Draft Technical Memorandum:

Habitat Assessment - Yakima River Hansen Pits to Yakima Canyon

Kittitas County, Washington

Prepared for
Kittitas County Flood Control Zone District

Prepared by
Herrera Environmental Consultants

DRAFT
TECHNICAL MEMORANDUM: HABITAT ASSESSMENT

YAKIMA RIVER – HANSEN PITS TO YAKIMA CANYON

Prepared for
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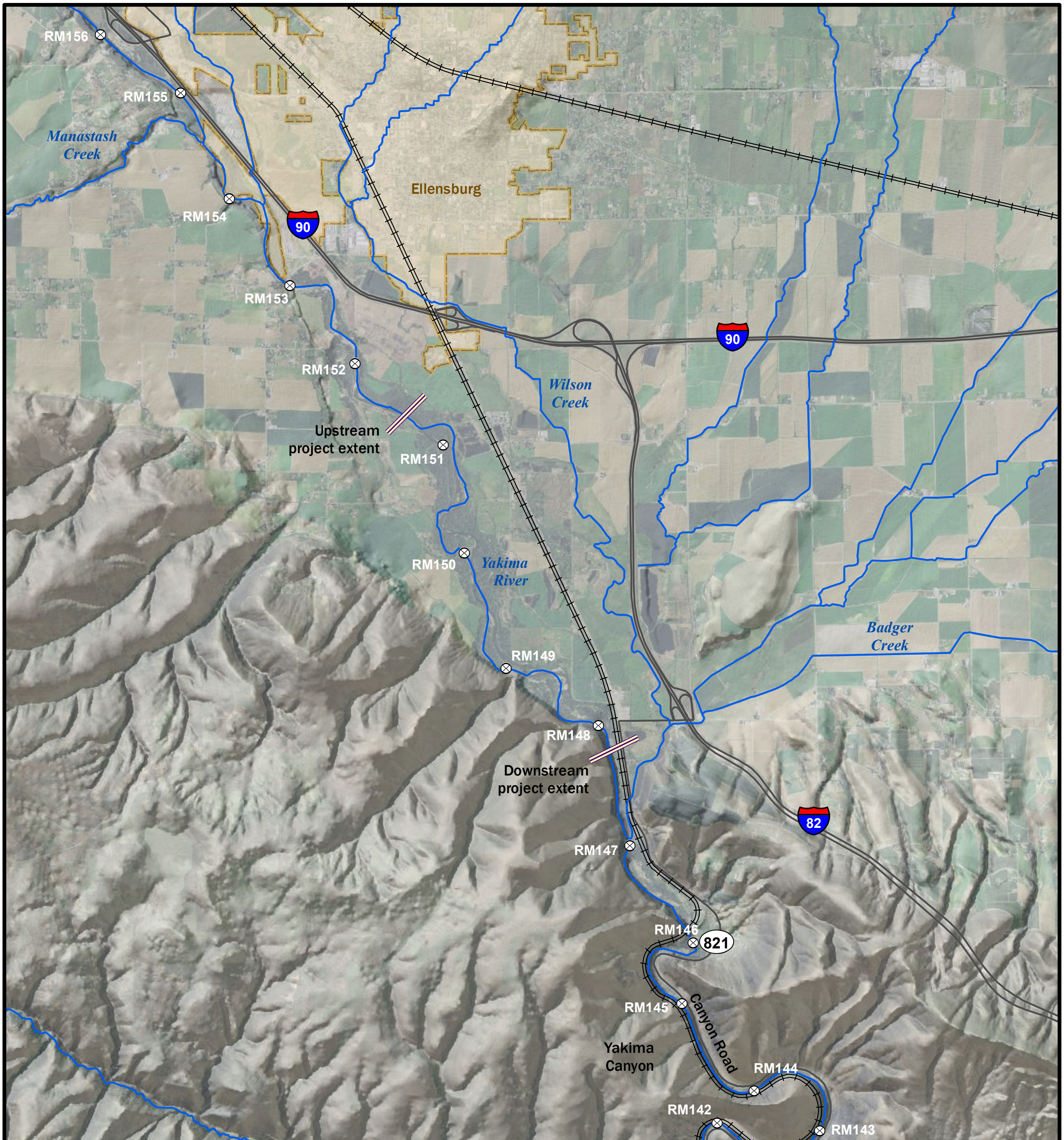
INTRODUCTION

As part of a project team with Watershed Science and Engineering (WSE), Herrera Environmental Consultants (Herrera) conducted an assessment of existing riverine, riparian, and floodplain habitat conditions along a reach of the Yakima River in Kittitas County, Washington. The project reach (Figure 1) extends from just upstream of the Hansen Pits at approximate River Mile (RM) 151.4, to the head of the Yakima Canyon, at approximate RM 147.8, between Ringer Loop Road and the confluence of Wilson Creek.

The habitat assessment is a part of a comprehensive, reach-scale assessment of flood and erosion hazards and habitat quality. The main objective of the habitat assessment was to inform the identification and development of projects to conserve, protect, restore, and/or enhance conditions within the project reach for key species, including spring Chinook salmon (*Oncorhynchus tshawytscha*) and summer steelhead trout (*Oncorhynchus mykiss*).

This technical memorandum documents the results of the habitat assessment. It includes a description of the existing geologic, hydrologic, and physical habitat conditions within the project reach.



Legend

- ⊗ River mile
- River
- Railroad
- Highway

Figure 1. Vicinity Map showing the Hansen Pits to Yakima Canyon Project Reach, Kittitas County, WA.

N

0 3,000 6,000 12,000

Feet

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Aerial: USDA (2013)

K:\Projects\Y2013\13-05594-000\Projects\vicinity_map.mxd (6/3/2014)

METHODS

The habitat assessment involved review of available background information followed by hydrologic analysis, review and interpretation of hydraulic model results, and delineation and description of habitat types. Generally speaking, this assessment was based on Bureau of Reclamation reach assessment guidance (Reclamation 2011).

Background Information Review

Herrera reviewed available information on fish species presence, life histories, listing status, and habitat; river hydrology; and land use practices and development.

The following reports and information sources were reviewed for background information and regional, watershed, and historical context:

- Habitat Limiting Factors Report for Water Resource Inventory Areas (WRIAs) 37-39, Final Report (Haring 2001)
- Effects of Geologic and Hydrologic Factors and Watershed Change on Aquatic Habitat in the Yakima River Basin, WA (Ring and Watson 1999)
- The Reaches Project: Ecological and Geomorphic Studies Supporting Normative Flows in the Yakima River Basin, WA (Stanford et al. 2002)
- Draft Geomorphic Assessment of the Water Gaps in the Yakima Basin, WA (ENTRIX, undated)
- Report on Biologically Based Flows for the Yakima River Basin (SOAC 1999)
- Yakima River Habitat Improvement Study: Schaake Reach, Ellensburg, WA. Interim report to the Yakima River Basin Water Enhancement Project (BOR 2003)
- Yakima River Habitat Improvement Study: Schaake Reach, Ellensburg, WA. Final report to the Yakima River Basin Water Enhancement Project (BOR 2004)
- Proposed Rehabilitation for the Schaake Reach of the Yakima River, WA (BOR 2007)

Hydrologic Analysis Data and Methods

Hydrology data were collected from existing reports and through analysis of data from the period of record (1977 to present) at US Bureau of Reclamation Gage ELNW (near Ellensburg, Washington). Gage ELNW was also used as the primary source of hydrologic data for a two-dimensional (2D) hydraulic model of the project reach developed by WSE.

