravels and supports incubation. ODFW does not regularly perform redd surveys below Union, but documented 3 redds in reach 3 downstream of Union in 2010 (McGowan 2010). Limiting factors listed for salmonids in this reach include low summer flow/fish passage, high summer water temperatures, limited juvenile rearing habitat, low dissolved oxygen, excess fine sediment, livestock grazing, anchor ice, and flooding (Appendix F). A 2011 habitat survey indicates that spawning and incubation habitat is fair, summer rearing is a mix of good and fair, and winter rearing habitat is fair for Chinook salmon (Appendix G). Riffles are prevalent in the middle of the reach and the substrate has few fines and more gravel, but little cobble. This reach lacks suitable pool area, undercut banks, large wood, cobble, and boulders. Steelhead ratings are similar in this reach. It should be noted that EDT model results indicate that this reach has high intrinsic spawning potential (Nowak 2004).

All life stages of spring Chinook salmon use reach 3 although spawning occurs on a limited basis. This reach appears to be heavily used by juvenile spring Chinook for overwintering habitat (Figure 50). During the winter of 2009 through 2010 ODFW fish tracking study, overwintering juveniles were common throughout this reach (Appendix H). Within the reach, the juvenile fish were most typically associated with deeper pools, cobble substrate, and where cover was the most plentiful. In both years of study, preliminary results show a preference for deeper pools with cover habitat that are more common in reach 3 than in reaches 1 and 2 (Appendix H).

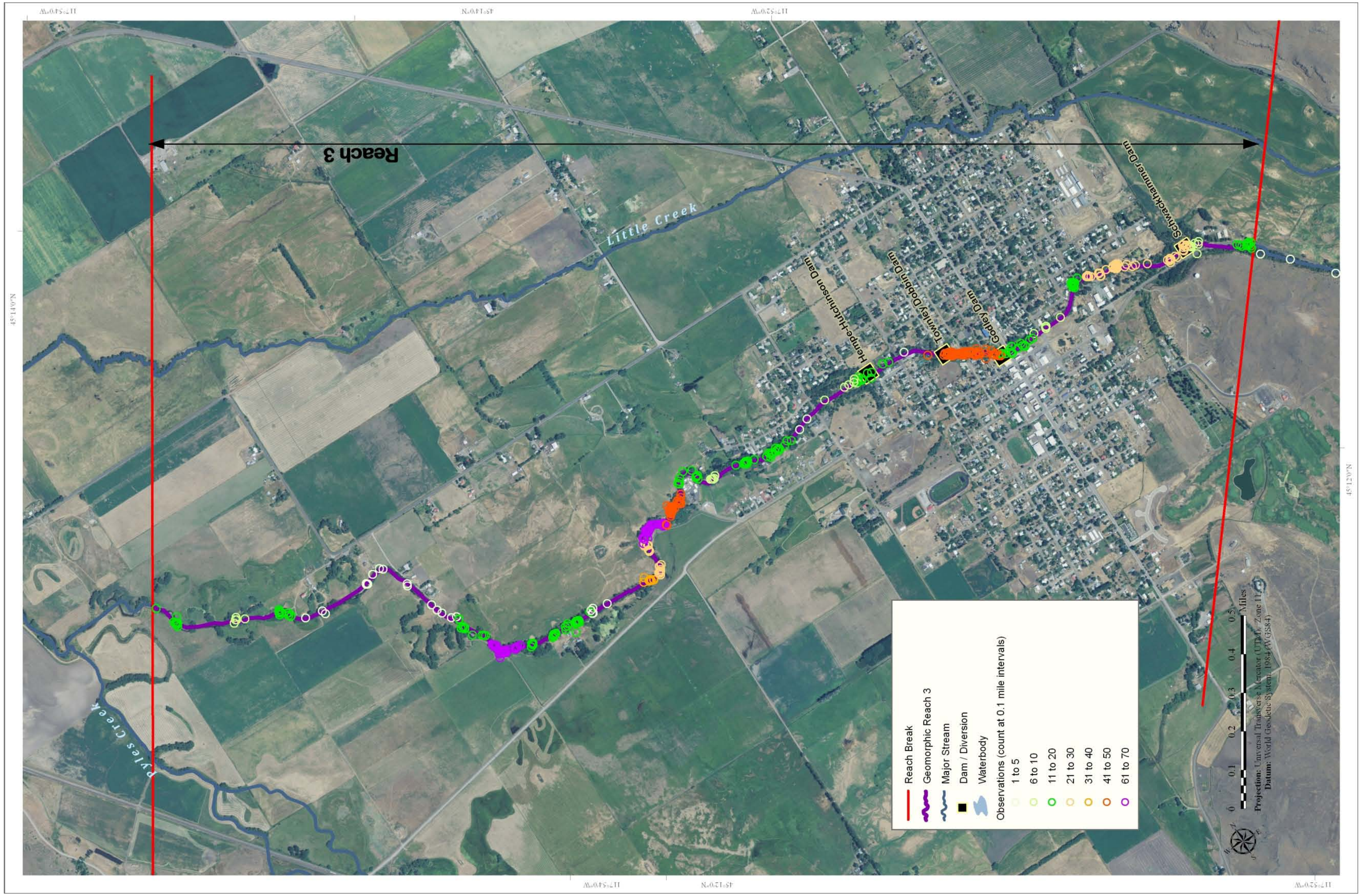


Figure 50. Overwinter fish tracking study results during the winter of 2009 to 2010 within reach 3.

Anthropogenic affects that may contribute to fish passage issues in reach 3 are the channel spanning diversion dams. In addition, the altered riparian and floodplain vegetation in the reach exposes the stream to more solar radiation, potentially increasing temperatures and contributing to fish passage issues. Temperatures may increase to the point of acting as a thermal barrier to both returning adults and in stream rearing juveniles.

Invasive Species and Predators

Reach 3 represents a change in physical conditions from the lower reaches in multiple ways with resulting changes in inhabitants as well. Stream type and water temperature are different from the lower reaches 1 and 2 and may reduce the occurrence or abundance of warm water invasive predators (i.e., Asian carp, smallmouth bass, largemouth bass, and brown bullhead). Predators that are likely present in this reach include northern pikeminnow, herons, king fishers, otters, and mink.

11.4 Reach 4 (RM 40.78 to 45.8)

11.4.1 General Location and Description

Four separate reaches were identified in the upper valley segment along Catherine Creek above RM 40.78. Reach 4 is a 5-mile-long alluvial valley reach that forms the lower end of the upper valley segment. This reach is located within a relatively narrow, unconfined valley with a moderate slope of 0.89 percent bounded by steep hillslopes. Alterations in the form of channelization particularly in the downstream end of the reach, has likely increased the transport capacity, leaving the bed armored in that section. Currently, much of the narrow valley is used for agriculture, primarily livestock, which have also had noticeable effects to the stream. Reach 4 starts just upstream of where Catherine Creek crosses Highway 203 upstream of Union, Oregon (Figure 51). It continues upstream in a relatively narrow but unconfined valley and ends where the valley constricts and has a naturally stronger influence on the morphology of the creek.

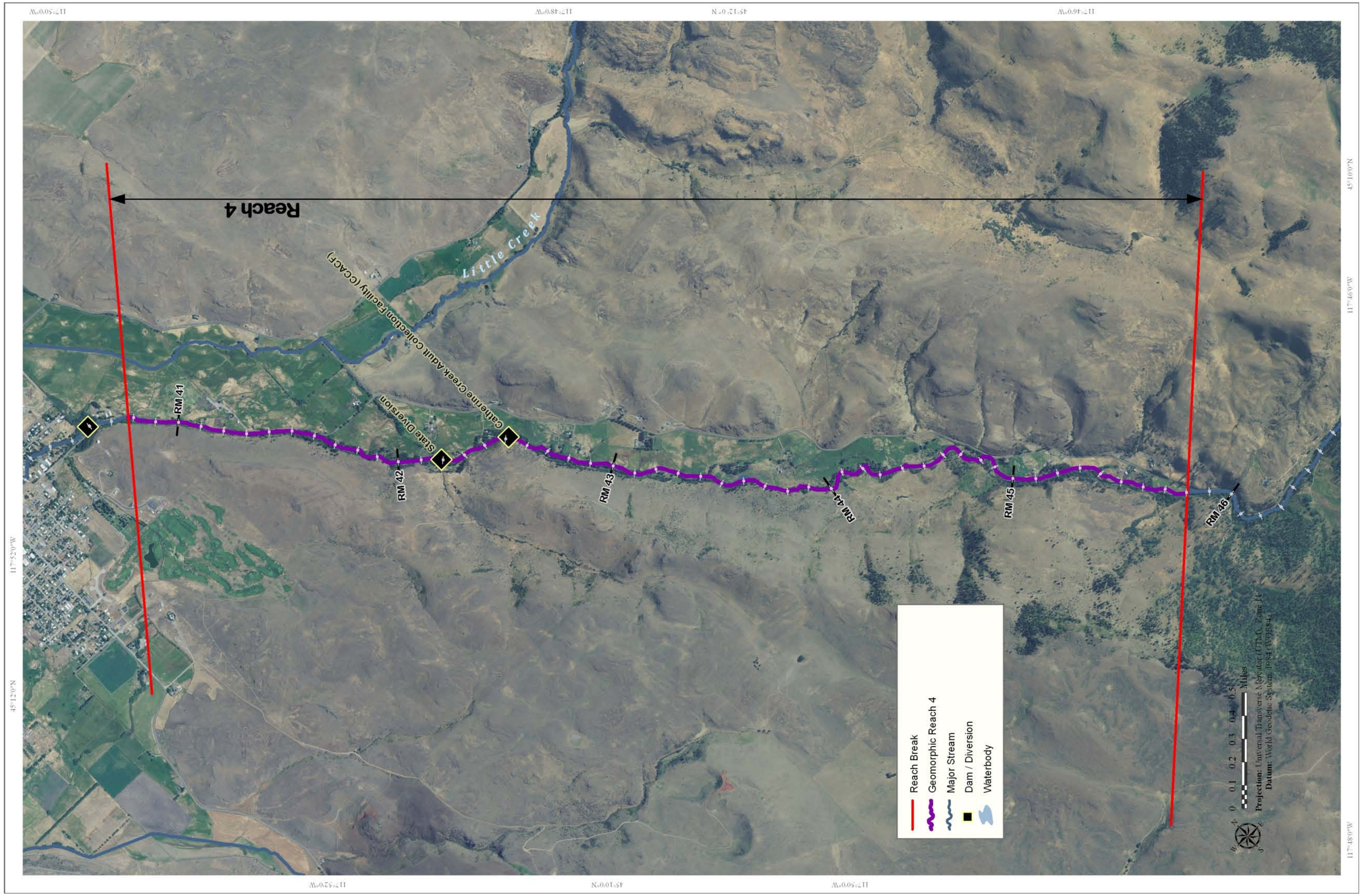


Figure 51. Reach 4 general map.

11.4.2 Historical Conditions

Historical Physical Descriptions and Fish Use

There is little historical data describing the valley and creek above the town of Union. Hypotheses presented about the historical conditions are based upon conceptual models of how typical rivers function without anthropogenic influences and evidence that can be interpreted from the physical characteristics visible in the field and on LiDAR images. The creek was likely slightly more sinuous than it is presently and it may have meandered more actively throughout much of this reach. The low gradient valley and broad floodplain suggest that the creek and floodplain may have been well connected and would have supported a substantial riparian community that would have been largely comprised of multi-age stands of cottonwood, willow, alder, and associated species. This could have contributed to LWD within the channel due to natural age-related mortality, erosion, and beaver activity.

The combination of meandering channel with available LWD and beaver complexes would have developed complex instream habitat for Chinook salmon and steelhead alike. Pools would have been common features in meander bends and at locations with instream large wood. Well-connected hyporheic zones would have contributed high-quality cool water and further resulted in diverse and complex fish refugia. Spawning habitat would have been common in pool tail-outs upstream of riffles between the meander bends and juvenile rearing habitat would have been similarly widespread in the form of overhanging banks and direct interaction of riparian vegetation with the channel as well as floodplain channels and ponds associated with beaver activity. The areas adjacent to the creek were likely an ephemeral complex combination of backwater channels, wetlands, and floodplains that supported a diverse community of aquatic and riparian species.

11.4.3 Present Conditions

Modifications

In the downstream end of reach 4, the general location of the creek along the left valley wall is likely controlled by cross-valley sloping caused by the Catherine Creek Fault that shows displacement down and to the east (Ferns et al. 2010). However, in the areas of RM 41.1 and 41.5, the 2009 LiDAR imagery show evidence of past migration in the form of channel scars. The 1937 aerial imagery shows differences in vegetation that also suggest that the stream could have meandered away from the left valley wall in these two areas prior to the original construction of Highway 203, the Medical Springs Highway. Additional channel scars are visible in the LiDAR in upstream portions of the reach. Migration in these locations was likely the result of the channels response to large flow events that delivered significant amounts of bedload and debris from upstream, choked the channel causing some avulsion, and then over time the channel eventually returned to its “original” position controlled by slope/topography (Appendix C). Channel manipulations were implemented before the earliest set of aerial photographs (1956), but further change can be detected after the 1957 photography. Although the majority of channel straightening and channelization had taken place by 1956 that would have decreased sinuosity, a comparison of old channel centerlines show that sinuosity has slightly increased in reach 4 from 1.05 in 1956 to 1.07 in 2008, likely due to the river readjusting to decreased levels of “management” (Figure 52). In addition, the amount of change in the sinuosity is small and could partially be contributed to parallax, where the edges of the areal image are distorted (Appendix C).

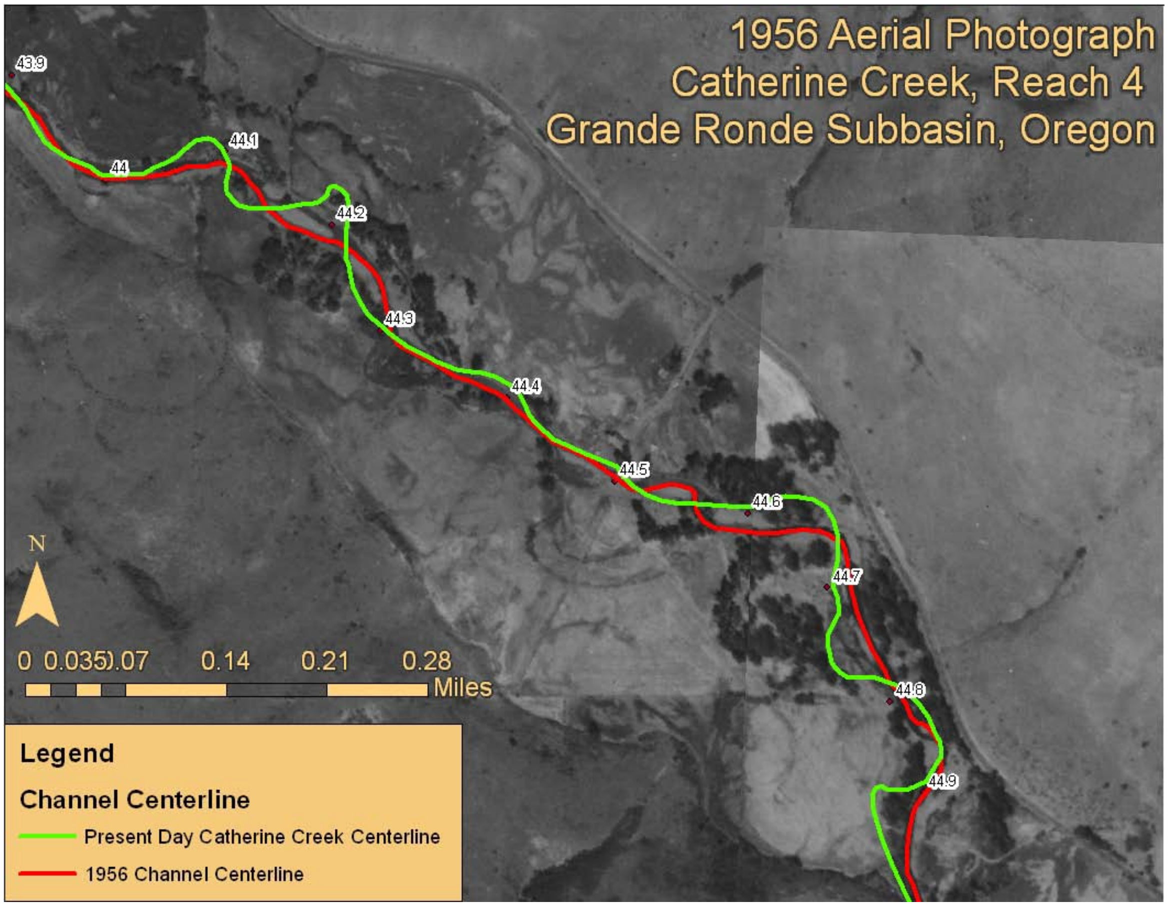


Figure 52. **A 19956 aerial image of reach 4 with the 1956 and present-day channel centerlines digitized to show an increase in sinuosity.**

Within reach 4 of Catherine Creek, the greatest change to hydraulic processes are channel straightening, low-head diversion structures, and bridges. Two diversion dams are located within this reach: the CCACF operated by the CTUIR at RM 42.5 and the “State” Diversion at RM 42.2. The CCACF was once known as the City of Union intake dam. The diversion structure was reconstructed in 1995 and later fitted with fish passage facilities (GRMW 2011). From 1997 to 2000, a temporary resistance board weir just upstream of the fish ladder was used to collect spring Chinook salmon for broodstock in the supplementation program. This was replaced by a concrete trap that was first used in 2001 (Boe 2011). A hydraulic weir was installed in 2001 and operated for the first time in 2002 (Boe 2011). The CCACF was totally reconstructed in 1995 and fish passage facilities were added circa 2000. A vertical-slot fish passage facility was added to the State Diversion in 2007. The CCACF has a total potential diversion capacity of 4.75 cfs although less is generally withdrawn (Hattan 2011). State Diversion has water rights for over 13 cfs; however, ditch capacity typically requires the discharge to remain under approximately 10 cfs.