Herrera analyzed the gage data to determine average daily flows over the course of a year as well as typical monthly flow conditions. Those flows were then used to inform the hydraulic modeling process and also to compare timing of typical fish habitat use with expected flow conditions in the project reach.

Review and Interpretation of Hydraulic Model Results

WSE developed a 2D hydraulic model of the project reach to inform the assessment of flood and erosion hazards as well as habitat conditions. Herrera determined modeled flow rates and interpreted model results as they pertain to habitat conditions.

Herrera selected two "fish flow rates" to be run in the 2D hydraulic model by WSE along with the typical recurrence interval peak flows. Those fish flow rates (1,000 cubic feet per second [cfs] and 3,000 cfs) represent typical flows during the low flow period of the year (September through February) and the higher flow period of the year (May through August). The fish flow rates were meant to represent typical habitat conditions, not peak flood flow conditions.

Herrera engineers and fish biologists together reviewed and interpreted the results of the 2D modeling by WSE to better understand and characterize existing habitat conditions within the project reach. Particular attention was paid to areas meeting key edge habitat requirements for juvenile salmonids:

- Less than 3 feet deep with flow velocity
- Less than 1.5 feet per second

In addition, the modeling results, combined with field observations, provided for better understanding of potential limiting factors related to flow velocity as well as fish access to key off-channel habitats.

Habitat Delineation and Conditions Assessment Methods

Habitat types and conditions were first assessed and delineated using available topographic and bathymetric data, aerial photography, and hydraulic model results. Due to geomorphic consistency throughout the project reach, no geomorphic sub-reaches were delineated as part of the assessment.

The habitat and land use types listed below were delineated throughout the project area. Definitions and descriptions of the listed habitat types, as well as the results of the existing conditions assessments, are provided in the *Habitat Mapping and Characterization* section of this document.

- **Aquatic (Active River and Off-Channel) Habitat Types**:
  - Main stem
  - Braid
  - Side Channel
  - Overflow Channel
  - Groundwater Channel

- Floodplain Pond
- Ditch

- **Terrestrial (Floodplain Vegetation and Land Use) Habitat Types**:
    - Deciduous Forest
    - Woodland
    - Scrub-Shrub
    - Prairie
    - Bare Ground
    - Agricultural Land
    - Developed Land
    - Major Road

The following primary data sources were used to inform the delineation:

- Aerial images (National Agriculture Imagery Program [NAIP] 2013)
- Historical aerial images (NAIP 2011, 1993, 1969, 1954)
- Lidar (2008)
- Surveyed bathymetric data of the project area river and floodplain from the US Bureau of Reclamation Schaake Reach Bathymetric Survey

Following the habitat and land use delineation based on existing data sets, Herrera conducted a one-day field assessment to confirm habitat delineations, assess habitat conditions, and begin determining potential restoration opportunities (not discussed in this report). The field assessment was conducted on March 26, 2014, by a fish biologist and by an engineer, both with experience in geomorphology, river restoration design, and vegetation. The biologist and engineer were accompanied by David Child, a local fishing guide and biologist who has been floating and fishing the project reach for over 14 years. The three travelled through the project reach by boat, stopping regularly to assess conditions on foot. During the float, David Child shared his insights and observations of geomorphic change and biological conditions he has experienced during his time on the river.

Herrera assessed the existing conditions of individual habitat types based on a number of metrics that varied depending on their applicability to each habitat type. The list of the key factors used to assess habitat conditions included:

- Geomorphic Reach Type
- Channel Type
- Functional Large Woody Debris (LWD) Rating

- Substrate Material Classification
- Stream Habitat Complexity Rating
- Riparian Habitat Quality Rating

Appendix A includes a detailed description of the individual habitat assessment metrics.

HISTORICAL HABITAT CONDITIONS

A significant body of information exists related to historical habitat conditions and the history of habitat degradation within the Yakima River watershed. The information is described in numerous reports, including Ring and Watson (1999), Snyder and Stanford (2001), and Haring (2001). Including a full summary of these documents is beyond the scope of this report. However, for contextual purposes, a brief summary of historical conditions and habitat degradation , is provided herein, as they relate to the project reach. For in-depth information, the reader is encouraged to review those documents.

The project reach is known to contain some of the best remaining floodplain and off-channel habitat in the Yakima River watershed, and every effort should be made to preserve the existing habitat. However, the quality and quantity of habitat, in comparison to historical conditions, have been significantly reduced.

Quantity and quality of habitat in the project reach for key salmonid species have been affected by all of the following activities, which have in one way or another damaged habitat or eliminated natural habitat forming processes:

- Logging/splash damming/log drives
- Clearing of LWD from the channel and floodplain
- Channel straightening
- Disconnection of floodplain and off-channel habitat by roads, railroads, and levees
- Hydrologic modifications resulting in reduced groundwater recharge and detriment to migration corridor and rearing habitat conditions (velocity, runoff timing)
- Altered riparian vegetation conditions, followed by colonization by invasive vegetation
- Flow diversions and returns and associated water quality degradation

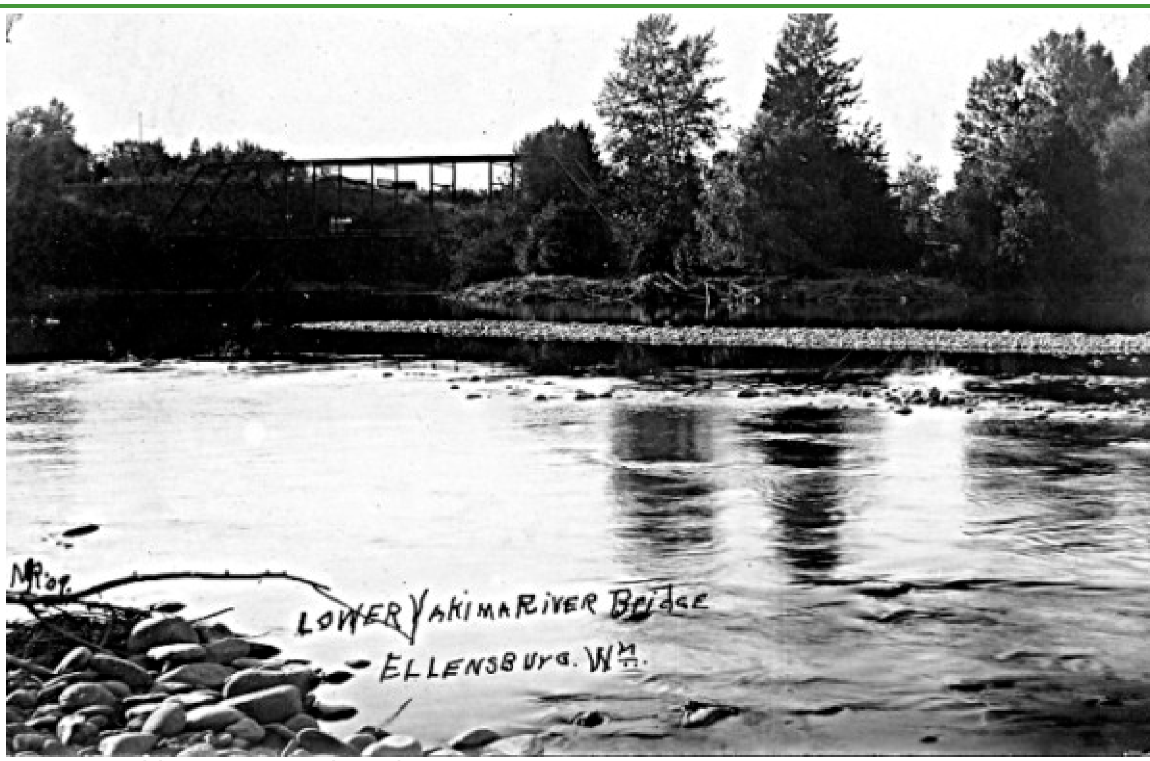
Of the most immediate consequence to restoration planning in the project reach are the effects of floodplain habitat quantity and quality through floodplain and off-channel habitat disconnection, hydrologic modifications, riparian vegetation conditions, and flow diversions/returns.

Historical Vegetation Conditions

While historical vegetation conditions in the project reach are not well documented in existing literature, a basic description can be developed based on observation of existing conditions, evidence or lack thereof of floodplain logging of ponderosa pine, and a limited number of historical photos (Figures 2 and 3). A review of the earliest available aerial photographic record shows that riparian canopy density and extent was significantly less in 1954 than it is at present. This suggests that there was at least some level of logging or other

Source: Yakima Memory (2014)

Figure 2. Historical Photo Showing Riparian Vegetation Conditions Near Ellensburg, Washington. Date unknown.



Source: Yakima Memory (2014)

Figure 3. Historical Photo Showing Riparian Vegetation Conditions Near Ellensburg, Washington. Date unknown.

type of deforestation that went on before 1954 within the project reach, though it is unclear to what extent. Given the known and well documented alterations in the hydrology of the project reach, it is likely that, prior to European-American settlement, the riparian area and floodplain were dominated by cottonwood stands with willow, alder, dogwood, and other shrubs in the understory. Invasive species, including reed canarygrass, would have not been present in the project reach. Individual tree size may have been larger diameter than at present, but the historical stands would have been shaped by periodic fire and flood events, resulting in a forest gallery with significant diversity and shrub mosaics. It appears unlikely that ponderosa pine or other conifer species were ever the predominant vegetation on the floodplain of the project area, though some very large ponderosa pines were likely present and would have contributed significantly to river morphology when recruited as LWD to the channel via natural channel migration.

Reach-wide Conditions

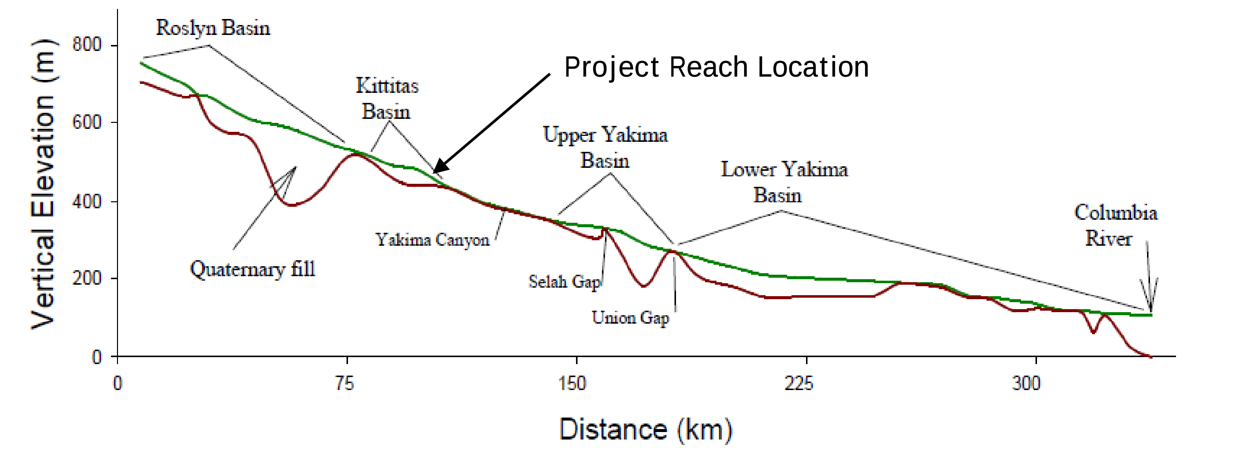
Geologic Setting

The project reach is in the Yakima Fold and Thrust Belt, a highly deformed region on the western edge of the Columbia Basin (Tabor et al. 1982). At the large scale, the surface of the region is composed of Columbia River basalts in ridges that align obliquely to the Yakima River. The bedrock of the fold belt, primarily the Grand Ronde basalt, which is a hard impermeable igneous rock, serves as bedrock in the entire reach. However, the project reach is located just upstream from where the Yakima River intersects one of these folds (i.e., the Yakima Canyon) (Figure 4). The confinement, over geologic time, has impounded water and sediment immediately upstream of the canyon. The net result is that the modern alluvial plain is larger in this area than anywhere else in the Kittitas Basin. This can be seen where the alluvial sediments (the region containing Qal shown in Figure 5) extend further west and east than similar locations upstream or downstream. Unlike areas farther upstream where the terrace deposits remaining from the last glacial period (Qt shown in Figure 5) intersect and interact with the river, the alluvial deposits in the project reach span the entire active floodplain, which means that in the absence of human-made impediments, the river is much freer to migrate within the project reach than elsewhere in the Kittitas Basin.

Another effect of the underlying geology on the project reach is the formation of water gaps between the fold belt ridges (e.g., Manastash Ridge). At the entrances to the bedrock reaches (i.e., Yakima Canyon), both surface and groundwater impounds on the underlying bedrock and is expressed at or near the ground surface at the point where the water flows through the water gap. Prior to development, the impounded water was primarily groundwater coming from flood waters in the Yakima River and tributaries that drained to unconfined areas in the Kittitas Basin. As a result, there was likely a large quantity of hyporheic contribution to the main stem in the project reach. In existing conditions, water still accumulates at downstream end of the project reach from various directions (north, east and west). However, since development of the basin and the construction of irrigation infrastructure, most of the water comes in at discrete points from irrigation return flows. Much less water arrives via the ground as compared to predevelopment conditions; the water that comes in often comes from leaking irrigation canals. Despite these changes, there are still signs of groundwater surface expression in existing conditions. The change from groundwater input to a mixed groundwater input and irrigation return system has lowered water quality and increased temperature in the return waters and the main stem of the Yakima River (Stanford et al. 2002, ENTRIX undated, and Ring and Watson 1999).