Three bridges are located within reach 4: two associated with Highway 203 and the third is a private crossing. Human features along this reach include two head gates and multiple sites of surface water return all associated with diversions, approximately 3,000 feet of bank protection, 900 feet of levee, and 5,800 feet of nearby roads.

Levees

Approximately 900 feet of levee are located within reach 4 mostly along the right bank just upstream of the CCACF diversion near RM 42.5. Additionally, approximately 0.8 miles, or 4,060 feet of Highway 203 act as a levee at the downstream end of the reach for a total of slightly less than 19 percent of the reach (Appendix C). Hydraulic modeling suggests that levees, including Highway 203, are typically not overtopped at flows less than the 50-year discharge. More than 70 percent of the leveed portion of the reach does not experience overtopping at flows less than the 500-year discharge that is similar to reach 3.

Hydraulics

The hydraulics of the reach have been altered from historic conditions through channel straightening and instream manipulation. The current slope of reach 4 at 0.83 percent is steeper than in downstream reaches 1, 2, or 3 as would be expected moving higher up into the watershed. Based upon 1D hydraulic model results, the State Diversion acts as a control on the water surface, causing an increase in water surface elevation at all flood flows (Figure 53) (Appendix D). Reach 4 channel capacity is most frequently reached at discharges with recurrence intervals between 5 and 10-years, which may be indicative of some degree of incision or channelization. The 100-year flood inundates portions of the upper end of this reach above the State Diversion at RM 42.5 (Figure 54). Downstream of State Diversion, a narrow area of the floodplain is inundated during the 100-year event.

Hydraulic modeling indicates that thirty percent of the reach 4 levees are overtopped at or below the 100-year peak discharge. Some levee locations require a discharge near the 500-year event to overtop. However, there are few levees in this reach with less than 19 percent of channel length affected by levees (including the Highway 203 road prism).

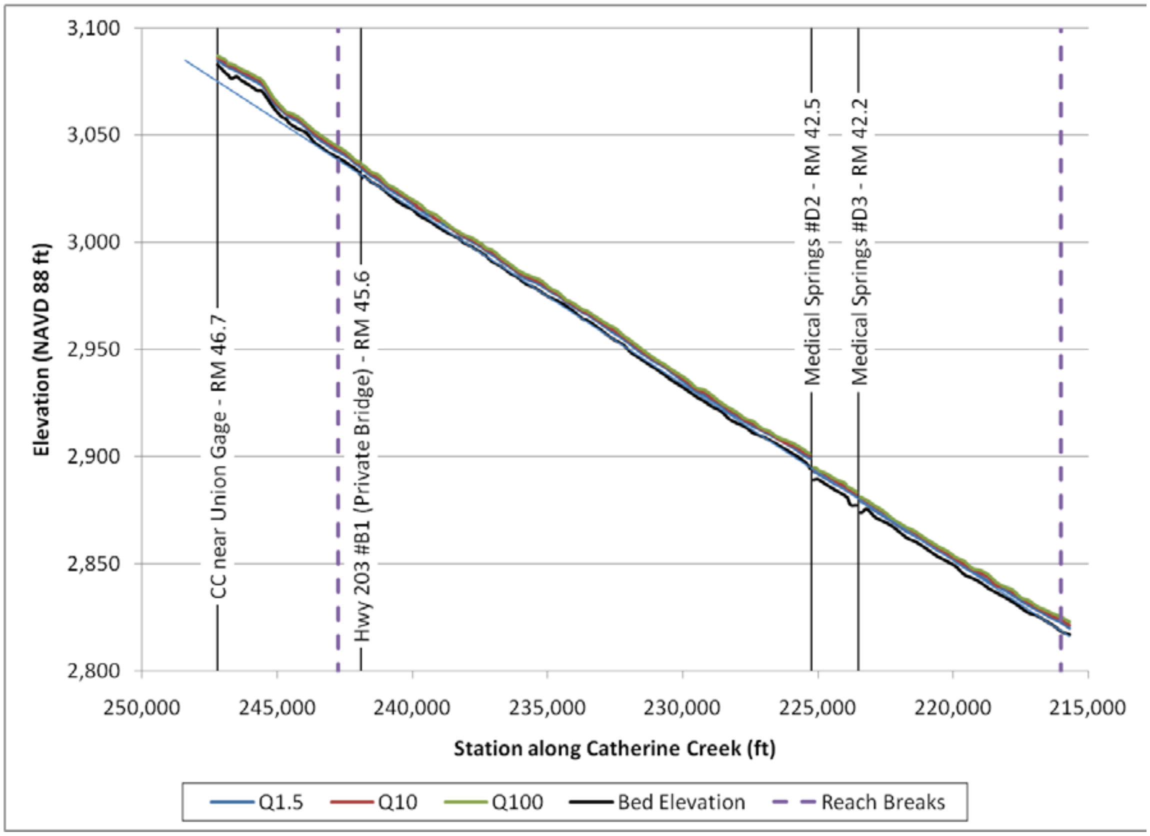


Figure 53. Computed water surface elevations along reach 4 (Appendix D). Medical Springs #2 is more commonly known as the Catherine Creek Adult Collection Facility (CCACF) and Medical Springs #3 is more commonly known as State Diversion.

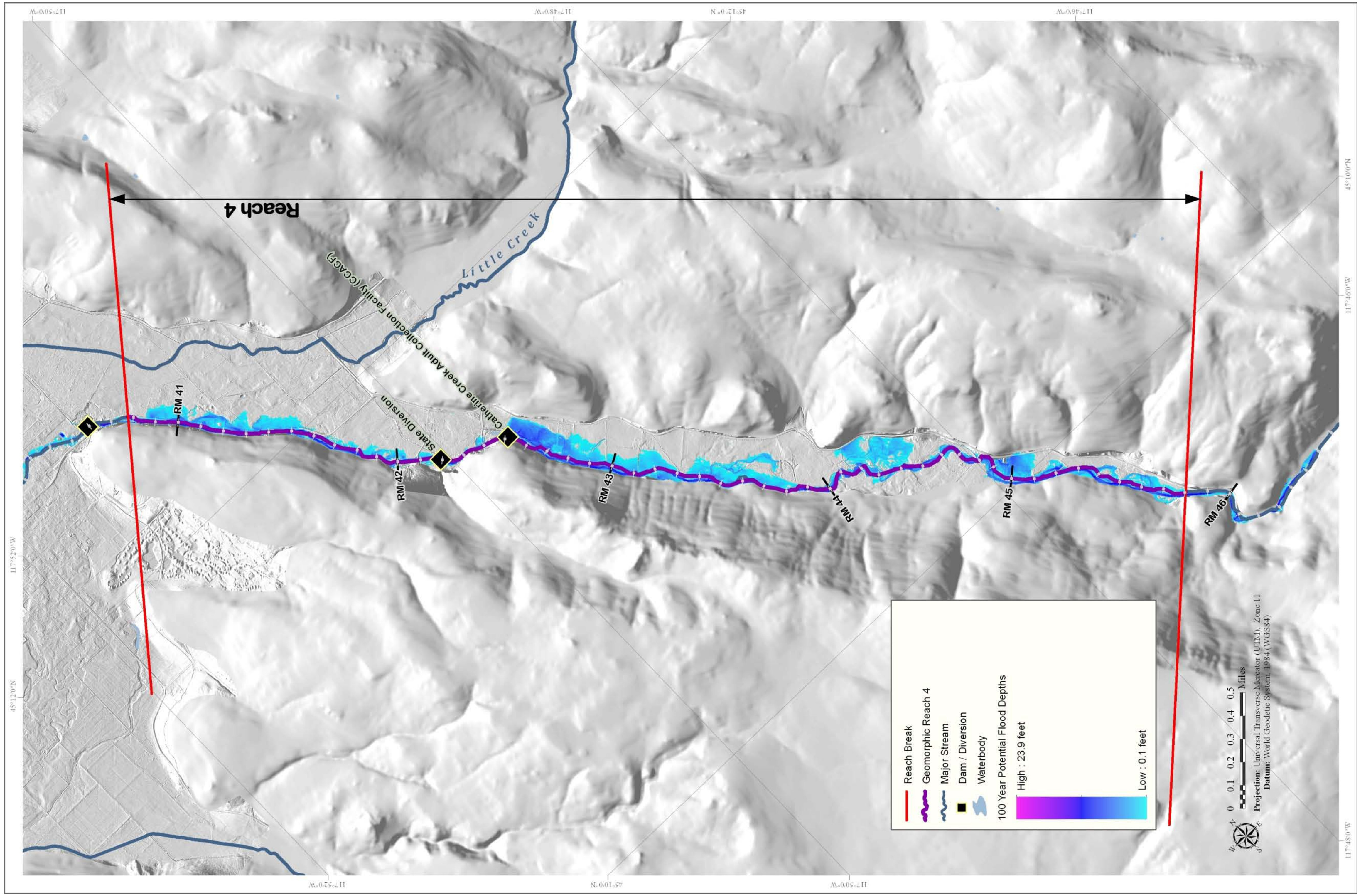


Figure 54. The depths of potential flooding within the bounds of the modeled cross sections for the 100-year discharge along reach 4.

Velocities in reach 4 (Figure 55) are similar, yet higher than velocities in reach 3. Within reach 4 modeled velocities increase with discharge, and the reach-averaged velocity is slightly higher at approximately 4.8 ft/s for the 1.5-year flood to 6.7 ft/s for the 100-year flood.

Hydraulic modeling within reach 4 shows corresponding increases in shear stress for increases in discharge (Figure 55). This is likely due to more flow staying in the channel at greater discharges rather than spilling onto the floodplain leading to increased in-channel depths and velocities. The magnitude of the in-channel shear stress is similar to that found within reach 3. Although the reach-averaged shear stress provides an overview of what is happening in the channel, high variability is present within the reach, which is typical of hydraulic modeling results. Generally, at cross sections where the larger discharges are contained with the channel, shear stresses and potential for instream change are higher. Figure 55 shows the variability of shear stress between cross sections for reach 4.

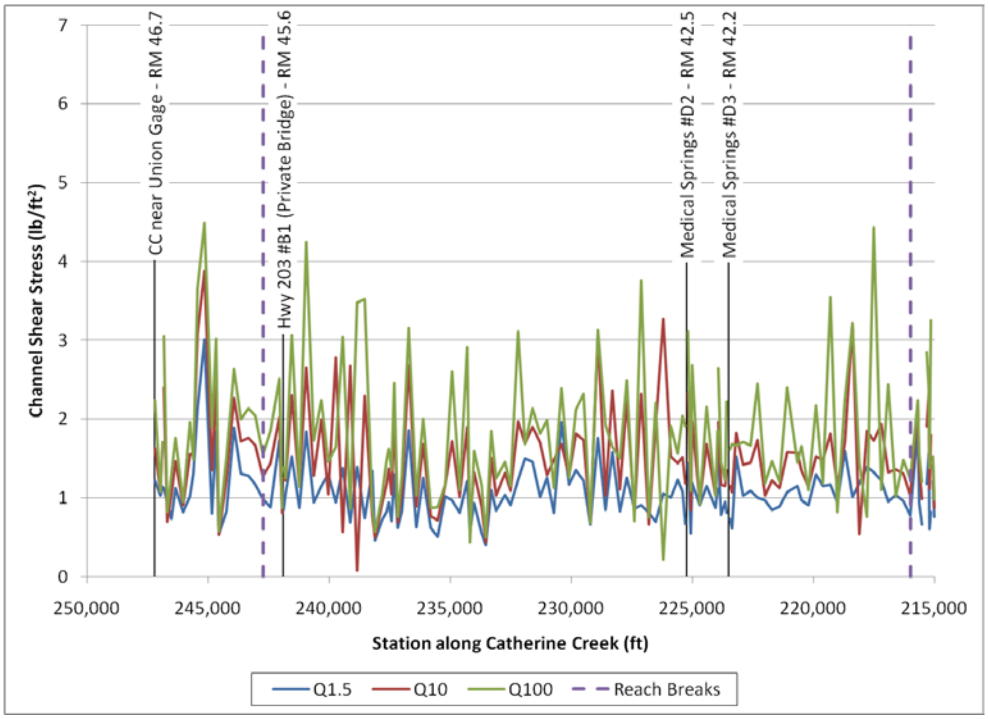


Figure 55. Channel shear stress in reach 4 on Catherine Creek (Appendix D). Medical Springs #2 is more commonly known as the CCACF and Medical Springs #3 is more commonly known as State Diversion.

Geomorphic Properties

The average valley gradient is approximately 0.89 percent and the average channel gradient is 0.83 percent resulting in a sinuosity of 1.07. The reach has an average width-to-depth ratio of 25:1. In the midsection of the reach, the creek meanders across the valley floor while in the downstream end of the reach; the creek is relatively straight and sits against bedrock along the left valley wall. This is likely controlled by cross-valley sloping caused by the Catherine Creek Fault, which shows displacement down, and to the east (Ferns et al. 2010) (Appendix C).

Bedrock and coarse alluvial material are the natural vertical and lateral migration controls in reach 4. In reach 4, areas with low migration rates exist at the bottom and top of the reach, although some local bank erosion is noted in the top section. The low migration rate in these sections can be attributed to bedrock and coarse alluvial material that act as natural vertical and lateral migration controls. In the mid section of reach 4 from approximately RM 44.0 to 44.95, accelerated rates of migration are noted locally with several points of stream avulsion. The most recent stream avulsion occurred during the spring high flow of June 2010 (Sixta et al. 2011; Dyke 2010; 2011) (Appendix C).

Floodplain

This reach of Catherine Creek shares the valley bottom with Highway 203 and many ranches and houses. The creek may have been relocated against the hillside to the southwest in some sections of the reach to accommodate these changes (Figure 56). Existing channel scars visible in the LiDAR collected in 2009 and are likely the channels response to large flow events that delivered significant amounts of bedload and debris from upstream. The episodic high sediment load would choke the channel, causing some avulsion. Over time, the channel would have eventually returned to its “original” position controlled by slope/topography and structural geology (Appendix C).

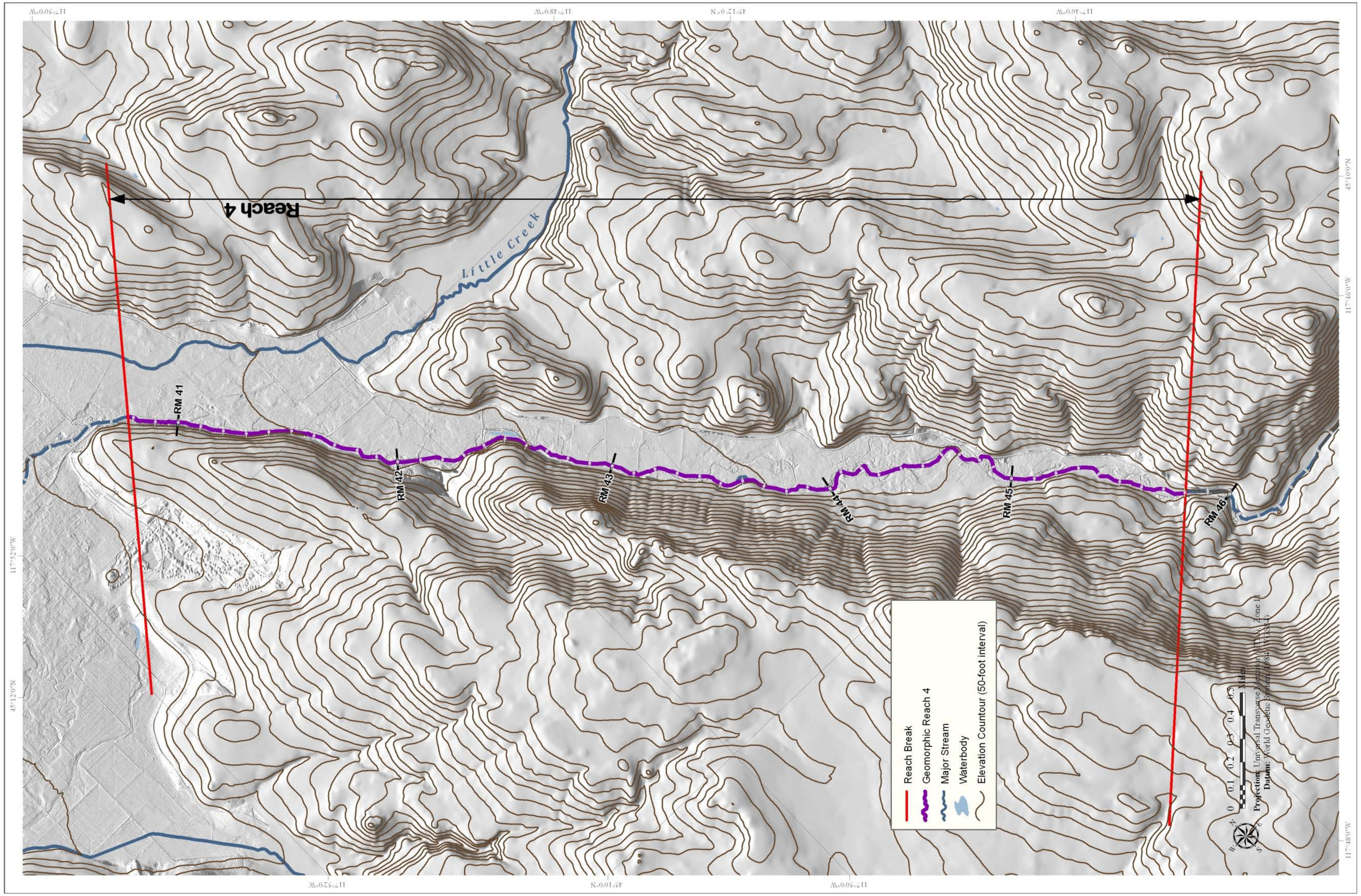


Figure 56. Reach 4 stream channel location.

Sediment

Channel substrate consists largely of gravel and cobble. Pebble counts from point bars within the reach indicate the average D_{50} is approximately 57.2 mm (course gravel) but a wide range of sediment was found including fine sands, gravels, and boulders (Appendix C). Valley soils are stony and cobbly silt loams (NRCS 2009). Results of incipient motion calculations indicate that the D_{50} sized materials mobilized during channel-forming flow (about a 1.5 to 2-year recurrence interval event). However, there is a wide range of conditions throughout the reach including slope, estimated bankfull area, wetted perimeter, and sediment in reach 4. Scour holes observed in the reach during low flows were typically associated with anthropogenic features or a local obstruction, such as large wood, that concentrated the flow and created local scour.

A wide size range of sediment was noted at the CCACF at RM 42.5. It was communicated anecdotally by the CTUIR staff that the material had been removed from the diversion baffles on an as needed basis in the past; however, budget constraints would likely prevent this from happening in the future (Appendix C).

There is active bank erosion along approximately 20 percent of the reach (Appendix G) with active channel migration taking place in the upper segments of the reach (Sixta et al. 2011). Recent migration has isolated an ODFW fish screen and partially captured an irrigation ditch at RM 44.2. From aerial photography, it appears that this upstream segment of reach 4 could also be a source of considerable amounts of fine sediment. Although not fully assessed as part of this TA, it appears that poor riparian condition, cattle grazing, and high stream energy related to channel manipulations could be factors destabilizing this reach.

Water Flow

Reach 4 is less affected by hydrologic alteration than downstream reaches mainly as a result of less direct human impact to the watershed above this reach. There is little agricultural use above this reach and no urban area. However, cumulative effects of roads and forestry practices may have had substantial effects. Roads are common in the upstream watershed. The forest road network and Highway 203 combined with their associated ditches and culverts could have substantial alterations to both magnitude and timing of peak flows; however, analysis of the upper watershed was not completed for this assessment.

The Catherine Creek near Union, Oregon stream gage located at RM 47.6, approximately 1 mile above reach 4 is representative of this reach with a record that starts in 1911. The mean daily flow exceedance hydrograph (Figure 57) presented here does not consider water withdrawals from the creek and, therefore, for low flows, better represents the upstream segments of this reach.

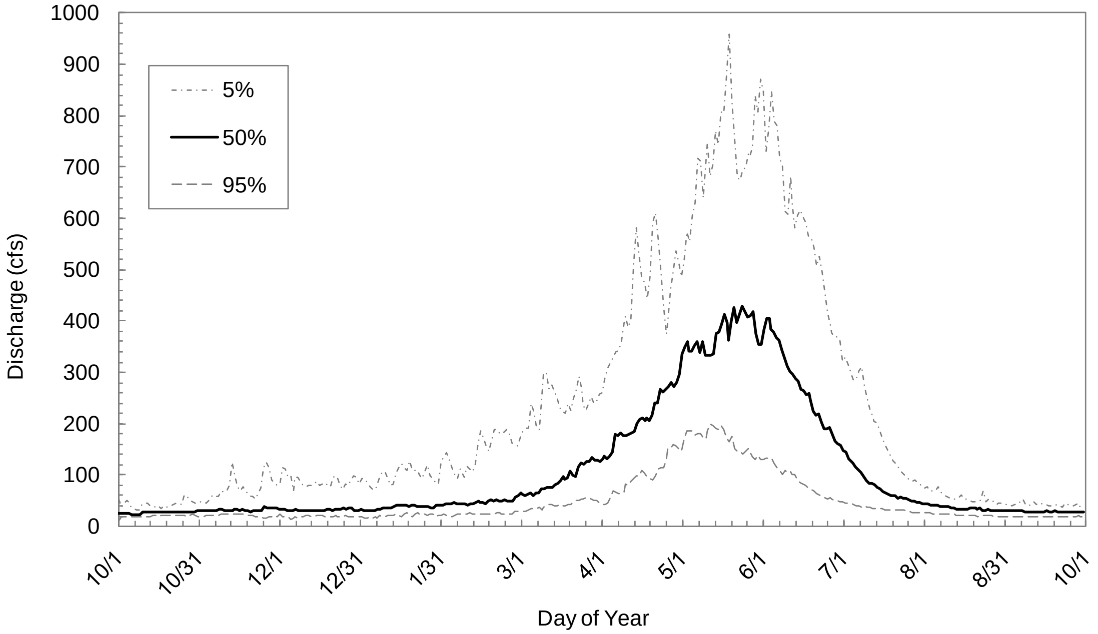


Figure 57. Mean daily flow percent exceedance values for the Catherine Creek near Union, Oregon stream gage. The 50 percent values indicate the average annual hydrograph.

Water Quality

Reach 4 of Catherine Creek is currently only listed for temperature on the ODEQ's Section 303 (d) list. Temperatures exceeded criteria in the late summer (August through September) likely due to natural background conditions combined with low flows, diminished hyporheic connectivity, and decreased riparian shading within this reach. In the 2000 TMDL, average 7-day temperatures for the reach for the 1st week of August of 1999 were approximately 72.0^{0}F, which exceed the ODEQ standard of 64.0^{0}F (ODEQ 2000.)

The 1999 continuous and FLIR temperatures correlated well upstream of Davis Dam in reaches 3 through 7 (ODEQ 2000). Within Reach 4, stream temperatures increased slowly downstream from RM 44.7 to about RM 41.6 where they reached a local maximum of 69.8^{0}F (Figure 58) (Watershed Sciences 2000). From that point to Davis Dam (RM 33.8 in reach 2), stream temperatures were relatively constant, fluctuating between 67.3 and 70.9^{0}F. The average median temperature in reach 4 was 68.2^{0}F. Other datasets including data collected by UCSWCD at RM 43 in 2002 and TIR data from CRITFC in 2010 show similar temperatures within this reach.

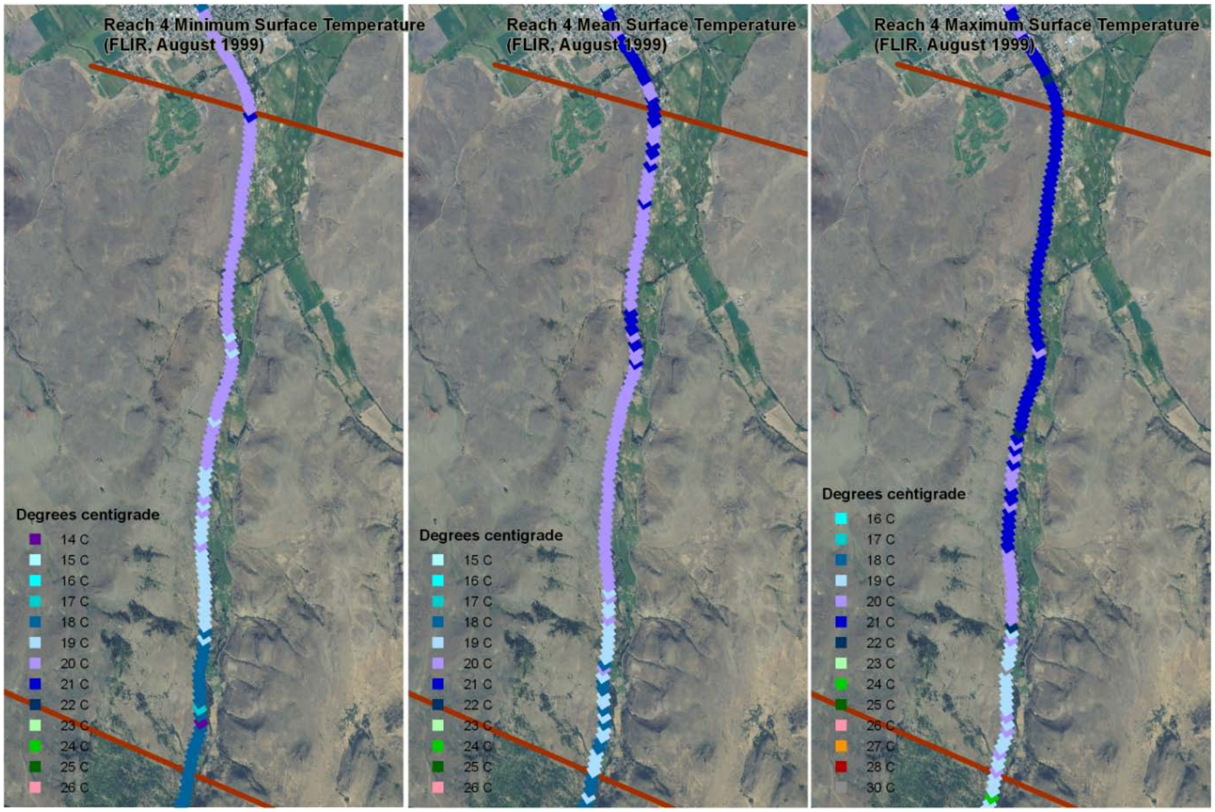


Figure 58. Stream temperature results for reach 4 from August 1999 FLIR data.

Habitat

Riffles are a dominant habitat type within reach 4, making up as much as 80 percent of the channel bed form. Suitable pools (relatively deep and with cover) are present; however, there are probably fewer pools than historically due to the possible channel straightening and loss of LWD in this reach. Additionally, the pools that are present are less complex and lack the depth typically associated with Chinook salmon habitat requirements. This is partly due to the channelized form throughout some of this reach and the somewhat low amount of LWD present, and partly due to the natural channel type (relatively straight, plane-bed to pool-riffle). The ODFW habitat assessment (Appendix G) indicates that the channel is constrained by terraces and has a riparian area comprised of grasses and small deciduous trees. Observed occurrences of large wood within the active channel were low. Small sections of large trees were observed along the banks and within the floodplain throughout reach 4. Although some large wood (cottonwood and Alder) was likely supplied to the stream from the banks on the valley floor by beaver activity, strong winds, or dying and toppling, the main source of large wood was likely from upland forests and incorporated into the system by mass wasting events or debris flows from rain-on-snow events or intense rainstorms.

Fish Use

Reach 4 supports all freshwater life stages of Chinook salmon and steelhead. Limiting factors in this reach include limited juvenile rearing habitat, limited adult holding habitat, anchor ice, and few deep pools (Appendix G). The 2011 ODFW habitat survey indicates that Chinook salmon spawning and incubation habitat is in fair condition as is summer rearing and winter rearing habitat (Appendix H). Steelhead spawning is fair to good, summer rearing is fair, and winter rearing habitat is good (Appendix H). The ODFW fish tracking study only covers the lower sections of this reach below the CCACF where the juveniles are collected for tagging (Appendix H). However, the ability to collect fish in this reach for tracking and the tracking data collected in the lower end of the reach suggest significant fish use (Figure 59).

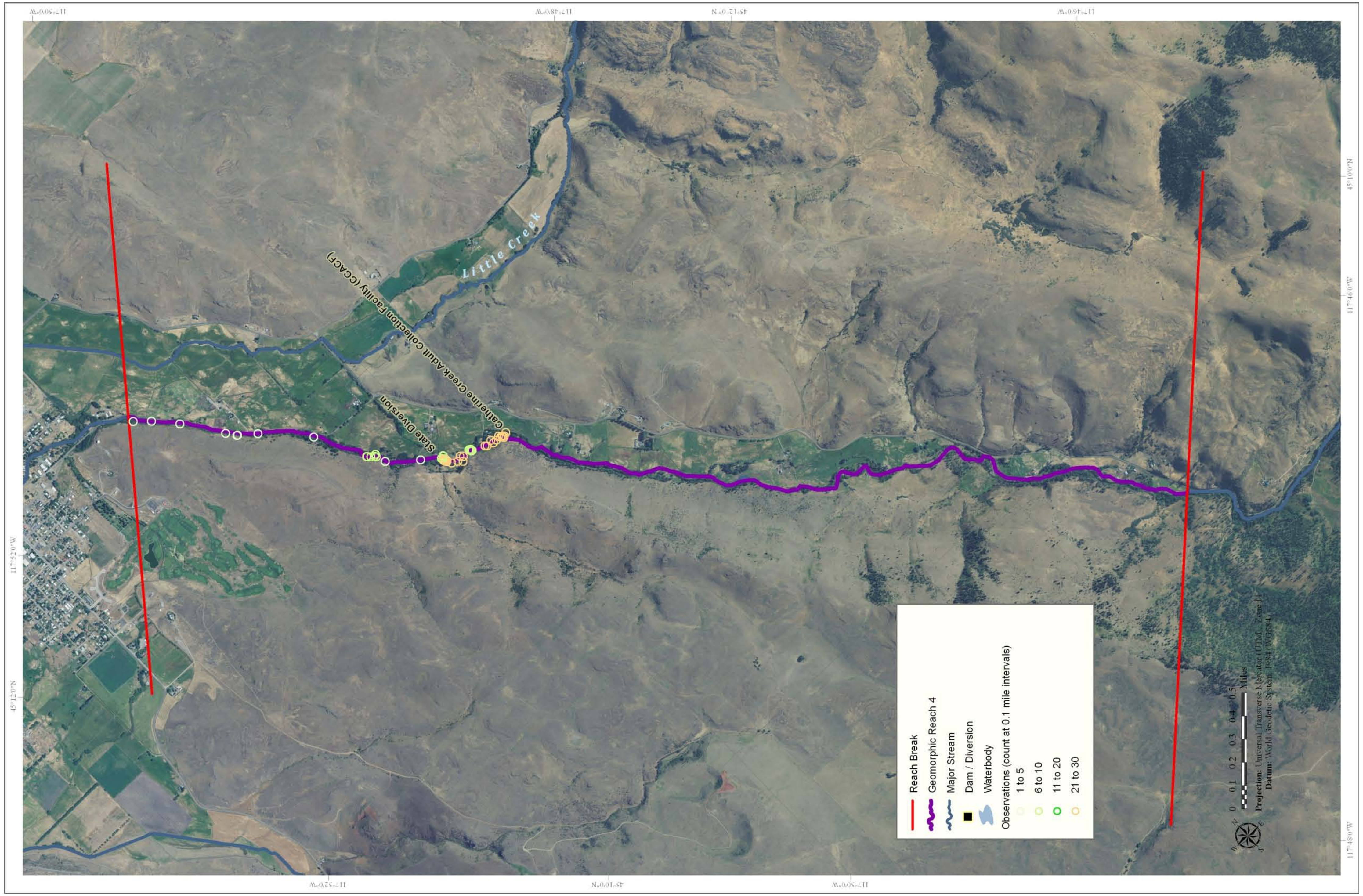


Figure 59. Overwintering fish tracking study results during the winter of 2009 to 2010 for reach 4.

11.5 Reach 5 (RM 45.8 to 50.11), Reach 6 (RM 50.11 to 52.0), and Reach 7 (RM 52.0 to 54.9)

11.5.1 General Location and Description

The remaining reaches of the upper valley segment of this assessment (reaches 5, 6, and 7) (Figure 60) have a limited known history and have experienced similar changes to one another. These three reaches have been grouped together to simplify discussion and make note of the important ways in which they are different. Reach 5 is naturally confined with an upstream boundary near the confluence of Catherine Creek and Little Catherine Creek. Reach 6 extends from the Little Catherine Creek confluence upstream through a more open, unconfined valley where the channel exhibits higher sinuosity and a relatively wider floodplain. Reach 7 is another naturally confined reach and continues upstream to the boundary of the national forest.

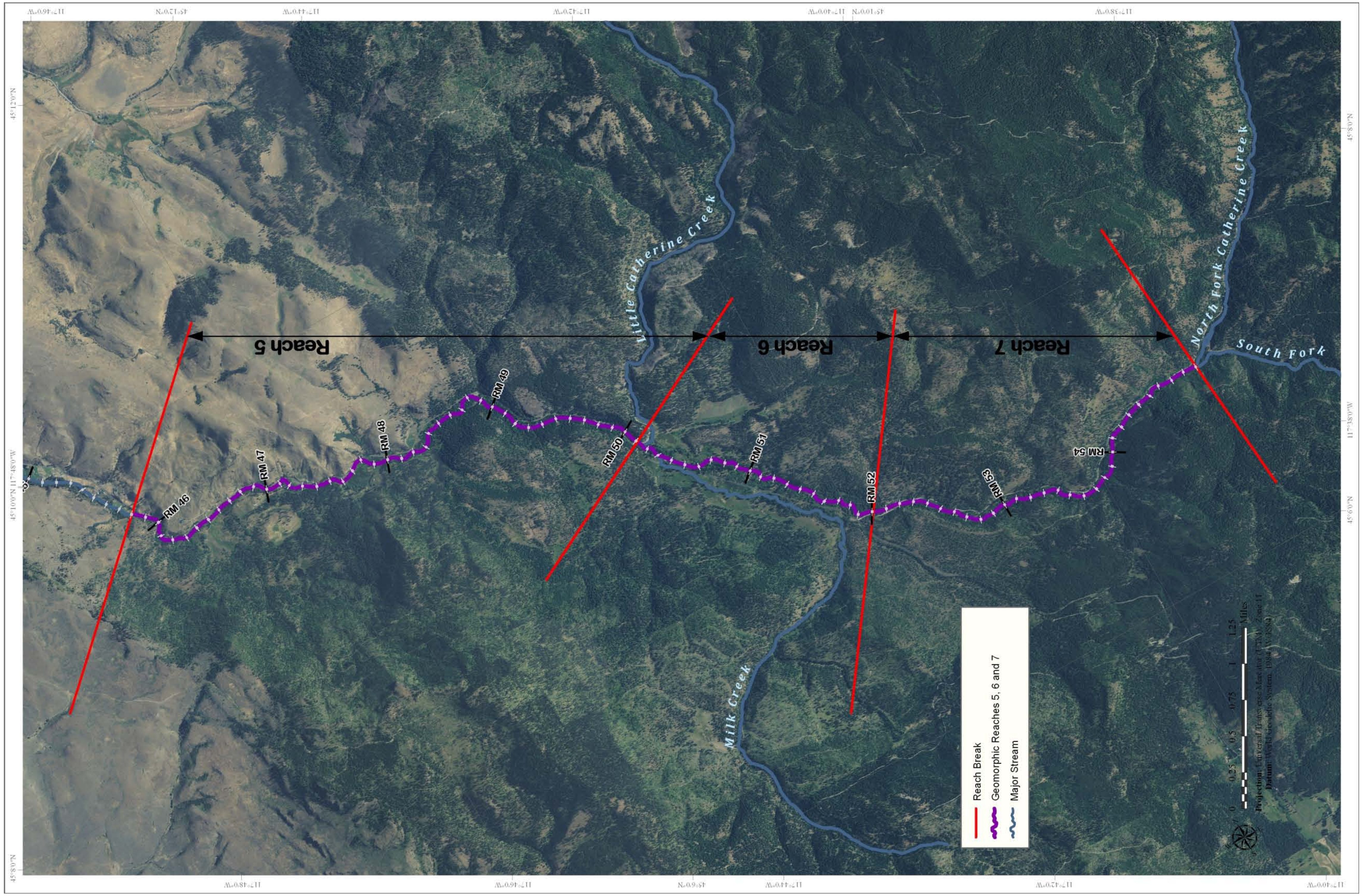


Figure 60. **Overview map of reaches 5, 6, and 7.**

11.5.2 Historical Conditions

There is little historical data describing Catherine Creek in this area. However, the creek would have been in a relatively similar form to what is seen today with some subtle differences. The highways and roads, which in some locations have an influence on the creek and/or floodplain, would not have been present. In locations where the roads are adjacent to the creek, the creek may have been slightly less confined locally. Medical Springs Highway/Highway 203 and small sections of riprap would have been absent; therefore, the channel migration and floodplain interaction processes that produce and maintain aquatic habitat would have been more prevalent in the unconfined reach 6. In other locations, before the road was present, colluvial and alluvial material as well as LWD would have entered directly into the channel adding to the habitat complexity.