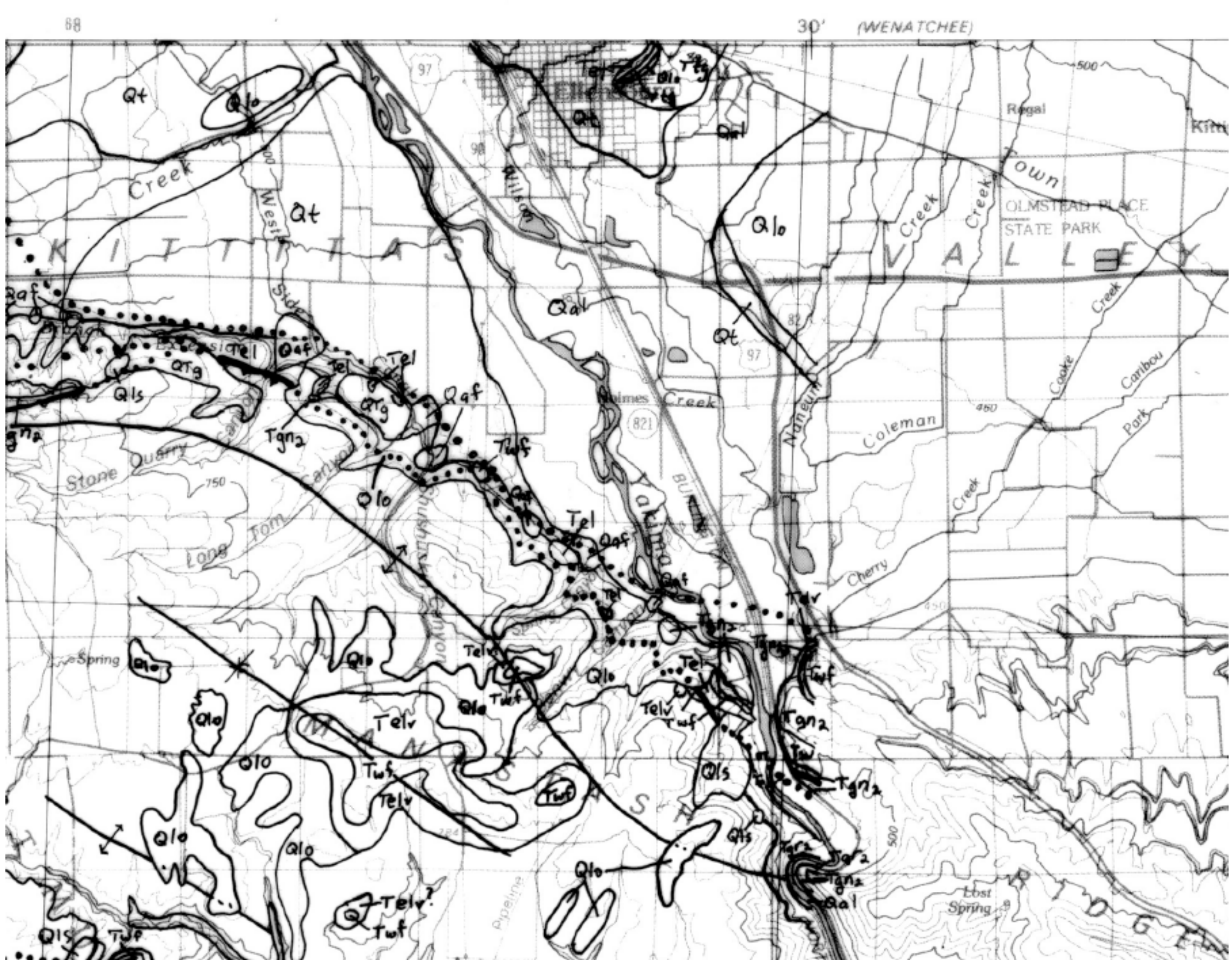
Hydrologic Setting

The hydrology and flow patterns in the Yakima Basin are highly altered, intensely managed, and well-studied. Irrigated agriculture and fish habitat concerns are the primary drivers for the modern flow regime on the Yakima River in the Kittitas Valley. The following passage from ENTRIX (undated) describes historical and existing conditions in the Yakima Basin



Source: Stanford et al. (2002)

Figure 4. Cross-sectional Profile Showing Basins and Water Gaps Along the Yakima River, Washington.



Source: Walsh (1986)

Figure 5. Geologic Map of the Project Reach within the Yakima West Quadrangle.

and the project reach, keeping in mind that the project reach is located in a groundwater upwelling zone associated with its location just upstream of the Yakima Canyon water gap.

> *Before alteration by European-Americans in the mid-nineteenth century, the basin hydrology included complex floodplain channel systems and surface/groundwater interactions. This modulated peak flows and provided the topographic and temperature diversity needed to support multiple salmonid life histories. The water generated by precipitation and snowmelt in the winter and spring would accumulate in the sediment of the basins. The deep alluvial deposits in the synclines between ridges allows for significant groundwater flows down the valley. When these flows encounter the water gaps the subsurface flows come to the surface as streamflow (Kinnison and Sceva, 1963). Highest flows occur with rain-on-snow winter storms, but spring snowmelt floods can last much longer—10 or more weeks (Park, 2008)…*
>
> *Today, six major reservoirs store water during high flows for use in irrigation during the summer low-flows (YSFWPB, 2004). Peak flows have diminished since the 1930s with the construction of the dams (Dunne et al., 1976). Although built for irrigation, the dams also reduce flood size, frequency, and duration (YRFMIST, 2004)…*
>
> *A local irrigation management system called "flip-flop" has significantly altered the hydrology of the basin. Under flip-flop, the U.S. Bureau of Reclamation (BOR) releases water from dams on the Yakima for irrigation withdrawal in April through September. Then flow is reduced on the Yakima in September when spring Chinook are spawning. This causes the Chinook to spawn lower on the river, where flows will be sufficient to keep the redds under water. At that time, flows are released into the Naches for diversion into irrigation… These alterations have also damaged ecological conditions for native salmonids and riparian vegetation. Groundwater upwelling from alluvial aquifers contributes cool water; thermal regimes play a significant role in aquatic ecology by controlling dissolved oxygen, metabolic rates, bioenergetics, and biodiversity (Stanford et al., 2002; Vaccaro, 2005). Today, the cool groundwater is replaced by irrigation returns that are warmer and possibly contaminated.*

Aside from altering the natural processes of groundwater recharge, the "flip-flop" flow regime has had two important, negative effects on native salmonids and their habitat. First, the reduction of peak flow volume and alteration of runoff timing has decreased the effectiveness of anadromous smolt outmigration. Historically, outmigration was timed to coincide with higher runoff flows, in effect giving outmigrating salmonids a "free ride" downstream. Under the altered flow regime, outmigrating salmonids must expend much more energy to leave the watershed. Second, extended periods of high flows through the summer months have significantly reduced the quality and quantity of available summer rearing habitat for juvenile salmonids. Under current conditions, high velocities that exceed the limits of juvenile fish swimming ability exist in most areas of the channel, even up the edges in many locations.