The confined form of the channel in reaches 5 and 7 suggests that hillslope processes have had a direct influence on the channel and little floodplain has ever been available (Figure 61). The large material entering from the hillsides may have collected and retained LWD for short periods of time and would have temporarily added to the complexity of habitats available in and adjacent to the channel. LWD complexes would likely have been relatively transient in these reaches and would have developed following episodic events such as large floods and debris flows that may have occurred within a few years of fires in the upper watershed. The debris jams would likely have then washed out with the next few significant high-water events.

The upstream reaches had a higher slope than downstream reaches and would have primarily been sediment source and transport reaches with sediment inputs occurring during large disturbance events such as forest fires and floods. While these events, which have been documented in the area along with associated fish kills (Gildemeister 1998), can have an immediate detrimental effect on the fish population, they tend to be a significant source of beneficial complex habitat with long-term benefits that outweigh the short-term loss. It is these disturbance events that create the conditions that regenerate riparian vegetation, deposit and rework clean substrate suitable for spawning, and develop overflow and erosional channels on floodplain areas that create rearing habitat and increased food sources and provide sediment and LWD to downstream reaches.

The riparian areas were likely a mix of narrow to extensive areas that alternated with changing confinement and floodplain extents. Where the riparian areas were narrow and hillslopes were directly connected to the channel, coniferous trees (ponderosa pine - *Pinus ponderosa*, western larch - *Larix occidentalis*, Douglas fir - *Pseudotsuga menziesii*, grand fir - *Abies grandis*, and subalpine fir - *Abies lasiocarpa*) would have been common. In reach 6, where floodplains are common there would have been substantial riparian communities that would have been largely comprised of multi-age stands of black cottonwood (*Populus trichocarpa*), various species of willow (*salix*), and alder (*Alnus*), redosier dogwood (*Cornus sericea*), and associated species with mixed conifers. This would have provided an abundant supply of LWD to the channel due to natural age-related mortality, flooding, erosion, and beavers (which were likely to have been abundant).

In reach 6, the combination of LWD, active floodplain, and beaver activity would have developed complex instream and off-channel habitat for Chinook salmon and steelhead alike. Pools would have been common features and extensive hyporheic zones would have further resulted in heterogeneous fish refugia. Spawning habitat would have been common and juvenile rearing habitat would most likely have been similarly widespread. In naturally confined areas such as reaches 5 and 7, it is likely that habitat conditions were not very different than today and these would have primarily been migration corridors and food production areas. Historic fish use was likely similar to today, with migration, spawning, and rearing throughout these reaches.

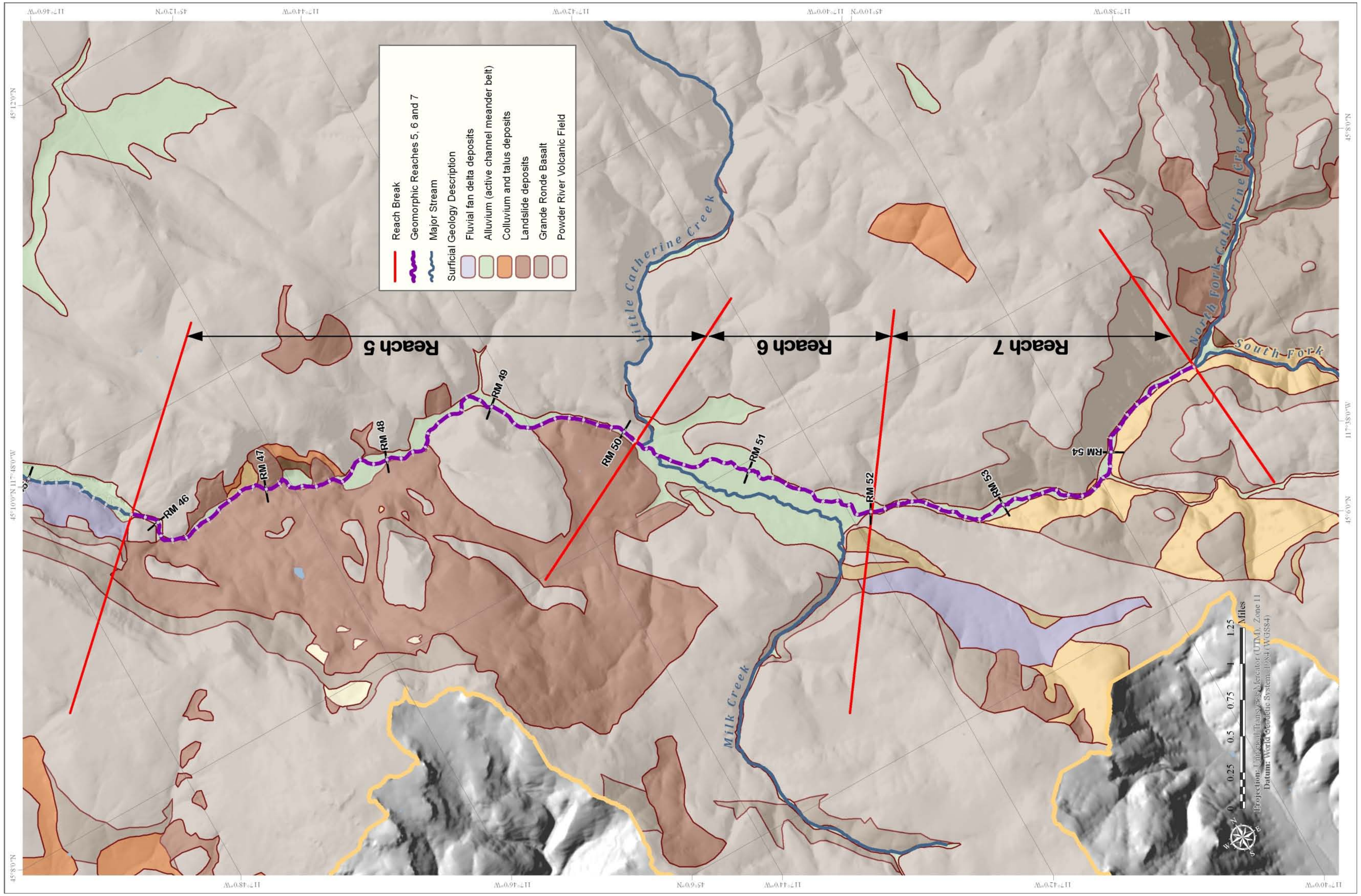


Figure 61. Surficial geologic deposits and "bare earth" hillshade topography along reaches 5, 6, and 7.

11.5.3 Present Conditions

Modifications

Most of the channel alterations, which include the construction of Highway 203, were completed sometime before the earliest set of available aerial photographs (1956). Changes that have occurred between 1937 and 2009 are detectable through remote analysis of the aerial photographs. In reach 6, there was a slight increase in sinuosity from 1.11 in 1964 to 1.19 in 2008, likely due to the river readjusting to decreased levels of "management." In reach 5, the sinuosity decreased from 1.08 in 1964 to 1.06 in 2008. In reach 7, the sinuosity remained relatively constant from 1956 to 2008. In both cases where amounts of increase and decrease in sinuosity were noted, the amount of change is small and could partially be contributed to parallax, where the edges of the areal image are distorted. In addition, the image quality of the earlier aerial photographs made precise mapping and analysis difficult (Appendix C).

The creek, streambanks, and floodplains in the upper reaches have all experienced changes from the historic condition; however, the degree of alteration decreases upstream from reach 5 to reach 7. The alterations typically include roads, bridges, culverts, and other road related infrastructure. Various bank protection features are also common where the road encroaches on the creek channel; however, these likely have limited effects in reaches 5 and 7 due to the naturally confined and armored condition of the channel (Appendix C). Land use practices are likely responsible for limited riparian and floodplain alteration in all three upper valley reaches (5 and 7.) This alteration has likely contributed to reduced overbank (flood) water storage, reduced infiltration and higher surface runoff, and changes to the vegetation communities, mainly in reach 6.

Within reach 5, Catherine Creek runs adjacent to Medical Springs Highway/Highway203 along the right bank for about a quarter of the reach length. Sub-angular to angular riprap protects the road prism in essentially all instances where the road prism forms the right bank of the stream. Another method of bank protection observed within the reach was cabled log bank protection along the left bank, downstream of the bridge near RM 47.6. There was approximately 6,600 feet of roadway within this reach along with 5,700 feet of bank protection most of which were associated with Highway 203. Five bridges also span the creek within this reach (Appendix C). However, these armored conditions are not significantly different from the natural bedrock and boulder talus channels banks would have been.

Reach 6 has undergone manipulations to the channel and floodplain. The 2009 LiDAR and digital elevation model imagery indicates that the main channel was cut off from the 26 acres of the floodplain along the left of the valley by Medical Springs Highway/Highway 203 in the upper half of the reach. In addition, vegetation has been cleared or altered and land use included grazing. Grazing does take place within the riparian area on the Eastern Oregon Agricultural Center property on an annual basis; however, the amount of time that the grazing is allowed is limited (DelCurto 2011). Additional anthropogenic features noted along the stream include small sections of bank protection (totaling 334 feet) associated with Medical Springs Highway/Highway 203 and a small section of gravel road, both of which are located at the upstream end of the reach (Figure 62) (Appendix C).

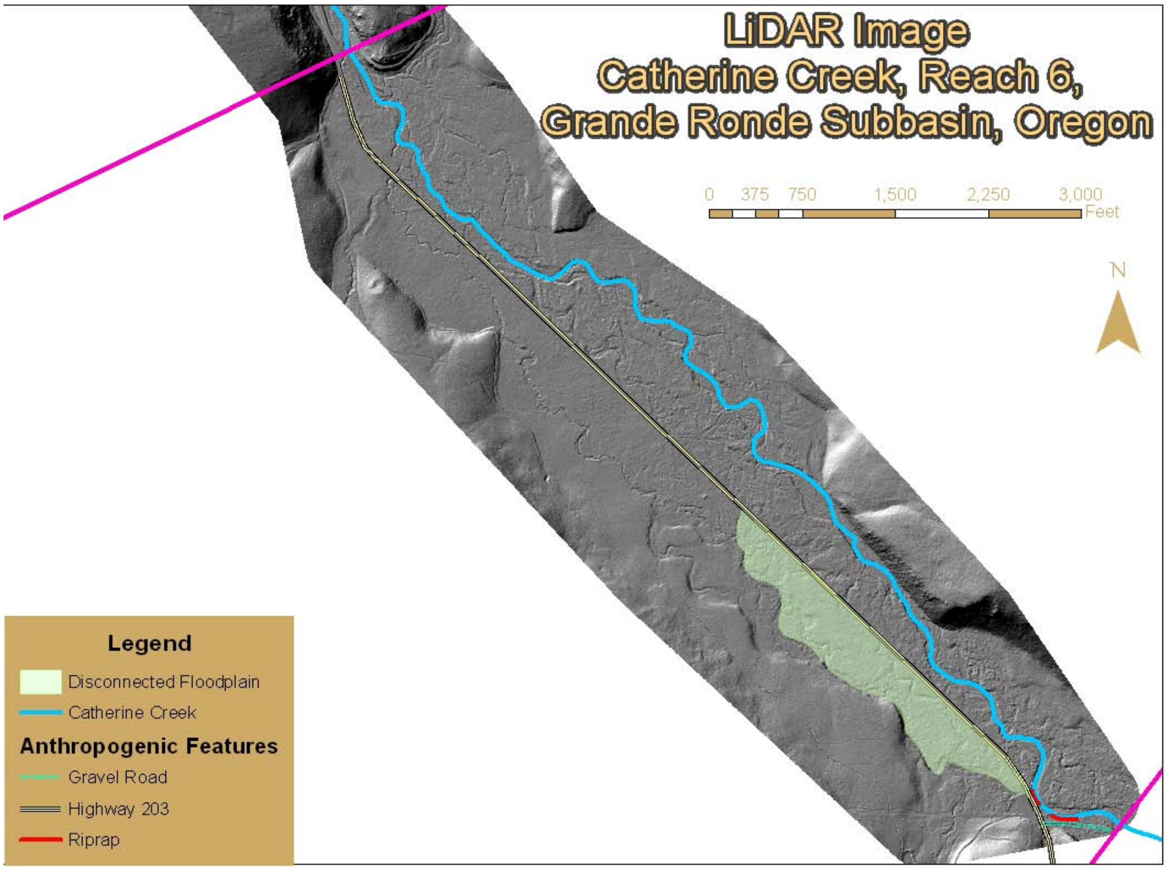


Figure 62. **A LiDAR based image of reach 6 showing the current location of Catherine Creek, the anthropogenic features, and a section of disconnected floodplain.**

Manipulations instream or within the floodplain in reach 7 appear to be minimal, aside from possible alteration to the vegetation. GIS data supplied by the USFS shows that upland vegetation has been altered by logging practices resulting in a reduction of the areal extent of land covered by large trees that can provide LWD to the stream via debris flows, landslides, and floods in the upland areas of the watershed. Human features along the banks include a single bridge near the downstream end and 15,140 feet of unpaved road. The road traces the north side of the valley along the transition from the floodplain of Catherine Creek to the adjacent upland slopes for the entire length of the reach. The road may slightly alter the timing of runoff and the sediment input to the system, but the impact to channel processes is likely minimal. It should be noted that the entire length of reach 7 was not surveyed due to access issues. If further assessment or project identification and development occur in reach 7, the entire distance of the reach should be evaluated (Appendix C).

Hydraulics and Geomorphic Properties

Hydraulic modeling was not performed above reach 4; however, geomorphic properties were measured from field, aerial photography, and LiDAR methods. In reaches 5, 6, and 7 little change has likely occurred, with slight or imperceptible results. Stream slopes range from 1.57 percent to 0.83 percent within reaches 5, 6 and 7, and valley gradients range from 1.64 percent to 0.89 percent (Table 5).

Table 5. Reach 5, 6, and 7 gradients, sinuosity, and width-to-depth ratio.

Geomorphic Reach	Valley Gradient (percent)	Stream Gradient (percent)	Sinuosity	Average Width: Depth
5	1.10	1.00	1.06	28:1
6	1.50	1.25	1.19	34:1
7	1.64	1.57	1.04	20:1

Floodplain

It is hypothesized that floodplains are activated in reach 6 during the 100-year event and likely at much lower recurrence intervals. Floodplain activation is not applicable in reaches 5 and 7 as these are confined reaches that do not typically develop floodplains.

Sediments

Median sediment sizes in reaches 5, 6, and 7 generally correlate to channel slope and confinement and associated energy regime where the more confined reaches have higher instream energy and larger bed material Table 6. Average D_{50} grain sizes from pebble counts are 63mm, 34mm and 71mm in reaches 5, 6 and 7, respectively (Appendix C). Incipient motion calculations indicate that the D_{50} sediment can be transported during channel-forming flow (approximately the 1.5 to 2-year recurrence interval event). Scour locations that could be observed at low flows were typically associated with boulders or local obstructions, such as large wood, that accelerated the flow and caused scour.

Table 6. Gradation analysis of in channel substrate

Reach	Diameter of Substrate (mm)				
	D_{15}	D_{35}	D_{50}	D_{84}	D_{95}
5	21.7	48.1	63.2	120.4	166.6
6	4.3	18.9	33.5	93.5	142.3
7	37.7	57.1	70.9	119.8	191.2

Water Flow

Some water withdrawal occurs in reaches 5 through 7, but the extent is unknown. A "push-up" diversion is present as well as a submersible pump to withdraw water from the diversion within reach 5. An inter-basin diversion (South Fork Catherine Creek Ditch) further upstream of reaches 5 through 7 takes water from the South Fork of Catherine Creek and carries it into the Powder River drainage. The water rights are relatively junior; therefore, this diversion is one of the first reduced and shut off. The ditch typically takes around 3 cfs before it is shut off between the 3rd week of July and the 2nd week of August (Hattan 2011). Early in the season this inter-basin diversion can take over 20 cfs.

The Catherine Creek near Union, Oregon stream gage at RM 46.7 is in the lower end of reach 5 and was used to calculate the flow exceedance hydrograph for reach 5 (Figure 63). Estimated flow exceedance hydrographs were adjusted to better represent reaches 6 (Figure 64) and 7 (Figure 65) by considering change in watershed area and average annual precipitation in the watersheds.

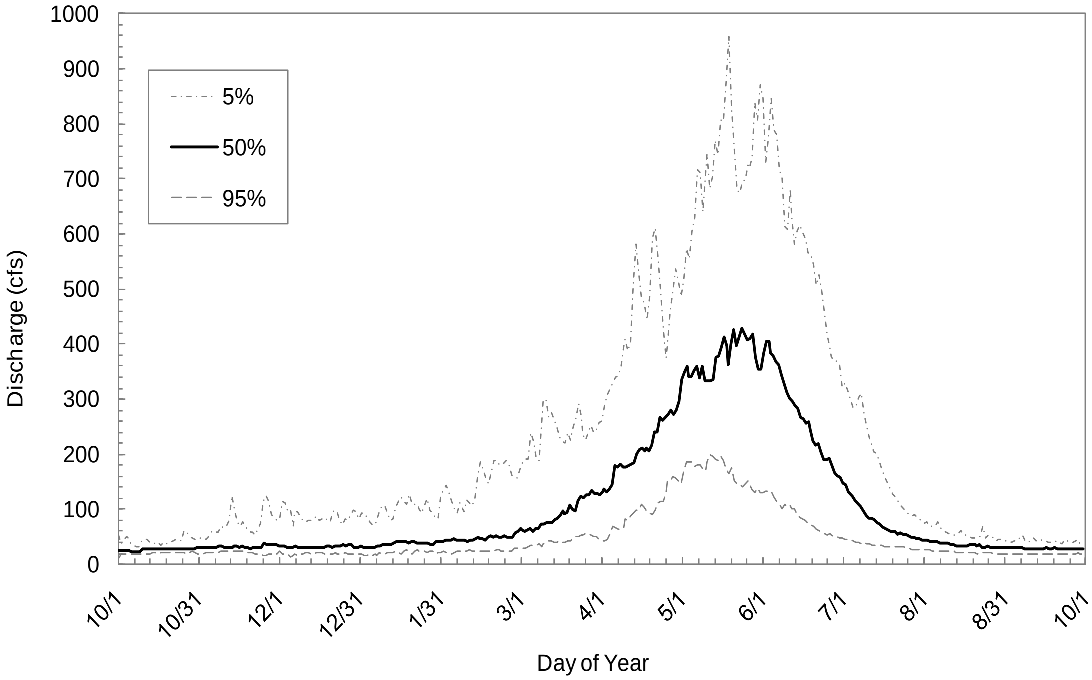


Figure 63. Mean daily flow percent exceedance values for the Catherine Creek near Union, Oregon stream gage which is in the lower end of reach 5. The 50 percent values indicate the average annual hydrograph.

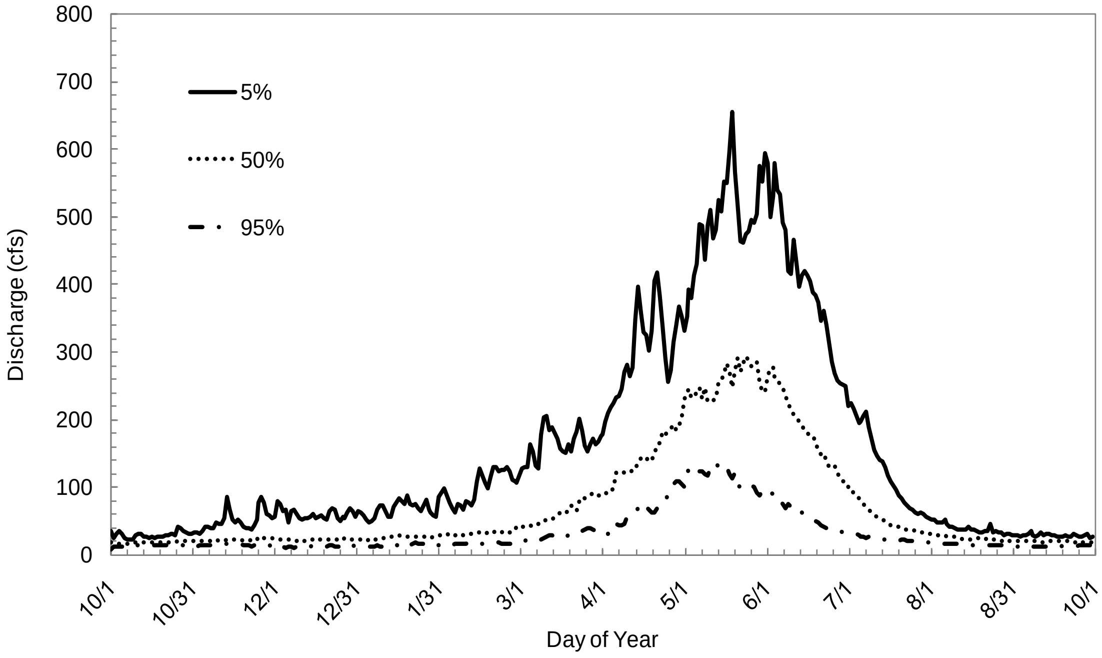


Figure 64. Estimated mean daily flow percent exceedance values for reach 6 based on the Catherine Creek near Union, Oregon stream gage. The 50 percent values indicate the average annual hydrograph.

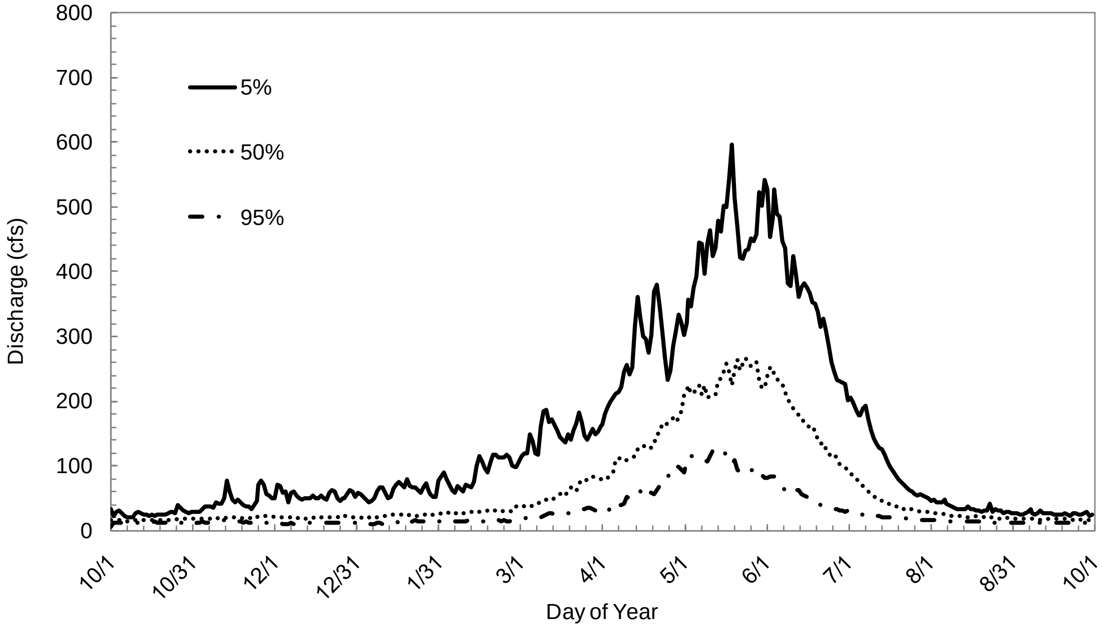


Figure 65. Estimated mean daily flow percent exceedance values for reach 7 based on the Catherine Creek near Union, Oregon stream gage. The 50 percent values indicate the average annual hydrograph.

Water Quality

Catherine Creek is listed for temperature on the ODEQ TMDL Section 303 (d) list for problems related to late summer low flow conditions for the entire stream up to the upper end of reach 7 at the confluence of the North and South Forks of Catherine Creek (ODEQ 2000.) Other limiting factors for salmonids within these three reaches include locally substandard riparian conditions and abundant fine sediment (GRMWP 1994.)

Habitat

The 2011 ODFW habitat survey rated reaches 5 and 7 as good spring Chinook salmon spawning and incubation habitat while reach 6 was rated fair. All three reaches were rated fair for summer and winter juvenile rearing. Steelhead ratings were similar except winter rearing which had a good rating on average. A limited number of pools greater than 1 meter deep were one of the main causes of the fair ratings. There is also less LWD than is necessary to achieve a good rating (Appendix G).

Small patches of large trees are common along the banks and on the floodplain throughout the upper reaches. Cottonwood and alder are the most common species present. Beaver dams are present in limited numbers in some areas and are adding to the available aquatic habitat and complexity in the upper reaches and may be supplying some of the LWD present in the channel. Other sources of LWD include blow down, maturation and natural death, and erosion. A common source in the more confined reaches includes direct input from hillslopes including mass wasting events and debris flows.

Cattle grazing has likely degraded the physical habitat in reach 6 and likely resulted in water quality degradation including increased fine sediments from disturbed banks and overland runoff and bacteria from manure in some locations within the upper valley.

Fish Use

Reaches 5, 6, and 7 support all freshwater life stages of spring Chinook salmon. It is currently thought that the limiting factors include a lack of juvenile rearing habitat, a lack of adult holding habitat, anchor ice, and in particular, a lack of deep pools (February 2011 Habitat discussion meeting, La Grande, Oregon).

12. Discussion

12.1 General

Changes to Catherine Creek and the Catherine Creek watershed (including the Grande Ronde Valley) have resulted in substantial negative effects to the creek and resident biota.

European settlers moved into the area in the mid-1800s and significant timber harvest, livestock grazing, and agricultural production began (Bach 1995). Wetlands and floodplains were drained and transformed into farmland. Large-scale changes in vegetation occurred as early as the 1870s with the introduction of livestock (ODEQ 2000).

Some of the most obvious and extensive alterations to Catherine Creek in the lower four reaches include:

- Re-direction of the Grande Ronde River to flow through State Ditch leaving the lower 22.5 miles of present-day Catherine Creek channel over-sized and shortening the path of the Grande Ronde River by 33 miles (Flow Technologies 1997).
- Draining Tule Lake in 1870 with a drainage ditch cut around it to direct Catherine Creek around the lake (Beckham 1995).
- Construction of nine permanent diversion dams, several minor push-ups dams, and numerous pump intakes.
- Draining wetlands and removing beaver and beaver complexes.
- Converting riparian areas to agricultural lands including crops and grazing.
- Cutting off meander bends and shortening the lower reaches by approximately 6-miles.

With an increasing population and subsequent increase in urbanization and agriculture came a need to alleviate the inundation of the valley that regularly occurred in spring. The actions undertaken included ditching and channelization, as described above, but also include the construction of a levee system. Constructed levees have decreased the functional floodplain area and quality, including shallow groundwater discharge, which historically added to summer baseflows. In some locations, roads may be functioning similarly to levees in that they constrain the channel and have disconnected some areas of floodplain.

The amount of water in the channel during the summer months has changed from historical conditions (Appendix A) and is having lethal effects on salmonids. The most obvious reason is irrigation diversions, which have the capacity to completely dry large segments of the creek, but other modifications also contribute. This includes disconnected floodplains due to channelization, levees, roads, and other changes that increase the rate of early season runoff with subsequent decrease in late season flows, decrease shallow groundwater storage, and reduce hyporheic function. In reaches 1 and 2 where hyporheic connections may have been a minimal contributor to baseflows, wetlands and shallow lakes, including beaver complexes would have been a major contributor of summer flows, but are now essentially non-existent. It is the cumulative effect of changes that contribute to the low summer flows that have a negative effect on salmonid populations. Changes such as channel and water efficiency improvements, and water storage projects implemented to benefit fish can contribute to the improved survival of spring Chinook salmon and steelhead.

12.2 Limiting Factors

Modifications to the watershed, floodplain, channel, and streambanks in Catherine Creek have a collective impact on the physical form, function, and processes to varying degrees for all reaches. Anthropogenic modifications directly and indirectly contribute to the known limiting factors including water quantity (low summer flows), water quality (elevated summer temperatures, low dissolved oxygen levels), poor habitat quantity and diversity (low abundance of pool habitat and lack of habitat diversity,) fish passage, excess fine sediment and degraded riparian conditions (NOAA Fisheries 2008a). These limiting factors likely affect all life stages of Chinook salmon to various degrees (NOAA Fisheries 2008a).

12.2.1 Water Quantity

Water quantity is listed as a limiting factor by NOAA Fisheries (2008). Water quantity is limiting typically in the later part of the summer when irrigation diversions and pumps are in operation (approximately mid-July through September) and baseflows are naturally low. Decreed water rights exceed the actual flow of Catherine Creek and permitted withdrawals can totally dry the creek in some locations (NOAA Fisheries 2008a). Within some reaches of Catherine Creek, typically below senior water rights (e.g., below Lower Davis Dam), limited flow is in large part a result of surface water diversion. However, it is unclear to what extent natural and other anthropogenic factors contribute to low baseflows. Low flows have likely always occurred within Catherine Creek during the late summer, but have likely been further reduced by historical logging within the watershed, channelization and road construction within the watershed, and channelization with modified floodplain interaction and wetland alteration within the valley. It is hypothesized that the combination of alterations to the watershed and the stream channel have likely changed the Catherine Creek hydrology with less attenuation of flow and higher peaks that occur earlier in time. If true, the change in the hydrology due to physical alterations within the watershed and stream channel would provide lower baseflows in late summer than those historically. Changes to the historical hydrology, and thus baseflows, would likely be cumulative as one moved from upstream to downstream, with the most profound effects found in the downstream reaches of the lower valley segment. Study of this hypothesis is beyond the scope of this document and represents a data gap. What is known is that for the current available flow conditions, during the late summer, surface water diversions create conditions in which little surface water can be found within sections of Catherine Creek. During dry periods, low flow may limit the ability for salmonids to holdup or migrate to sustainable refugia (NOAA Fisheries 2008a).

Another data gap regarding water quantity yet to be resolved is that of return flows and groundwater inputs. Reclamation performed a thermal survey of the creek in the summer of 2010 to identify possible inputs to the creek from groundwater and return flow

(Appendix C). During this survey, several locations within reaches 1 and 2 showed some variation in temperature that may indicate cold-water return flow or groundwater inputs, but this data has not been fully analyzed or verified to determine sources or magnitudes of groundwater inputs. Water quantity is a limiting factor throughout the studied area and is likely the most profound in reach 2 as low baseflows combined with senior water rights appropriations upstream can create conditions where little to no surface water may exist in portions of this reach during the irrigation season.

Additional inputs to the system occur downstream through the reach and include identified, but not verified, groundwater sources and minor tributary flows such that additional flow accumulates in reach 1. However, it appears that much of this additional flow is then utilized as irrigation withdrawn by pumping from the reservoir created by Elmer Dam. Several data gaps exist with regard to water quantity and include gaining a better understanding of:

- The locations and magnitudes of groundwater and return flow sources (inflows) and sinks (outflows).
- The reach specific changes to the unit hydrology of Catherine Creek due to watershed, floodplain, and channel modifications.
- The effects of climate change on the unit hydrology of Catherine Creek.

12.2.2 Water Quality

Water quality is listed as a limiting factor by NOAA Fisheries (2008a). The primary water quality issues are temperature, sediment, water withdrawal, and riparian condition (Nowak et al. 2004). A number of water quality parameters in Catherine Creek exceed standards established by the ODEQ. Due to water quality standards violations, Catherine Creek is included on Oregon’s 1998 Section 303(d) list (Table 7) (ODEQ 2000). Temperatures exceed standards throughout the entire stream studied; however, most of the remaining water quality standard violations occur on the lower reaches of Catherine Creek, from the mouth to RM 42.5 (reaches 1, 2, 3, and a portion of reach 4). The exception is sedimentation, which only exceeds ODEQ standards in the North and South Forks of Catherine Creek, as well as little Catherine Creek. Although these upper tributaries are not specifically included in this assessment, they contribute sediment to the mainstem of Catherine Creek.

Table 7. Reaches in Catherine Creek included in the 1998 Section 303(d) list for violating water quality standards (ODEQ 2000). (Note: Table below from ODEQ refers to "Union Dam," which is referred to in this report as CCACF and is located at RM 42.5.

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

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

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

Temperature data are probably the most comprehensive of water quality data for Catherine Creek and exist in the form of continuous monitoring data and thermal imagery. Existing temperature data confirm that summer temperatures typically exceed the ODEQ standard of 64.0^{0}F, which was established based on optimal temperatures for salmonid species. Temperatures are particularly high in the lower reaches of the creek, where they can reach 80^{0}F in August (Justice, McCullough, and White 2011; McCullough et al. 2011; Watershed Sciences 2000). The only sections of the creek that did not consistently exceed 64.0^{0}F were the North and South Forks and the very upper reaches of mainstem Catherine Creek (Justice, McCullough, and White 2011; McCullough et al. 2011; Watershed Sciences 2000; ODEQ 2000). As stated throughout this document, high temperatures beyond undetermined yet likely cooler historical conditions are likely the result of cumulative modifications throughout the watershed, floodplain, and channel. Water quantity directly affects water temperatures. Low summer flows (natural or reduced from modified watershed conditions) entering the study area are further reduced by surface diversion and are impounded behind several diversion dams, which allow surface waters to be heated further than if left unimpeded. To compound the matter, riparian conditions throughout the study area, although highly variable, are rated as substandard (GRMWP 1994; Nowak 2004; NOAA Fisheries 2008a). While not the only issue, riparian habitat degradation has been identified as the most serious problem in the subbasin (Nowak 2004). Riparian vegetation is especially sparse and provides little shade cover in lower Catherine Creek (Appendix H). Stream shade was below reference condition levels along 56 percent of miles surveyed on Catherine Creek (Huntington 1994).

Sediment is only included on the 303 (d) list for the North and South Forks of Catherine Creek, although there appears to be a problem throughout the stream in regards to salmonid spawning and egg incubation habitat. NOAA estimates that the approximate percent function of egg survival to emergence is 30 percent of potential due to fine sediment levels (CRITFC 2009). Another source of sediment within the study area appears to be from vertical and lateral erosion due to increased stream energy from channelization and reduced riparian function from vegetation alteration, vegetation removal, and livestock grazing (Appendix C).