Modern Surface Hydrology

Data from the Yakima River at US Bureau of Reclamation Gage ELNW (near Ellensburg) were used to determine appropriate flow rates at which access to side channel habitat should be assessed. Figure 6 shows the daily average of mean daily flows over the period of record from 1977 through 2013. The plot clearly shows the effect of the “flip-flop” water management scenario, with high flows in the range of 2,500 to 3,700 cfs persisting throughout the summer dry period and dropping off precipitously to below 1,000 cfs in September, when the “flip-flop” shifts to releases from the Naches River system.

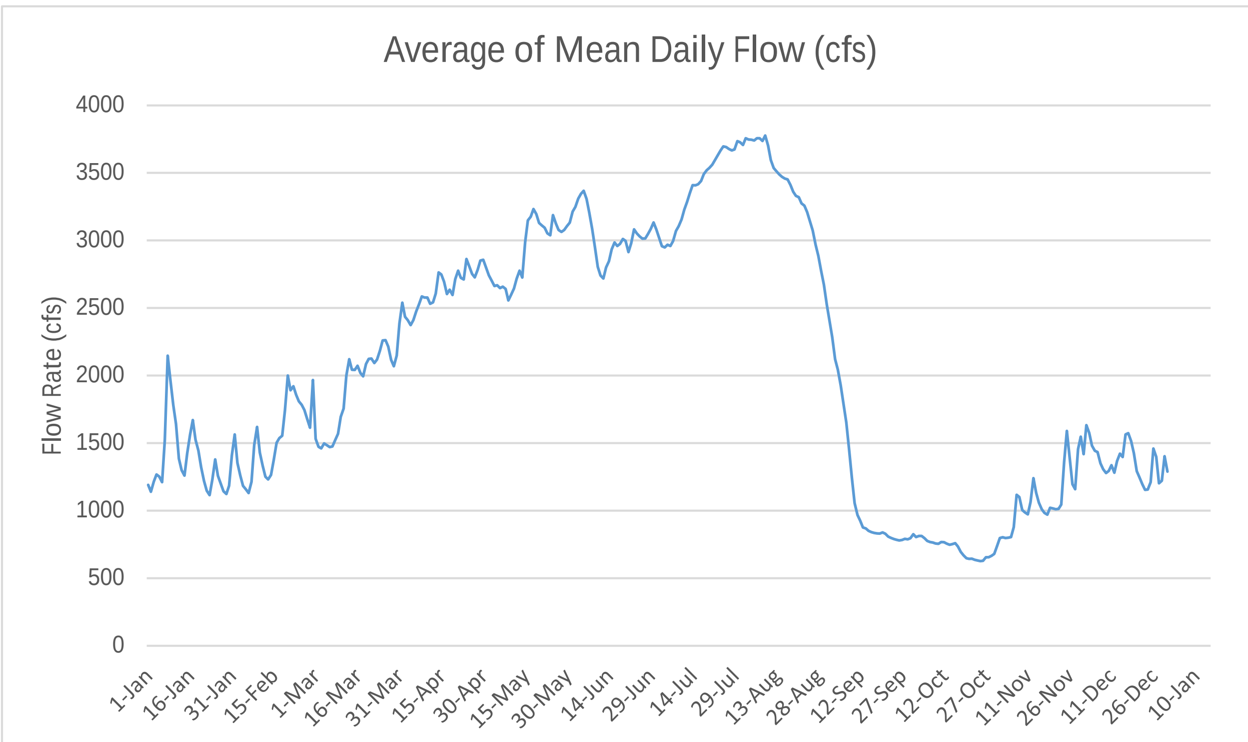


Figure 6. Daily Average Flow Rates for Yakima River at Yakima River at US Bureau of Reclamation Gage ELNW (Near Ellensburg).

Based on the existing flows shown in Figure , Herrera selected two “fish flow rates” to be run in the 2D hydraulic model by WSE along with the typical recurrence interval flows. Herrera selected 1,000 cfs to represent typical flows during the low flow period of the year (September through February) and 3,000 cfs to represent typical flows during higher flow period of the year (May through August). The selected fish flow rates were meant to represent typical habitat conditions, not peak flow conditions.

Fish Use/Presence

Fish presence and use of habitat in the project reach was investigated by reviewing existing reports and studies. The project reach of the Yakima River is known to be used by several salmonid species during all or part of their life cycle. Some species, including spring Chinook salmon (*Oncorhynchus tshawytscha*), summer steelhead trout (*Oncorhynchus mykiss*), and rainbow trout (*Oncorhynchus mykiss*) are expected to use portions of the system during the entire year. Sockeye salmon (*Oncorhynchus nerka*) and Coho salmon (*Oncorhynchus kisutch*) are both considered extinct as native populations in the upper Yakima River, but reintroduction efforts are showing some promise and adults of both species have returned to spawn above Roza Dam in recent years (DART 2014).

A fairly robust population of resident rainbow trout inhabits the project reach and represents an important recreational fishing opportunity in the region. In contrast, historically abundant runs of anadromous species such as spring Chinook and steelhead have declined to tiny fractions of their historical numbers as a result of factors both within and outside of the project reach and watershed. For example, between only 100 and 400 wild adult summer steelhead have returned to the upper Yakima River above Roza Dam in recent years, while estimates of historical steelhead run size range from 20,800 to as many as 100,000 fish.

Table 1 shows monthly habitat requirements of key salmonid species in the project reach of the Yakima River and the corresponding monthly mean daily river flows. As shown in Table 1, one or more life stages in each of the key salmonid species rely on habitat within the project reach. Combined, salmonids have year-round dependency on the project reach. Given its geomorphic characteristics, the project reach historically provided several key habitat functions, including providing foraging, rearing, and overwintering opportunities, as well as flood refugia and spawning habitat. Rearing floodplain habitat could have been used year round, providing habitat partitioning for both anadromous and resident salmonid species, thus minimizing predation risk and allowing multiple species to coexist. The rearing floodplain habitat likely also provided thermal refugia during the summer due to groundwater upwelling.

Despite the current degree of hydrologic regime modification and floodplain disconnection, key habitat functions provided by the project reach include most or all of the historical habitat functions, though in greatly reduced quantity and/or quality. Hydrologic modifications and resultant warming of summer backwater habitats and cooling of overwintering areas may be the most significant. The current lack of large, persistent log jams in side channels limits the quality of the habitat (especially for juveniles) as it results in few locations where fish can find refuge from high velocity flows that persist through summer in the flip-flop flow regime.

Table 1. Fish Species and Life Stages in the Project Reach of the Yakima River.												
Month	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
Average of Mean Daily Discharge (cfs) [a]	**1,376**	**1,521**	**1,917**	**2,641**	**2,919**	**3,039**	**3,376**	**3,392**	**1,153**	**721**	**1,077**	**1,366**
25th Percentile	**688**	**869**	**1,349**	**1,723**	**1,792**	**2,489**	**3,037**	**3,190**	**873**	**599**	**716**	**655**
75th Percentile	**1,959**	**1,566**	**2,364**	**3,121**	**3,814**	**3,965**	**3,803**	**3,665**	**1,285**	**829**	**1,160**	**1,315**
Adult Summer Steelhead Trout - *Oncorhynchus mykiss*												
Spawning Run [b,c]	■	■	■	■	■				■	■	■	■
Spawning [b]			■	■	■	■						
Juvenile Summer Steelhead Trout - *Oncorhynchus mykiss*												
Emergence to Overwintering/Rearing [b]	■	■	■	■	■	■	■	■	■	■	■	■
Smolt Outmigration [b]			■	■	■	■						
Rainbow Trout - *Oncorhynchus mykiss*												
Adult [d]	■	■	■	■	■	■	■	■	■	■	■	■
Juvenile [d]	■	■	■	■	■	■	■	■	■	■	■	■
Adult Spring Chinook Salmon - *Oncorhynchus tshawytscha*												
Spawning Run [b,c]				■	■	■	■	■	■			
Spawning [b]							■	■	■			
Juvenile Spring Chinook Salmon - *Oncorhynchus tshawytscha*												
Emergence to Overwintering/Rearing [b]	■	■	■	■	■	■	■	■	■	■	■	■
Smolt Outmigration [b]			■	■	■	■						
Sockeye/Kokanee Salmon - *Oncorhynchus nerka* - native population extinct. Reintroduction effort in process.												
Spawning Run [b,c]							■	■	■			
Smolt Outmigration [b]				■	■	■						
Adult Coho Salmon - *Oncorhynchus kisutch* - native population extinct. Reintroduction effort in affect by the Yakama Tribe												
Spawning Run [c]									■	■	■	■
Spawning [e]	■									■	■	■
Juvenile Coho Salmon - *Oncorhynchus kisutch*												
Emergence to Overwintering [e]	■	■	■	■	■	■	■	■	■	■	■	■
Smolt Outmigration [e]			■	■	■	■						
Cutthroat Trout - *Oncorhynchus clarkii*												
Adult [d]	■	■	■	■	■	■	■	■	■	■	■	■
Juvenile [d]	■	■	■	■	■	■	■	■	■	■	■	■

Data Sources for Table:

[a] US Bureau of Reclamation Gage ELNW (near Ellensburg, WA)
[b] Haring (2001)
[c] Columbia River DART at Roza Dam
[d] Known year round presence
[e] David Child (personal communication 4/24/2014)

HABITAT MAPPING AND CHARACTERIZATION

Existing aquatic and terrestrial habitat types (described in detail in the subsections below) are delineated in Figures 7 and 8. Figure 7 shows habitat units as a mosaic of shaded polygons over a hillshade background, while Figure 8 shows only the outlines of habitat units overlaid on an aerial photograph, so that the reader has a visual representation of vegetation conditions in each delineated habitat unit. Definitions and descriptions of the aquatic habitat types were derived directly from Lestelle et al. (2004). In addition to showing the habitat types, Figures 7 and 8 show the locations of observed large woody debris (LWD) accumulations, bank armoring and riprap, and levees and channel plugs.

Appendix A includes more detailed descriptions of the habitat assessment metrics utilized in the habitat type condition descriptions below.

River and Floodplain Habitat Type Descriptions

Active River Habitat Types

The **active river** is composed of the main stem, side channels, and braids (if present). The project reach exhibits good to excellent floodplain connectivity where it is not constrained by levees, as well as numerous active side channels and off-channel habitats.

The reach is an anastomosing gravel bedded stream type (DA4) according to the Rosgen (1996) stream channel classification system.

Main Stem Habitat Type

Definition

The **main stem** is defined as the channel that conveys the primary flow of the river.

Typical Habitat Conditions

The main stem channel within the project reach, on average, ranges from 150 to 200 feet wide. The main stem exhibits characteristics of a response reach (Montgomery and Buffington 1998) in which morphological adjustments occur in response to changes in sediment supply. Overall channel gradient is approximately 0.24 percent, and the sinuosity of the main stem channel is 1.3. Channel substrate is primarily gravel and cobble, with significant amounts of sand and fines in the subsurface sediment gradation. Banks are composed primarily of fines mixed with gravels and cobble, and vary in stability from stable to very unstable depending primarily on the status of riparian vegetation. The main stem channel exhibits a pool/riffle channel type (Montgomery and Buffington 1998), with scour pools typically forming adjacent to accumulations of LWD or along outside meander bends with bank hard points (natural or artificial).

The main stem within the project reach was Properly Functioning for LWD (see Appendix A), though larger and more accumulations of LWD would be expected in less impacted reaches with similar morphological and vegetation characteristics. Presence of mature cottonwood forests along much of the reach, combined with significant beaver activity, provide an active source of additional LWD recruitment.

Main stem stream habitat complexity was Fair trending towards Good (McBride 2001). As described earlier, scour pools typically exist adjacent to accumulations of LWD or along outside meander bends with bank hard points (natural or artificial). While there is reasonable variety in channel habitat units, the relatively uniform and small substrate provides very little in terms of microtopography and small-scale velocity (hydraulic) refuges. Main stem resting habitat for adult salmonids and rearing habitat, especially, appeared lacking due to high flow velocities and lack of cover in most of the active channel. Edge habitat also appears limited based on field observations and the results of 2D hydraulic modeling conducted by WSE. The model results show velocities over 1.5 feet per second (fps) and often over 4 fps at flows of 3,000 cfs, which, due to irrigation "flip flop" hydrology, are sustained or exceeded for much of the time from May through August.

Riparian habitat quality along the main stem channel was Moderate to High (see Appendix A). Buffer widths typically exceed 100 feet, and native woody plant species are dominating the canopy layer of vegetation, but invasive reed canarygrass is ubiquitous as groundcover, and localized grazing and clearing has resulted in some areas of disturbed or highly compacted ground that is supporting little or no vegetation.

Photos 1 and 2 show typical habitat conditions in the main stem within the project reach.

Photo 1. Typical main stem channel and riparian condition.

Photo 2. Typical main stem channel condition including LWD accumulations.

Side Channel Habitat Type

Definition

According to Lestelle et al. (2004), "a **side channel** is an active stream channel separated from the main channel by a vegetated or otherwise stable island (Knighton 1988) and carries surface water at flows less than bankfull. In contrast, **overflow channels** (discussed below) carry water only during flood or high water events."