Data on nutrients, pH, DO, ammonia toxicity, and bacteria were only found for the segment of the stream below river mile 43, just upstream of Union. This lower portion of Catherine Creek typically exceeds the ODEQ standard of 6 µ/L of Orthophosphate as P (USWCD nd; Miles nd; ODEQ 2007). Dissolved inorganic nitrogen (DIN) level standards of 26 µ/L are usually only exceeded below the town of Union, but not upstream or further downstream, which is probably due to algal and aquatic weed growth consuming nitrogen (USWCD nd; Miles nd). Bacteria levels also occasionally exceed ODEQ standards, which require that a 30-day log mean for a minimum of five samples cannot exceed 126 organisms per 100mL, particularly just downstream of Union. The Union WWTP stopped discharging effluent into Catherine Creek during summer months in 2001 per ODEQ recommendations. Ammonia levels appeared to decrease but the nutrient and bacteria levels detected below Union suggest that the urban land use area that the stream flows through is a significant non-point source of nutrient and bacteria loading. Catherine Creek has large 24-hour fluctuations in pH and DO with levels very near violations of water quality standards due to considerable aquatic plant and algae activity (Miles nd). It is unclear what the natural and unnatural sources are that create conditions when nutrients and temperatures affect other water quality parameters such as dissolved oxygen levels in Catherine Creek. However, it is clear that there is a direct correlation between low flows and excessive temperatures combined with a source (or multiple sources) of required nutrients to create algal problems especially within the lower valley segment of Catherine Creek.

12.2.3 Poor Habitat Quantity/Diversity

Poor habitat quantity and diversity is listed by NOAA Fisheries (2008a) as the result of a “low abundance of pool habitat and lack of habitat diversity.” The ODFW 2011 habitat survey of Catherine Creek confirms a low abundance of pool habitat and relatively low diversity of habitat (from modeling results) largely due to a lack of LWD and channelization throughout much of the study area (Appendix G).

Habitats are created through physical processes, which are renewed with changes, or spatial variability, in stream energy. Modifications to the channel alter physical processes resulting in altered habitat conditions. Pools are created at locations where abrupt changes in physical characteristics result in convergence of stream energy such as occur at bends, channel obstructions, and constrictions. Channelization and clearing can drastically reduce pool development by eliminating those areas of variability that promote flow and energy convergence that create and maintain pools. Historically, Catherine Creek has been managed for draining of floodwaters and routing of surface water for irrigation needs. Historic alterations have homogenized large portions of the creek within the study area for these purposes through logging, channelization efforts, beaver removal, and snagging and clearing of riparian vegetation (Gildemeister 1998). Past efforts to create efficient stream channels have altered stream energy, which has directly altered the ability for Catherine Creek to create and maintain pools and other instream habitat.

Other factors that contribute to poor habitat conditions include channel-spanning diversion dams, which likely alter sediment transport through the system. Each channel-spanning dam produces an artificial grade control, limiting stream power, and sediment transport capacity. These altered conditions exist upstream of each dam and can create sediment traps that are likely having significant influence on sediment transport processes through the system. Construction of levees, roads, and bank protection along the channel banks within all reaches may also reduce habitat quantity and diversity directly by riparian alteration and indirectly by increasing the stream power within the channel. Additionally, areas exist throughout the study area that are used for grazing of livestock with a minimal or no riparian buffer to the stream channel, which can lead to reduced native riparian vegetation, introduction of invasive weeds, and soil compaction which further limit the stream’s ability to renew habitat through natural stream processes.

Salmonids have evolved to inhabit natural streams in which habitats are created, destroyed, and renewed through physical processes that are related to stream sediments, energy dissipation, and riparian vegetation (large wood in the Pacific Northwest). Catherine Creek has been managed for other purposes to include the efficient outflow of floodwaters, installation of structures for diversion, bank protection, flood control, and vegetation alteration and removal. These management efforts as well as historic logging practices have greatly simplified the stream channel by altering the energy profile of the stream. Historically, the stream channel meandered more in reaches 1, 2, 3, and 4 as evidenced by historical oxbows, which would have created more pool habitats. Large wood was likely found to a much greater extent throughout the study area and would have created channel obstructions for pool development and habitat diversity. Finally, sediment transport processes have likely been altered from increased stream power in channelized and leveed reaches to decreased stream power upstream of channel-spanning diversion structures. The combination of alterations has led to a stream with limited habitat diversity.

12.3 Reach Discussion

The following section discusses some of the changes that have likely occurred from past to present in regards to physical habitat forming processes and resulting habitat value for ESA-listed spring Chinook salmon and steelhead at the reach scale within the study area of Catherine Creek.

12.3.1 Reach 1

Fish Habitat

Reach 1 was formerly the Grande Ronde River channel and likely had juvenile Chinook rearing habitat although the extent of use is unknown. It likely functioned as an intermittent lake with a mosaic of wetland habitats adjacent to multiple small spring-fed creeks. The unnamed creeks that formed from the springs along the eastern border of the reach would have provided a nearly constant temperature water source that would have been warmer than the main channel in the winter and cooler in the summer. This would have created valuable micro-habitats at their outlets with desirable water temperatures. It is difficult to know if high temperatures would have limited juvenile fish in the summer. There could have been years when maximum acceptable temperatures were exceeded; however, the historical accounts of long-term and seasonal flooding, the extensive wetlands, and springs would likely have made year-round rearing possible. If and when temperatures were not conducive, natural habitat connectivity would likely have allowed relatively easy migration to more preferable habitats. The period of time that temperature conditions were favorable would have been much longer than in the present condition.

Both summer and winter rearing habitat within reach 1 was rated fair by ODFW (Appendix G). The fair rating was based on all but one aspect of rearing habitat including substrate, pool area, complexity, and cover in the poor category and only stream gradient rated as good, which gave an overall rating of fair. However, the ODFW habitat model was developed with data from and for application in more typical mountain streams with higher gradients, gravel and larger bed material, step-pool and pool-riffle morphologies, and more abundant LWD. It does not apply well to this reach, which likely should be rated as poor quality for both winter and summer rearing.

During the summer months, reach 1 develops lethal temperatures for salmonids (ODEQ 2000). Further, multiple native and invasive species reside in the warm water temperatures and slow moving water of reach 1. Habitat within reach 1 currently favors invasive species such as carp, smallmouth bass, bullhead catfish, and bull frogs, which according to ODFW were all common in reach 1 (Appendix G). These invasive species may prey on juvenile fish and/or compete for limited resources.

Winter rearing habitat within reach 1 is likely poor based upon the 2011 ODFW habitat survey (Appendix G) and the 2009 and 2010 ODFW overwintering fish tracking study (Appendix H). The fish tracking study showed minimal use of reach 1 by overwintering juvenile salmonids fitted with tracking devices during the winter of 2009 and 2010. However, all fish must pass through this area of degraded habitat when out-migrating. Due to the required use of this reach by fish as a migration corridor and the presently degraded condition, this reach may be a reasonable candidate for improvement.

Reach 1 mainly functions as a migration corridor for ESA-listed spring Chinook salmon and steelhead. It has always been a migration corridor, but several modifications have made migration more difficult for both upstream and downstream migrants. Elmer Dam, located at RM 13.1, demarcates a hydraulic change within reach 1 and presents challenges to migration. Fitted with a fish ladder, this dam apparently causes little physical difficulty for upstream adult migrants to pass although the thermal stratification of the water column directly above the dam can increase the potential to create a thermal migration barrier directly downstream during low flow conditions. Juvenile fish, once downstream, might have difficulty going back upstream once they cross Elmer Dam. They may also be stressed as a result of the warm, slow-moving waters caused by the very low channel gradient on the valley floor. Salmonids require moving water to help them navigate and judge upstream and downstream directions. The stagnant water confuses them and they may become even more vulnerable to invasive predators and disease that thrive in such conditions.

Because reach 1 formerly contained both Catherine Creek and Grande Ronde River flows, it would have had a much higher discharge throughout the year including during the low flow season. Further, since the existing upstream diversions did not exist historically, low summer flows would not have been nearly as extreme as currently experienced. Upstream reaches of Catherine Creek and the Grande Ronde River would have provided higher baseflows and additional flow would have been gained within reach 1 from groundwater, off-channel beaver ponds, and spring creeks all located along the reach. The cumulatively higher low flows would have resulted in water temperatures lower than currently experienced and helped provide significantly more habitat.

Rhinehart Gap has a substantial backwater effect on the lower Grande Ronde River and Catherine Creek. The combination of this backwater effect and the hydrograph timing of the Grande Ronde River and Catherine Creek have significant effects on the hydraulics within reach 1. During typical spring flood conditions, the Grande Ronde River hydrograph rises earlier than Catherine Creek and remains high for an extended period. During the initial rise, the Grande Ronde River can flow upstream into Catherine Creek as far as Elmer Dam. This creates a condition of stagnant and even reverse flow that can occur on a nearly annual basis. This condition can confuse and stress out-migrating fish as they try to navigate "downstream." Conditions within this reach mimic those found in stagnant reservoirs, which have been shown to reduce migration rates of juvenile salmon (Raymond 1969). Additionally, studies have shown that reservoir conditions that support predatory fish provide increased mortality upon juvenile Chinook salmon (Rieman et al. 1991).

Juvenile fish may find themselves off-channel either by choice while seeking refuge, by confusion, or because of the attraction from current created by moving water. Presently, off-channel conditions pose several likely hazards to juvenile fish including the possibility of stranding as they are left behind levees or within oxbows when the water recedes. Conditions for outmigration through reach 1 may have always been somewhat challenging for juvenile fish as Rhinehart Gap historically produced a backwater lake during spring runoff and a mosaic of wetland channels existed off the main channel. However, flow was all in the downstream direction as this was the Grande Ronde River channel and had the combined flows of both Catherine Creek and the Grande Ronde River. Additionally, when fish sought refuge off of the main channel, they were likely presented with connected side channels (i.e., an escape) that had protective cover from predators and no introduced predatory species were present.

Conditions in reach 1 were likely never appropriate for spawning, in part because sediments within this reach consist of silty sand (fluviolacustrine) deposits. These fine-grained sediments are indicative of frequent flooding and a very low energy environment that would not provide the size of substrate necessary for spawning by spring Chinook salmon or steelhead. Additionally, egg incubation requires clean water and dissolved oxygen passing through the substrate (hyporheic flow) which has likely never been present in this reach because of the low gradient and cohesive, low permeability soils.

12.3.2 Reach 2

Fish Habitat

Reach 2 was likely and is currently an important reach of river for juvenile rearing Chinook salmon and steelhead populations, however, it now has extremely limited habitat. It historically contained a shallow lake (Tule Lake) and a mosaic of wetland habitats that likely fluctuated in size with the seasons. It likely contained vast amounts of complex habitats including micro-habitats with variable water temperatures. It is difficult to know if temperatures would have limited juvenile fish in the summer historically; there could have been years when maximum acceptable temperatures were exceeded but it was likely infrequent and short term if it occurred. If, and when, temperatures were not conducive, natural habitat connectivity would likely have allowed relatively easy migration to more preferable habitats.

Both summer and winter rearing habitat within reach 2 were rated fair by ODFW for spring Chinook salmon and poor for steelhead (Appendix F). The fair rating was based on all but one aspect of rearing habitat including substrate, pool area, complexity, and cover to be in the poor category, with only stream gradient rated as good, which gave an overall rating of fair (Appendix G). However, the ODFW habitat model was developed with data and for application in more typical mountain streams with higher gradients, gravel and larger bed material, step-pool and pool-riffle morphologies, and more abundant LWD. It does not apply well to this reach, which likely should be rated as poor quality for both winter and summer rearing.

During the summer months, reach 2 develops lethal temperatures for salmonids (ODEQ 2000). Further, multiple native and invasive species reside and appear to thrive in the warm water temperatures and slow moving water in reach 2. Habitat within reach 2 currently favors invasive species such as carp, smallmouth bass, largemouth bass, bullhead catfish, and bullfrogs.

Winter rearing habitat within reach 2 is limited and of poor quality based upon the 2011 ODFW habitat survey (Appendix G) but the 2009 and 2010 ODFW fish tracking study (Appendix H) showed the common use of reach 2 by overwintering juvenile salmonids. All fish must pass through this area of degraded habitat when out-migrating and a substantial proportion of juveniles overwinter in this area. Due to the required use of this reach by fish as a migration corridor, the presently degraded condition suggests this reach is a logical candidate for improvement.

Reach 2 functions as a migration corridor and as juvenile rearing habitat for ESA-listed spring Chinook salmon and steelhead. Several modifications within the reach, including diversion dams, have made migration more difficult for both upstream and downstream migrants. Upper Davis (RM 35.0) and Lower Davis (RM 34.4) dams present a challenge to migration. Fitted with fish ladders, these dams may cause little physical difficulty for upstream adult migrants to pass although the thermal stratification of the water caused by low velocities due to the very low gradient may increase the potential to create a thermal migration barrier during the summer. Juvenile fish, once downstream, may have difficulty going back upstream once they cross the dams. They may also be stressed as a result of the warm, slow water pools upstream of the dams.

Juvenile fish may find themselves off-channel either by choice while seeking refuge, by confusion, or because they are attracted by moving water created by current. Presently, off-channel conditions pose several likely hazards to juvenile fish including the possibility of stranding as they are left behind levees or within oxbows when the water recedes. These off-channel areas currently provide little refuge or cover from predators including invasive species and birds, such as herons and cormorants known to inhabit this reach. Historically, when fish sought refuge off of the main channel, they were likely presented with connected side channels (i.e., an escape) that had protective cover from predators and no introduced predatory species were present.

Conditions in reach 2 were likely never appropriate for spawning as the reach consists of silty sand (fluviolacustrine) deposits. These fine-grained sediments are indicative of frequent flooding and a low gradient that develop a low energy environment that would not provide the size of substrate necessary for spawning by spring Chinook salmon or steelhead. Additionally, egg incubation requires clean water and dissolved oxygen passing through the substrate (hyporheic flow) which has likely never been present in this reach because of the low gradient and cohesive, low permeability soils.

12.3.3 Reach 3

Fish Habitat

All life-stages of spring Chinook salmon and steelhead used reach 3 historically and that pattern continues presently (Appendix F). However, the modifications that have taken place have changed and limited the available habitat and the quality of the habitat, which has had an influence on fish use. Historically, the reach was likely good quality summer and winter juvenile rearing habitat and provided good spawning and incubation habitat. The 2011 ODFW habitat survey rates this reach from fair to good depending on the species and life-stage (Appendix G).

The fair quality rating is a result of a limited number of pools, limited pool complexity, and low abundance of LWD (Appendix G). Although pools are not likely to be particularly abundant near the apex of the alluvial fan, it is likely that they were more common than they are today due to the channelization and minimal woody debris. Channelization and other channel modifications have straightened the channel in the downstream third of the reach reducing the number of pools formed and maintained by meander bend geometry. LWD is also important for pool formation and maintenance but the availability of LWD to the channel has decreased. Reductions in riparian zone quantity, complexity, and stand age class variability have led to less LWD being available and fewer pools and less pool complexity.

Pools also provide complex stream bottom topography associated with suitable spawning grounds. Pool-riffle series provide variable water velocities and energy forces that are necessary for downwelling and upwelling water, which support incubation and can sort appropriately size spawning gravels when present.

The overall reduction in pools has led to less cover and refugia resulting in reduced habitat. Juvenile fish require complex pools to have size appropriate hiding places, food, and deep pools for protection from extreme temperatures, including ice. If such habitat is not present or is already being used by others, fish will have to seek out other locations, which may or may not be suitable.

12.3.4 Reach 4

Fish Habitat

Catherine Creek spring Chinook salmon utilize reach 4 for all freshwater life stages. Changes to reach 4 include channel straightening and bank protection, roadway construction, and clearing of the floodplain. While this reach presents fair substrate and conditions for spawning, the success of redds once they are in place is unknown. Excess energy within portions of this reach may create conditions in which redds are “blown out” during late fall and winter flood conditions or by anchor ice.

The 2011 habitat survey by ODFW rated the reach as fair for both summer and winter rearing habitat for spring Chinook salmon throughout. The fair rating was due mostly from a lack of suitable pool area, undercut banks, large wood, and cobble substrate. The same rating of fair was given for steelhead in this reach for summer rearing, but a “good” rating was received for the whole reach for winter steelhead rearing. Most of the reach had few pools, but there was adequate depth and structure for rearing steelhead.

The ODFW habitat survey rated the reach as fair for spawning to emergence for both spring Chinook salmon and steelhead. The fair rating of reach 4 for spawning was a result of limited cobble in the riffle substrate consisting of mostly gravels (Appendix G).

12.3.5 Reaches 5, 6, and 7

Fish Habitat

All life-stages of spring Chinook salmon and steelhead likely used reaches 5, 6, and 7 historically and that pattern continues presently. Modifications that have taken place in these reaches, although relatively minor in comparison to downstream reaches, have decreased the available habitat and the quality of the habitat, which has had an influence on fish use. Historically, these reaches most likely would have been good quality summer and winter juvenile rearing habitat and provided good spawning and incubation habitat. This is particularly true in reach 6 which is unconfined and has more potential for pool-riffle sequences, meander bends, and LWD accumulation.

The 2011 ODFW habitat survey rated reach 6 as fair for Chinook salmon rearing and good for spawning and emergence. Steelhead ratings are good for spawning and winter rearing and fair for summer rearing. While ratings for reaches 5 and 7 are somewhat similar, they are likely much closer to the historical and potential ratings than reach 6. Less than optimal ratings among these three reaches was generally a result of limited pool area and pool complexity, but excess fine sediment, few undercut banks, and reduced LWD abundance also decreased the ratings (Appendix G).

12.4 Data Gaps

This TA is a large-scale evaluation of the physical processes and fish habitat conditions along Catherine Creek and is designed to provide broad understanding of the creek. TAs are a first step in a multi-tiered approach to effectively and efficiently implement salmon habitat rehabilitation projects. During the TA process, data gaps are identified that indicate needs for future work and provide a basis for developing a priority system for completion when working towards a finer-scale process understanding and project development.