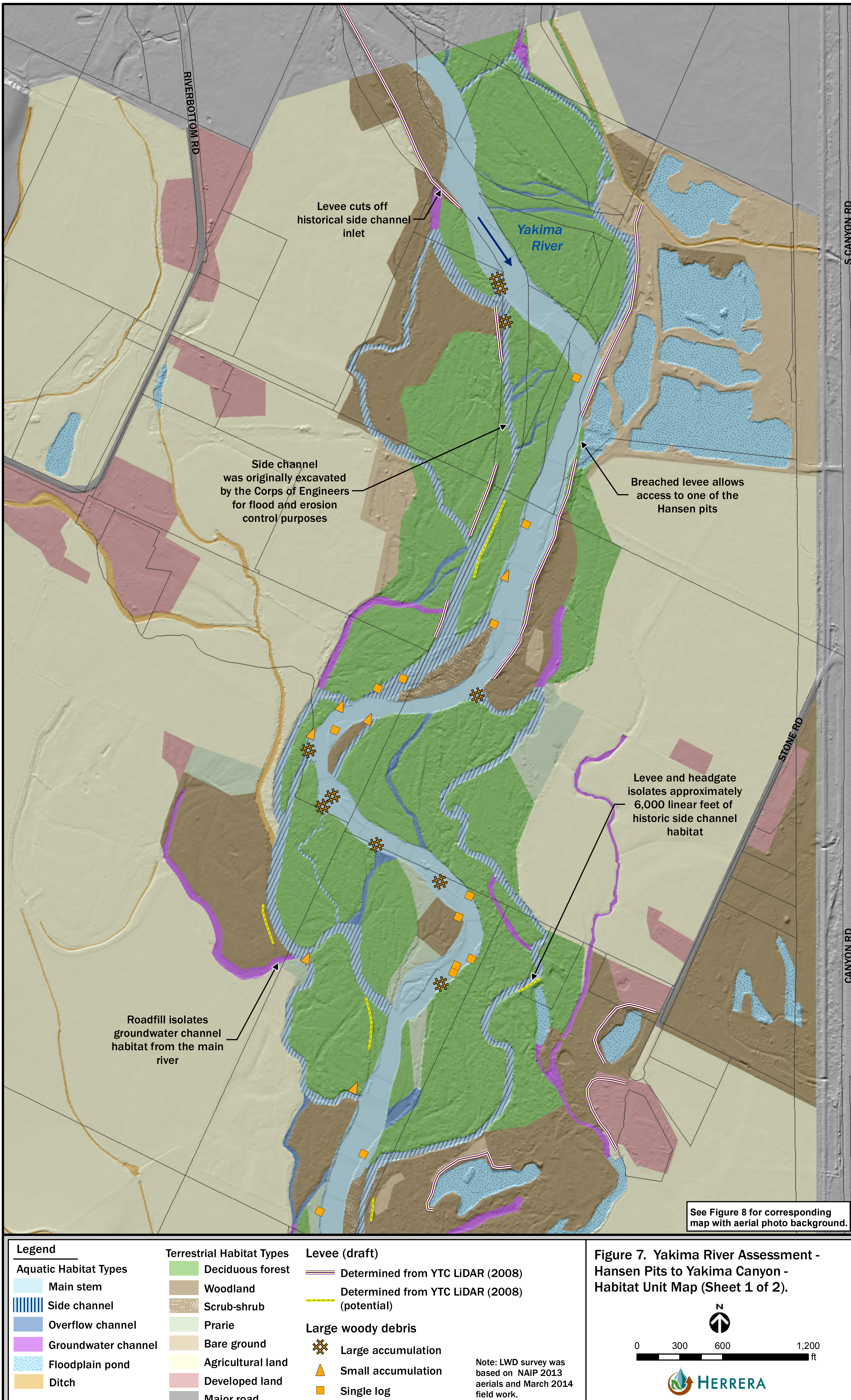
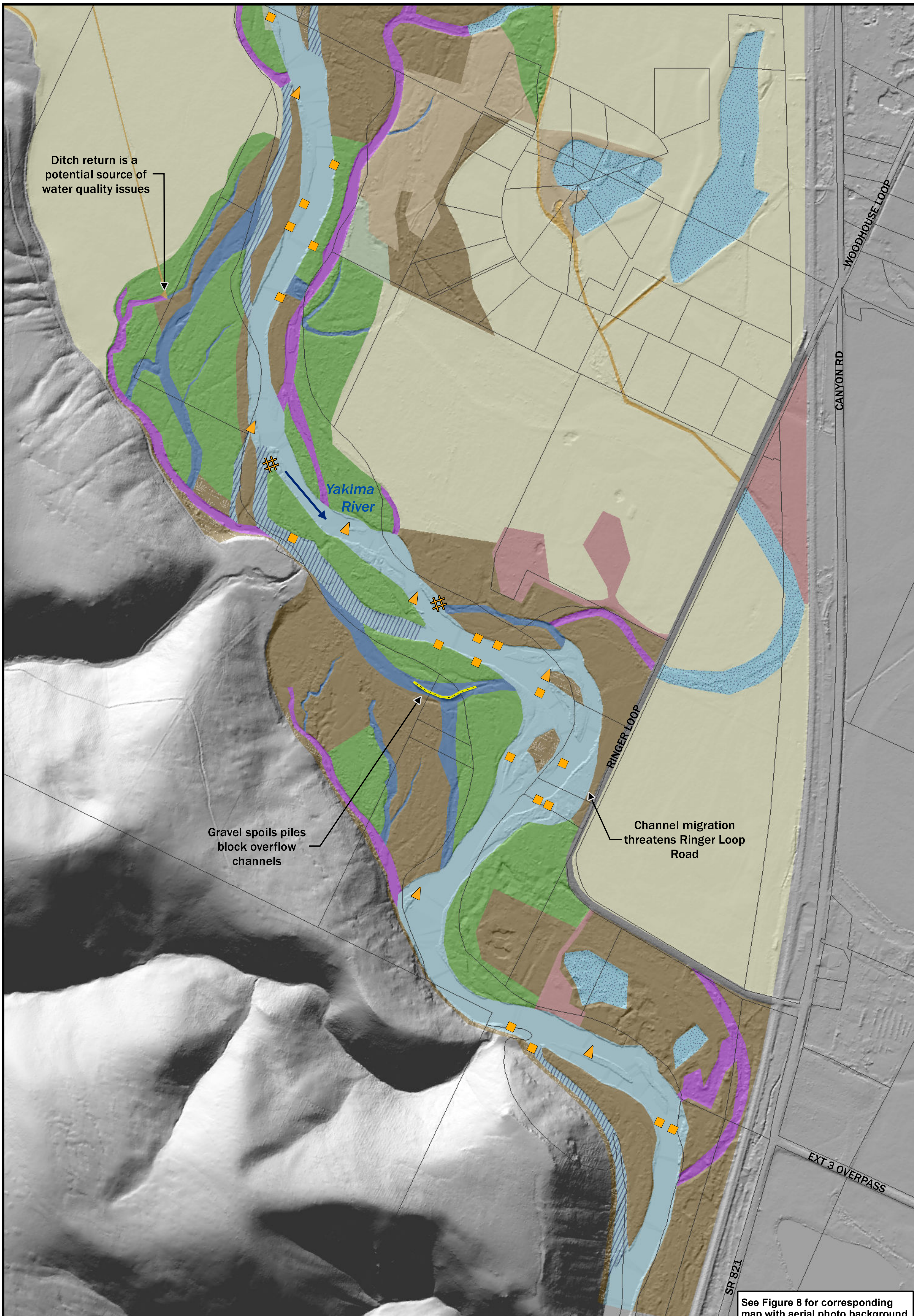


Figure 7. Yakima River Assessment - Hansen Pits to Yakima Canyon - Habitat Unit Map (Sheet 1 of 2).