Much of the data necessary for a finer level of analysis on the identified reaches were gathered during preparation of this TA; however, considerable data gaps still exist. The following is a listing of data needs to further refine and improve understanding of specific reach functions, processes, forms, and habitat needs in order to identify and implement the most beneficial and effective habitat rehabilitation actions.

12.4.1 General Data Needs

A central, but important data gap to be answered in all reach assessments is the determination and delineation of areas to protect and those to improve. It is generally accepted that a top priority for salmonid habitat includes protection of existing substantial and well-functioning habitats (Roni et al. 2002). Once identified the high-quality habitat areas can also be used as a guide or goal for other areas. Non-functioning and disconnected habitats with appropriate potential for rehabilitation also need to be delineated together with other areas that are in poor condition, but may not have significant potential for salmon habitat improvement.

Water Quantity Data Needs

An identified data gap is a lack of understanding of the total water budget for the subbasin area. This information would be helpful in determining potential actions to address water quantity issues that are limiting fish in Catherine Creek. Throughout reaches 1 through 4, a complex system of diversions, irrigation ditches, cross-valley transfers, points of use, storage, and returns exist.

Fish Biology Data Needs

A significant data gap exists in defining existing causal mechanisms of mortality that has been documented in the Grande Ronde Valley to migrating juvenile Chinook salmon.

Beyond overwintering and migration questions being addressed by ODFW research, additional data gaps include data and analyses needed to answer the following key biologic questions within the study area that are critical information needed for improving the survival of Catherine Creek spring Chinook salmon as listed below:

1. Are habitat conditions for juvenile spring Chinook salmon (Age 0 to fry) in rearing areas upstream of Pyles Creek limiting such that those conditions are forcing fish downstream earlier than what they experienced historically?
2. Are the upstream watershed and downstream valley habitats disconnected during critical periods that challenge fish survival (e.g., low flows, anchor ice)?

A further need involves the interaction of predators and competitors including introduced and non-native species with juvenile anadromous fish.

Low Flow Migration Barriers

1. Are juvenile spring Chinook salmon or steelhead being stranded in any parts of reaches 1 through 4?
2. If so, is the migration barrier due to a physical or thermal barrier?
3. Can the barrier(s) be remedied such that the condition would not be lethal?

12.4.2 Reach Specific Data Needs

Reach 1

1. How often and when do flow reversals or stagnant conditions occur?
2. How far upstream can these conditions reach?
3. Are these conditions leading to increased out-migrant mortality?
4. Could changes to Catherine Creek or the Grande Ronde River eliminate or reduce these negative impacts?
5. Does the “underfit stream” condition of reach 1 lead to more extreme low flow barriers and higher water temperatures?

It is not known if fish are stranded after the floods recede.

Further data gaps include:

1. Locations of unscreened diversions.
2. Locations and magnitude of groundwater inflows.
3. Physical structures counts and locations – levees, diversions, pumps, storage areas, roads, bridges.
4. Details of Elmer Dam operations (changes and timing).

5. Habitat conditions in oxbows and egress functions.

Reach 2

As in reach 1 the oxbows, levees, and other structures may be a source of out-migrant mortality and require further consideration. Other data gaps include:

1. Locations of unscreened diversions.
2. Locations and magnitude of groundwater inflows.
3. Physical structure counts and locations – levees, diversions, pumps, storage areas, roads, bridges.
4. Details of Elmer Dam operations (because the backwater effects of Elmer Dam reach upstream into the lower end of reach 2).

Reach 3

1. What are the sediment transport characteristics throughout this reach, including:
    - How much bedload is being trapped in the diversion dams and what are the downstream effects to habitat?
    - Are the diversions cleaned out and what is the operational schedule? Are there times when diversions can pass bedload? If so, how often is this condition likely to occur and what size material can pass?
2. Is the carrying capacity of pools, for supporting summer or winter rearing juveniles, reached on a regular basis such that some fish are forced downstream into less desirable habitat?
3. Is winter rearing mortality high as a result of anchor ice or ice flows in combination with minimal deep water pools or other necessary refugia?

Reach 4

Data gaps in reach 4 include all the general data gaps as well as those indicated in reach 3. In addition, there are further data gaps concerning the amount of incision in the reach and the extent of reduced instream and riparian habitat associated with the highway.

Reach 5, 6, and 7

Data gaps in reaches 5, 6, and 7 are minimal largely because the amount of modification in these reaches is minimal. The only known data gap of significance is the determination of areas for protection and improvement.

13. Conclusions

13.1 Reach 1

Reach 1 is an important reach to develop and maintain appropriate conditions for salmonids and it is currently in poor condition.

Specific needs in reach 1 to improve spring Chinook salmon and steelhead survival include:

- Locating specific areas for protection and improvement.
- Minimizing out-migrant mortality.
- Improving habitat complexity and connectivity.
- Increasing LWD abundance and retention.
- Improving riparian community extents, recruitment, and function.
- Maximizing fish passage for all life stages at all diversions.
- Increasing summer low flow.

While the existing limiting factors are relatively straightforward and relate back to the changes that have initiated them, it may not be possible to simply reverse many of the changes. For instance, landownership, concern over flooding, water rights and other factors would likely prevent the return of the Grande Ronde River into a more historic channel alignment. Similar issues would also likely prevent the return of a substantial beaver population as well as many of the other historic conditions within the watershed. Since it may be impossible to restore fully the processes that would naturally develop and maintain salmonid habitat in this reach, direct construction of habitat may be necessary. Improving conditions within the reach may require addressing the limiting factors in new ways.

The loss of complex aquatic habitat, low summer discharges, high summer temperatures, and low dissolved oxygen in reach 1 is principally a result of the:

1. Redirection of the Grande Ronde River.
2. Water withdrawal in this reach and upstream reaches which removes a majority of the flow and can completely dry the creek.
3. Extirpation of beaver.
4. Draining of wetlands and lakes.
5. Clearing of riparian areas.
6. Changes in land use, especially urban areas and drained agricultural lands.
7. Effects of diversion dam backwater/reservoir.

Several approaches to address this reach would require extensive study. This reach is 22.5 miles long and lacks specific habitat typically preferred by the target species. Implementing individual projects may still leave extended distances between specific types of habitats such as refugia for juveniles. This problem is further accentuated by similar habitat issues in reach 2. A single habitat project in the middle of reaches 1 and 2 would still leave nearly 20 miles of creek with little to none of the specific habitat type targeted by the project.

The development of simple, inexpensive habitat improvement designs that can be easily repeated at new locations may aid in the implementation of habitat projects that provide the necessary habitat connectivity on a large scale.

This would allow more, simple habitat projects to be completed that reduce the distance, and therefore risk for salmonids, between specific habitat types. Initially, a pilot project could be constructed and used for the ODFW study and to help provide future design guidance.

Conducting a more detailed hydrologic and hydraulic study (including a 1-D unsteady model) would assess current hydraulic conditions experienced by out-migrants. The results could potentially be paired with existing and future ODFW fish tracking results to determine the relationship between out-migrating fish velocities and water velocities.

This approach involves a study of the flooding and related hydraulic conditions with the goal of identifying potential actions that may include improving floodplain connectivity and processes, reducing or negating fish stranding, and adjusting the geomorphic configuration of the channel to better match the discharge of Catherine Creek in the absence of Grande Ronde River water. The hydraulic model could be further combined with ecosystem models and stream temperature models to guide the design of habitat related projects. It could be especially beneficial to guide floodplain reconnection projects by providing guidance for shaping of the banks to improve hydrologic and hydraulic conditions optimized to build and sustain riparian and near edge habitats.

A water balance could provide guidance to help address the low flow concerns and provide a framework for determining the amount of benefit of potential actions.

A reach-scale assessment that combines the findings of these studies, a more detailed geomorphic assessment, and an analysis of instream and riparian conditions at a finer-scale than this TA would guide future project planning and design.

13.2 Reach 2

Specific needs in reach 2 to improve spring Chinook salmon and steelhead survival include:

- Locating specific areas for protection and improvement.
- Minimizing out-migrant mortality.
- Improving habitat complexity and connectivity.
- Increasing LWD abundance and retention.
- Improving riparian community structure and function.
- Maximizing fish passage at all life stages at diversions .
- Increasing summer instream flows.

The loss of complex aquatic habitat, low summer discharge and subsequent high summer temperatures and low dissolved oxygen principally results from:

1. Extirpation of beaver.
2. Draining of wetlands and Tule Lake.
3. Water rights that exceed the available water supply.
4. Channelization.
5. Clearing of riparian areas.
6. Changes in land use, especially to urban areas and drained agricultural lands.
7. Secondary effects of existing diversion dams,(i.e., thermal stratification of the water column).

While the existing limiting factors are relatively straightforward and relate back to the changes that have initiated them, it may not be possible to simply reverse many of the changes. Landownership, concern over flooding, water rights and other factors would likely prevent the return of Catherine Creek to a more historic channel alignment and the redevelopment of Tule Lake. Similar issues would also likely prevent the return of a substantial beaver population as well as many of the other historic conditions within the watershed. Since it may be impossible to fully return the processes that would naturally develop and maintain salmonid habitat in this reach, direct construction of habitat may be necessary. Improving conditions within the reach may require addressing the limiting factors in new ways.

Similar to reach 1, several approaches to address this reach may require further study. This reach is nearly 15 miles long and lacks certain specific habitat types used by the target species. Implementing individual habitat projects to provide these specific habitat types would still leave extended distances between these habitats. This problem is further accentuated by the similar habitat issues downstream in reach 1. A single habitat project in the middle of reaches 1 and 2 would still leave nearly 20 miles of creek with little to none of the specific habitat types targeted. In addition, this reach has invasive predators that may benefit from habitat projects to the detriment of salmonids.

As in reach 1, conducting a more detailed hydrologic and hydraulic study (including a 1-D unsteady model) developed to assess current hydraulic conditions experienced by out-migrants would provide results that could potentially be paired with existing and future ODFW fish tracking results to determine the relationship between out-migrating fish velocities and water velocities. If a relationship is found the model could be revised to test proposed conditions and determine expected out-migrant benefits of various actions. This could be accomplished as a combined effort for reaches 1 and 2 as both reaches would be required to properly model boundary conditions within the hydraulic model.

Also as in reach 1, a water balance could provide guidance to help address the low flow concerns and provide a framework for determining the amount of benefit of potential actions.

The ODFW fish tracking studies noted in reach 1 previously would also be applicable to reach 2.

13.3 Reach 3

Specific needs in reach 3 to improve spring Chinook salmon and steelhead survival include:

- Locating specific areas for protection and improvement.
- Improving habitat complexity and connectivity.
- Increasing LWD abundance and retention.
- Increasing summer instream flows.
- Examining alternative grazing options in riparian areas.
- Improving riparian community structure and function.
- Returning channel to a meandering planform where feasible and appropriate.
- Locating and assessing local and upstream sources of bedload and fine sediment.
- Refine fish passage as necessary (e.g., Swackhammer smolt bypass pipe).

The loss of complex in-channel habitat may be one of the main causes of limited Chinook salmon production in this reach. The loss of high quality habitat is principally a result of reduced summer flows, increased summer water temperatures, excess fine sediment, and reduced fish passage which are all or partly a result of:

1. Channelization.
2. Clearing of native riparian areas for agriculture and domestic use.
3. Extirpation of beaver.
4. Draining of wetlands and connected habitats.
5. Diversion dams.
6. Water withdrawals.
7. Degraded streambanks and poor riparian condition.
8. Imported sediments from upstream reaches.

Evidence suggests that this reach is high priority for implementing habitat projects with an influence on returning processes that will create and maintain high-quality instream habitat.

An assessment of this reach that includes a more detailed geomorphic assessment and an analysis of instream and riparian conditions at a finer scale would inform future habitat rehabilitation efforts. The assessment should focus on responding to limiting factors, determining areas to protect and rehabilitate, and the development of a guide for future project planning and design. Further, Appendix B – Water Quality, indicates that ODEQ has suggested that the town of Union not discharge effluent during summer months because of water quality concerns. This should be further evaluated to determine if sewage treatment improvements such as tertiary treatment could provide increased flow to Catherine Creek without adversely impacting water quality.

13.4 Reach 4

Specific needs in reach 4 to improve spring Chinook salmon and steelhead survival include:

- Locating specific areas for protection and improvement.
- Improving habitat complexity and connectivity.
- Increasing LWD abundance and retention.
- Examining alternative grazing options in riparian areas.
- Improving riparian community structure and function.
- Maximizing summer instream flows.

The loss of complex in-channel habitat may be one of the main causes of limited Chinook salmon production in this reach. The loss of habitat in this reach is principally a result of:

1. Channelization.
2. Clearing of native riparian areas for agriculture use.

3. Livestock grazing.
4. Extirpation of beaver.
5. Draining of wetlands and connected habitats.
6. Diversion dams.

Fish passage problems, reduced habitat quantity and diversity, reduced summer flows, increased summer water temperatures, degraded riparian conditions, low DO, and excess fine sediment are all results of a combination of:

- Degraded streambanks and poor riparian condition.
- Stream channelization with ensuing altered hydraulics.
- Livestock grazing.
- Upland forestry practices and road building.

An assessment for this reach that provides an evaluation of floodplain connections, diversions, road and channel interactions, fine sediment sources, and other processes related to the limiting factors identified would assist in the development of the most effective habitat actions for this reach. The reach assessment should provide a clear analysis of areas for protection and areas that could benefit from rehabilitation.

13.5 Reaches 5, 6, and 7

Specific needs in reaches 5, 6, and 7 to improve spring Chinook salmon and steelhead survival include:

- Protecting good quality habitats.
- Locating specific areas for protection and improvement.
- Increasing LWD abundance and retention.
- Improving riparian community structure and function.
- Focusing on improving areas where roads and related infrastructure have encroached on the channel.
- Evaulating feasibility of and need for beaver reintroduction.

Rehabilitation efforts should focus on the limiting factors affecting spring Chinook salmon including the lack of deep pools and limited channel complexity.

Improving the quantity and complexity of pools in the upper reaches should include a return of the processes and forms that tend to create and maintain pool habitats including the addition of LWD, allowing the channel to meander within and across its floodplain, and, where possible, beaver activity.

The riparian condition and function should also be improved where possible. This could include planting in specific areas reducing or even eliminating grazing in and near the channel and riparian zone. Improving the riparian area could itself benefit in channel complexity, protective cover, and be a source of nutrients and macro-invertebrates.

14. Reach Prioritization

An IDT meeting was held on September 12, 2011 to present and discuss the Catherine Creek TA. The goal of the meeting was to provide a final update on the TA and collect input and feedback regarding priority reaches to focus upcoming reach assessments.

Further, it was agreed that reaches 5 through 7 are currently in relatively good condition and therefore not a priority for focusing immediate resources. Reaches 1 through 4 have a substantial gap between the current and potential habitat quantity and quality, have high fish use, and experience high fish mortality. Therefore, reaches 1 through 4 were selected as priority reaches.

The next steps include conducting geomorphic reach assessments in reaches 3 and 4 with further hydrologic and hydraulic analysis and continued support of the ODFW fish tracking study as it continues to identify the causes of juvenile fish mortality.

Reaches 1 and 2 are technically more challenging and several larger questions remain which will be investigated further in order to determine assessment or action needs. These include further study of the cause(s) of fish mortality and the assessment of the unsteady hydraulic connections between the Grande Ronde River and Catherine Creek. Specifically, this investigation will attempt to determine the effects of the current channel configuration and resultant slow or even reverse flow velocities in lower Catherine Creek on outmigration of smolts. The results will also provide a framework for developing existing conditions flow models to determine the effect of future proposed projects.

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16. Geospatial Data Source and Description

100 Year Potential Flood Depths − *CatherineCrk_inundation_100yr*, Reclamation Technical Service Center. Depth results from a steady-state 1-D HEC-RAS model of potential flooding for the 100-year discharge within the bounds of defined cross sections. Modeled water surface elevations were subtracted from the terrain surface (derived from LiDAR) to calculate potential flooding depths.

Background Imagery − *National Agriculture Imagery Program (NAIP) aerial imagery (2009)*, USDA Farm Service Agency. Aerial imagery acquired during agricultural growing seasons in the continental U.S.

Bull Trout Habitat Use − *Bull Trout Habitat Distribution*, Oregon Department of Fish and Wildlife, 06/09/2008. These data describe areas of suitable habitat believed to be used (currently and historically) by wild, natural, and / or hatchery fish populations and are based on professional judgment.

Catherine Creek Study Reaches − *NHD Flowlines*, U.S. Geological Survey. The National Hydrography Dataset (NHD) is a feature based database of the nation's surface water drainage system.

Catherine Creek Tributary Assessment Study Area − Catherine Creek Study Area, Reclamation PNGIS. Based on FEMA 100-year flood plain.

Catherine Creek Watershed − *CatherineCreekWatershed*, Reclamation PNGIS. Created from the USGS 10-meter National Elevation Dataset.

City Limits − *CityCivilDivisions*, NAVTEQ. NAVTEQ incorporated and enhanced data from a number of sources to produce a geospatial dataset of boundaries for medium and larger sized U.S. cities.

Dam/Diversion − *Dams_xy*, Reclamation River Systems Analysis Group. Location coordinates collected using GPS.

Elevation Contour − *Contours_50ft_CCW*, Reclamation PNGIS. Created from the USGS 10-meter National Elevation Dataset.

FLIR − *Catherine Creek*, Oregon Department of Environmental Quality (ODEQ). ODEQ contracted with Watershed Sciences, LLC to map and assess stream temperatures in the Grande Ronde River basin using Forward Looking Infrared (FLIR). The FLIR survey was conducted from August 20-26, 1999 to capture daily strem temperatures between the hours of 2:00 and 6:00 P.M..

Geomorphic Landform Description − *Soil Survey Geographic Database (Union County and Wallowa-Whitman National Forest)*, USDA Natural Resources Conservation Service. This digital soil survey provides the most detailed level of soil geographic data developed by the National Cooperative Soil Survey.

Grande Ronde River Contributing Area – *GrandeRondeContributingArea*, Reclamation PNGIS. Created from the NRCS Watershed Boundary Dataset by combining the Lower Grande Ronde, Upper Grande Ronde, and Wallowa Subbasins (HUC 8 features).

Land Cover/Land Use − *NLCD 2006 Land Cover*, U.S. Geological Survey. The National Land Cover Database (NLCD) is public domain information on land use and land cover.

Major Stream − *NHD Flowlines*, U.S. Geological Survey. The National Hydrography Dataset (NHD) is a feature based database of the nation's surface water drainage system.

River Mile − *CatherineCrk_rivermile*. Reclamation PNGIS. Calculated from the Pacific Northwest (PNW) Hydrography Framework dataset.

Reach Break − *ReachBreak*, Reclamation River Systems Analysis Group. Stream break locations are based on landform and stream morphology.

Spring − **NHD Points**, U.S. Geological Survey. The National Hydrography Dataset (NHD) is a feature based database of the nation's surface water drainage system.

Spring Chinook Habitat Use − *Oregon Fish Habitat Distribution - Spring Chinook*, Oregon Department of Fish and Wildlife, 02/05/2010. These data describe areas of suitable habitat believed to be used currently by wild, natural, and / or hatchery fish populations and are based on sampling, professional opinion, or modeling.

Spring Chinook Over-wintering Observations − *SpringChinook_20091021_20100322*, Reclamation and Oregon Department of Fish and Wildlife (ODFW). The data were collected as a joint effort between Reclamation and ODFW to track juvenile Spring Chinook and determine their spatio-temporal distribution in Catherine Creek, a tributary of the Grande Ronde River.

Summer Steelhead Habitat Use − *Oregon Fish Habitat Distribution – Summer Steelhead*, Oregon Department of Fish and Wildlife, 03/09/2010. These data describe areas of suitable habitat beleived to be used currently by wild, natural, and / or hatchery fish populations and are based on sampling, professional opinion, or modeling.

Surface Elevation − *10-meter digital elevation model (DEM) and hillshade*, Reclamation PNGIS. Created from USGS National Elevation Dataset 1/3 arc-second FLT (binary) files.

Surficial Geology Description − *Oregon Geology*, Oregon Department of Geology and Mineral Industries (DOGAMI). Oregon DOGAMI digitally compiled geologic data for the entire state of Oregon, bringing together the best available geologic mapping from state and federal agency sources. **Map Credits** − The mapping of surficial geology is based on the work of Mark Ferns and Vicki McConnell (Oregon DOGAMI, 2002. A groundwater case study: Catherine Creek and the Upper Grande Ronde Valley. Cascadia, volume 2 number 1, page 7.)

Waterbody − *NHDWaterbodie*s, U.S. Geological Survey. The National Hydrography Dataset (NHD) is a feature based database of the nation's surface water drainage system.

Disclaimer

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18. Glossary

Term	Definition
action	Proposed protection and/or rehabilitation strategy to improve selected physical and ecological processes that may be limiting the productivity, abundance, spatial structure or diversity of the focal species. Examples include removing or modifying passage barriers to reconnect isolated habitat (i.e., tributaries), planting appropriate vegetation to reestablish or improve the riparian corridor along a stream that reconnects channel-floodplain processes, placement of large wood to improve habitat complexity, cover and increase biomass that reconnects isolated habitat units.
adfluvial	Fish that migrate between lakes and rivers or streams. These fish may also be called lacustrine and are sometimes further characterized as to whether they spawn in outlet tributaries (allacustrine) or inlet tributaries (lacustrine-adfluvial).
alluvial deposit	*alluvium*

Term	Definition
alluvial fan	An outspread, gently sloping mass of alluvium deposited by a stream, esp. in an arid or semiarid region where a stream issues from a narrow canyon onto a plain or valley floor. Viewed from above, it has the shape of an open fan, the apex being at the valley mouth.
alluvial plain	A level or gently sloping tract produced by extensive deposition of alluvium, usually adjacent to a river that periodically overflows its banks; it may be situated on a flood plain, a delta, or an alluvial fan.
alluvium	A general term for detrital deposits made by streams on river beds, floodplains, and alluvial fans; esp. a deposit of silt or silty clay laid down during time of flood. The term applies to stream deposits of recent time. It does not include subaqueous sediments of seas and lakes.
anadromous fish	A fish, such as the Pacific salmon, that spawns and spends its early life in freshwater but moves into the ocean where it attains sexual maturity and spends most of its life span.
anthropogenic	Caused by human activities.
aquifer	A body of rock that is sufficiently permeable to conduct ground water and to yield economically siginificant quantities of water to wells and springs.
avulsion	The rapid abandonment of a channel and the formation of a new river channel.
bajada	A broad, continuous *alluvial slope* or gently inclined detrital surface extending from the base of mountin ranges out into and around an inland basin, formed by the lateral coalescense of a series of separate but confluent *alluvial fans.*
bedrock	The solid rock that underlies gravel, soil or other superficial material and is generally resistant to fluvial erosion over a span of several decades, but may erode over longer time periods.
beneficial use	Legislatively approved use of water for the best interest of people, wildlife and aquatic species (ODEQ 2000).
canopy cover (of a stream)	Vegetation projecting over a stream, including crown cover (generally more than 1 meter [3.3 feet] above the water surface) and overhang cover (less than 1 meter [3.3 feet] above the water).
cfs	Cubic feet per second; a measure of water flows

Term	Definition
channel forming flow	Sometimes referred to as the effective flow or ordinary high water flow and often as the bankfull flow or discharge. For most streams, the channel forming flow is the flow that has a recurrence internal of approximately 1.5 years in the annual flood series. Most channel forming discharges range between 1.0 and 1.8. In some areas it could be lower or higher than this range. It is the flow that transports the most sediment for the least amount of energy, mobilizes and redistributes the annually transient bedload, and maintains long-term channel form.
channel morphology	The physical dimension, shape, form, pattern, profile and structure of a stream channel.
channel planform	The two-dimensional longitundinal pattern of a river channel as viewed on the ground surface, aerial photograph or map.
channel stability	The ability of a stream, over time and under the present climatic conditions, to transport the sediment and flows produced by its watershed in such a manner that the stream maintains its dimension, pattern and profile without either raising or lowering the elevation of the streambed.
channel units	Morphologically distinct areas within a channel segment that are on the order of at least one to many channel widths in length and are defined by distinct hydraulic and geomorphic conditions within the channel (i.e. pools, riffles, and runs). Channel unit locations and overall geometry are somewhat stage dependent as well as transient over time, and observers may yield inconsistent classifications. To minimize the inconsistencies, channel units are interpreted in the field based on the fluvial processes that created them during channel forming flows, then mapped in a geographic information system (GIS) to provide geospatial reference.
channelization	The straightening and deepening of a stream channel, to permit the water to move faster, to reduce flooding, or to drain marshy acreage.
control	A natural or human feature that restrains a streams ability to move laterally and/or vertically.
degradation	Transition from a higher to lower level or quality. A general lowering of the earth’s surface by erosion or transportation in running waters. Also refers to the quality (or loss) of functional elements within an ecosystem.
diversity	Genetic and phenotypic (life history traits, behavior, and morphology) variation within a population. Also refers to the relative abundance and connectivity of different types of physical conditions or habitat.
ecosystem	An ecologic system, composed of organisms and their environment. It is the result of interaction between biological, geochemical and geophysical systems.

Term	Definition
evapotranspiration	Loss of water from a land area through transpiration of plants and evaporation from the soil.
extirpation	The loss of a local or regional population, with the species continuing to survive elsewhere.
fan delta	A gently sloping alluvial deposit produced where a mountain stream flows out into a lowland.
fine sediment	Sand, silt and organic material that have a grain size of 6.4 mm or less.
FLIR **thermal imagery**	Forward looking infrared radiometer (FLIR) thermal imagery is a direct measure of the longer wavelengths emitted by all bodies. The process by which bodies emit longwave radiation is described by the Stefan-Boltzmann 4th Order Radiation Law. FLIR monitoring produces spatially continuous stream and stream bank temepration information. Accuracy is limited to 0.5oC. FLIR thermal imagery often displays heating processes as they are occuring and is particularly good at displaying the thermal impacts of shade, channel morphology and groundwater mixing (ODEQ 2000).
floodplain	The portion of a river valley, adjacent to the channel, which is built of sediments deposited during the present regimen of the stream and is covered with water when the river overflows its banks at flood stages.
fluvial	Produced by the action of a river or stream. Also used to refer to something relating to or inhabiting a river or stream. Fish that migrate between rivers and streams are labeled “fluvial”.
fluvial geomorphology	The study of stream channel and floodplain pattern and geometry as well as the sediment, sediment sources and sediment transport regimes, and the analysis of how the stream channel and floodplain form and function interact.
fluvial process	A process related to the movement of flowing water that shape the surface of the earth through the erosion, transport, and deposition of sediment, soil particles, and organic debris.
general indicator	Reach, valley segment, watershed, and basin scale indicators (i.e., water quality) that are used to define or refine potential environmental deficiencies caused by natural or anthropogenic impacts that negatively affect a life stage(s) of the species of concern (i.e., limiting factor). Sometimes referred to as pathways.

Term	Definition
geomorphic reach	An area containing the active channel and its floodplain bounded by vertical and/or lateral geologic controls, such as alluvial fans or bedrock outcrops, and frequently separated from other reaches by abrupt changes in channel slope and valley confinement. Within a geomorphic reach, similar fluvial processes govern channel planform and geometry resulting from streamflow and sediment transport.
geomorphology	The science that treats the general configuraion of the earth's surface; specif. the study of the classification, description, nature, origin and development of landforms and their relationships to underlying structures, and the history of geologic changes as as recorded by these surface changes.
GIS	Geographical information system. An organized collection of computer hardware, software, and geographic data designed to capture, store, update, manipulate, analyze, and display all forms of geographically referenced information.
gradient	Reach gradient estimated by valley gradient reported in percent (%) from 1:24,000 topography.
habitat connectivity	Suitable aquatic and/or terrestrial conditions that are linked together and needed to provide the physical and ecological processes necessary for the transfer of energy (i.e. food web) to maintain all life stages of species that are dependent on the riverine ecosystem.
habitat unit	A channel-wide segment of a stream which has a distinct set of characteristics. Habitat units and channel units are used interchangeably in the literature, however, habitat units are identified and measured during low-flows and sometimes include several channel units. For example, "pool habitat" is measured from the head of the pool scour to the crest of the pool tailout, which technically includes the following "channel units", pool, run, and riffle.
hydrogeology	The science that deals with subsurface waters and with related geologic aspects of surface waters.
hyporheic flows	The hyporheic zone is a region beneath and alongside a stream bed, where there is a mixing of shallow groundwater and surface water. The flow dynamics and behavior in this zone (termed hyporheic flow) is recognized to be important for surface water/groundwater interactions, as well as fish spawning, among other processes.
incipient lethal limit	Temperature levels that cause breakdown of physiological regulation of vital bodily processes, namely: respiration and circulation (ODEQ 2000).

Term	Definition
indicator	A variable used to forecast the value or change in the value of another variable; for example, using temperature, turbidity, and chemical contaminents or nutrients to measure water quality.
indicator species	Used for development of Oregon's water temperature standard as sensitive species that if water temperatures are reduced to protective levels will protect all other aquatic species (ODEQ 2000).
lacustrine	Pertaining to, produced by, or formed in a lake or lakes.
large woody debris (LWD)	Large downed trees or parts of trees that are transported and depositied by the river during high flows and are often deposited on gravel bars or at the heads of side channels as flow velocity decreases. The trees can be downed through river erosion, wind, fire, landslides, debris flows, or human-induced activities. Generally refers to the woody material in the river channel and floodplain with a diameter of at least 20 inches and has a length greater than 35 feet in eastern Cascade streams (USFS 2006b).
limiting factor	Any factor in the environment that limits a population from achieving complete viability with respect to any Viable Salmonid Population (VSP) parameter.
load allocation (LA)	A term referred to in the Clean Water Act that refers to the portion of the receiving waters loading capacity attributed to either one of its existing or future nonpoing sources of pollution or to natural background sources (ODEQ 2000).
loading capacity	A term referred to in the Clean Water Act that establishes an accepted rate of pollutant introduction to a waterbody that is directly related to quality water standard compliance(ODEQ 2000).
outer zone (OZ)	Area that may become inundated at higher flows, but does not experience regular ground-disturbing flows; generally coincidental with the historic channel migration zone unless the channel has been modified or incised leading to the abandonment of the floodplain.
parcel	A smaller unit within a subreach that has differing impacts on physical and/or ecological processes than an adjacent unit, and the need to sequence or prioritize potential rehabilitation actions within the context of the subreach and reach.
periphyton	Algae and other small autotrophs that are attached to substrate (submerged rock, vegetation, etc.). Periphyton consists of complex assemblages of diatoms, green algae, and cyanobacteria (blue-green algae) and, to a lesser degree, yellow-brown algae, euglenoids and red algae (ODEQ 2000).

Term	Definition
reach-based ecosystem indicators (REI)	Qualitative and/or quantifiable physical and/or biological indicators that are referenced to watershed characteristics and reach characteristics.
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
redd	An anadromous fish nest made in the gravel substrate of a stream where a fish will dig a depression, lay eggs in the depression and cover it forming a mound of gravel (ODEQ 2000).
riparian area	An area adjacent to a stream, wetland, or other body of water that is transitional between terrestrial and aquatic ecosystems. Riparian areas usually have distinctive soils and vegetation community/composition resulting from interaction with the water body and adjacent soils.
riprap	Materials (typically large angular rocks) that are placed along a river bank to prevent or slow erosion.
river mile (RM)	Miles measured in the upstream direction beginning from the mouth of a river or its confluence with the next downstream river.
shear stress	The erosive energy associated with flowing water (ODEQ 2000).
side channel	A distinct channel with its own defined banks that is not part of the main channel, but appears to convey water perennially or seasonally/ephemerally. May also be referred to as a secondary channel.
sinuosity	Ration of the length of the channel or thalweg to the down-valley distance. Channels with sinuosities of 1.5 or more are called “meandering”.
site potential	Physical and biological conditions that are at maximum potential, taking into account local natural environment constraints and conditions (ODEQ 2000).
smolt	Juvenile salmonid one or two years old that has undergone physiological changes adapted for a marine environment. Generally, the seaward migrant stage of an anadromous fish species (ODEQ 2000).
spawning and rearing habitat	Stream reaches and the associated watershed areas that provide all habitat components necessary for adult spawning and juvenile rearing for a local salmonid population. Spawning and rearing habitat generally supports multiple year classes of juveniles of resident and migratory fish, and may also support subadults and adults from local populations.
stream bank stability	The measure oif detachment, entrainment, and transport of stream bank soil particles by local water velocity and shear stress (ODEQ 2000).

Term	Definition
sub-lethal limit	Temperature levels that cause decreased or lack of metabolic energy for feeding, growth or reporductive behavior, encourage increased exposure to pathogens, decreased food supplies, and increased competition from warm water tolerant species.
subbasin	A subbasin represents the drainage area upslope of any point along a channel network (Montgomery and Bolton 2003). Downstream boundaries of subbasins are typically defined in this assessment at the location of a confluence between a tributary and mainstem channel. An example would be the Grande Ronde River subbasin.
subreach	Distinct areas comprised of the floodplain and off-channel and active-channel areas. They are delineated by lateral and vertical controls with respect to position and elevation based on the presence/absence of inner or outer riparian zones.
subreach complex	A subreach that has been subdivided, or parceled, into smaller areas due to complicated anthropogenic impacts and the need to sequence implementation actions.
swale	A low tract of land, especially one that is moist or marshy.
terrace	A relatively stable, planar surface formed when the river abandons its floodplain. It often parallels the river channel, but is high enough above the channel that it rarely, if ever, is covered by over-bank river water and sediment. The deposits underlying the terrace surface are primarily alluvial, either channel or overbank deposits, or both. Because a terrace represents a former floodplain, it may be used to interpret the history of the river.
Total Maximum Daily Load (TMDL)	TMDLs are written plans and analyses established to ensure that the waterbody will attain and maintain water quality standards. The OAR definition is “The sum of the individual wasteload allocations (WLAs) for point sources and LAs for nonpoint sources and background. If a receiving water has only one point source discharger, the TMDL is the sum of that point source WLA plus the LAs for any nonpoint sources of pollution and natural background sources, tributaries, or adjacent segments. TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure. If Best Management Practices (BMPs) or other nonpoint source pollution controls make more stringent load allocations practicable, then wasteload allocations can be made less stringent. Thus, the TDML prcess provides for nonpoint source control tradeoffs.”
tributary	A stream feeding, joining, or flowing into a larger stream or lake (Neuendorf et al. 2005).

Term	Definition
underfit stream	A stream whose discharge is small relative to the size of the channel through which it flows as indicated by aspects of the geometry of the channel (e.g., cross-section are, meander wavelength).
valley segment	An area of river within a watershed sometimes referred to as a subwatershed that is comprised of smaller geomorphic reaches. Within a valley segment, multiple floodplain types exist and may range between wide, highly complex floodplains with frequently accessed side channels to narrow and minimally complex floodplains with no side channels. Typical scales of a valley segment are on the order of a few to tens of miles in longitudinal length.
vertical channel migration	Movement of a stream channel in a vertical direction; the filling and raising or the removal or erosion of streambed material that changes the elevation of the overall streambed over an entire reach or subreach.
viable salmonid population	An independent population of Pacific salmon or steelhead trout that has a negligible risk of extinction over a 100-year time frame. Viability at the independent population scale is evaluated based on the parameters of abundance, productivity, spatial structure, and diversity (ICBTRT 2007).
watershed	The area of land from which rainfall and/or snow melt drains into a stream or other water body. Watersheds are also sometimes referred to as drainage basins. Ridges of higher ground form the boundaries between watersheds. At these boundaries, rain falling on one side flows toward the low point of one watershed, while rain falling on the other side of the boundary flows toward the low point of a different watershed.