Legend

Aquatic Habitat Types
- Main stem
- Side channel
- Overflow channel
- Groundwater channel
- Floodplain pond
- Ditch

Terrestrial Habitat Types
- Deciduous forest
- Woodland
- Scrub-shrub
- Prarie
- Bare ground
- Agricultural land
- Developed land
- Major road

Levee (draft)
- Determined from YTC LiDAR (2008)
- Determined from YTC LiDAR (2008) (potential)

Large woody debris
- Large accumulation
- Small accumulation
- Single log

Note: LWD survey was based on NAIP 2013 aerials and March 2014 field work.

Figure 7. Yakima River Assessment - Hansen Pits to Yakima Canyon - Habitat Unit Map (Sheet 2 of 2).

N

0 300 600 1,200 ft

HERRERA

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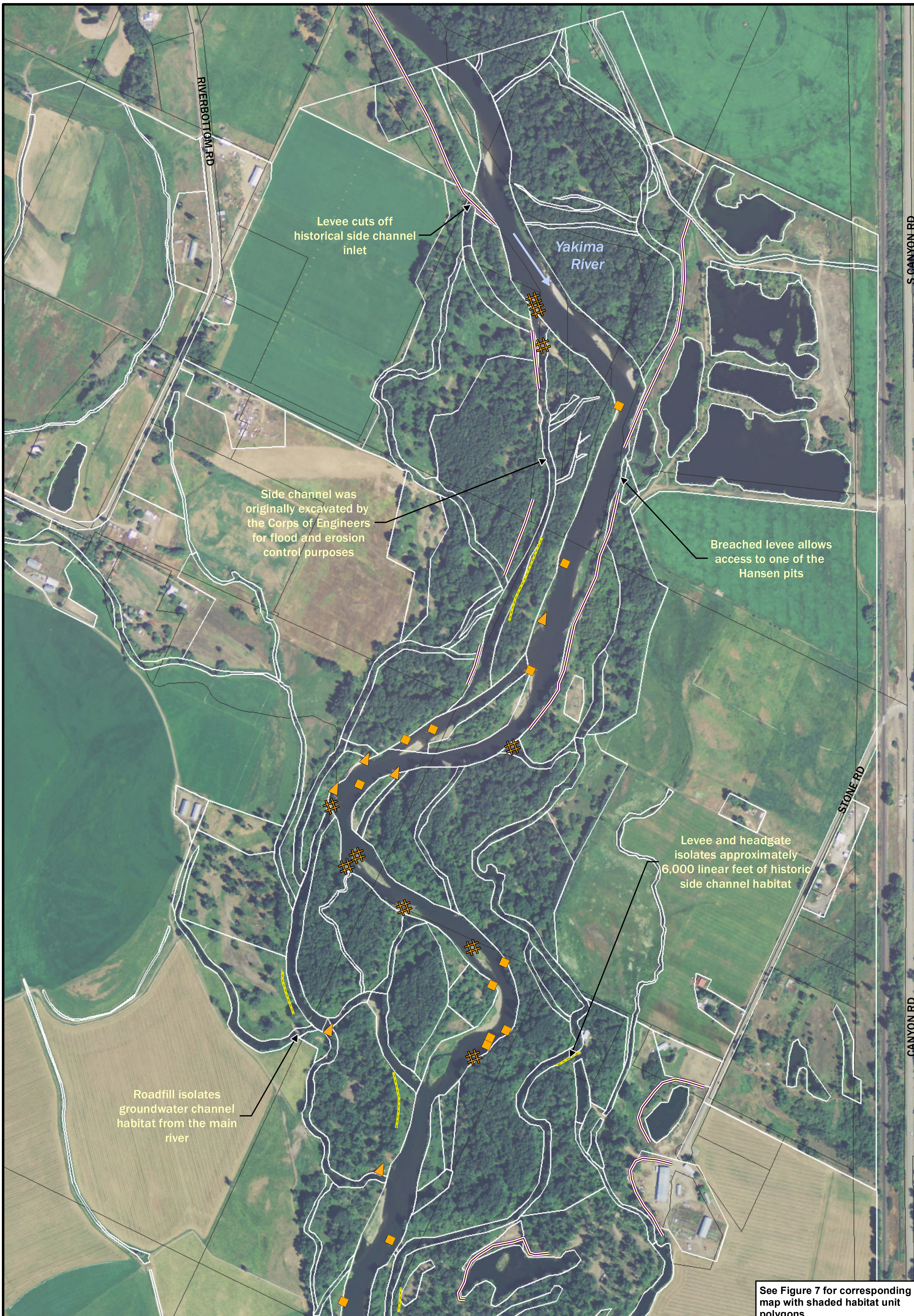

Legend

Habitat type

Levee (draft)

- Determined from YTC LiDAR (2008)
- Determined from YTC LiDAR (2008) (potential)

Large woody debris

- Large accumulation
- Small accumulation
- Single log

Note: LWD survey was based on NAIP 2013 aerials and March 2014 field work.

Figure 8. Yakima River Assessment - Hansen Pits to Yakima Canyon - Habitat Unit Map (Sheet 1 of 2).

0 300 600 1,200 ft

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Legend

Habitat type

Levee (draft)

Determined from YTC LiDAR (2008)

Determined from YTC LiDAR (2008) (potential)

Large woody debris

Large accumulation

Small accumulation

Single log

Note: LWD survey was based on NAIP 2013 aerials and March 2014 field work.

Figure 8. Yakima River Assessment - Hansen Pits to Yakima Canyon - Habitat Unit Map (Sheet 2 of 2).

0 300 600 1,200 ft

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Typical Habitat Conditions

Side channels are numerous within the project reach and vary greatly in both overall length and size. Identified side channels within the project reach vary in length from less than 500 feet to more than 6,500 feet, and vary in typical width from 25 feet to 50 feet, with occasional shorter channels as narrow as 15 feet and as wide as 100 feet. While diverse in size, the observed side channels were similar in overall morphology and habitat. The side channels exhibit characteristics of a response reach (Montgomery and Buffington 1998) in which morphological adjustments occur in response to changes in sediment supply. Overall side channel gradients were in the range of 0.16 to 0.52 percent, with most similar to the main stem slope of 0.024 percent. Sinuosity of side channels varied from 1.02 (very straight) to over 1.4, with a general trend that side channels 3,000 feet long or longer had significantly greater sinuosity (over 1.25) than shorter side channels. Side channel substrate is primarily gravel and cobble, with significant amounts of sand and fines in the subsurface sediment gradation. One significant exception to this is the side channel on river left at the very upstream end of the project reach, which had substrate composed primarily of sand and fines, with small patches of gravel. Banks are composed primarily of fines mixed with gravels and cobble, and vary in stability from stable to very unstable depending primarily on the status of riparian vegetation. Like the main stem channel, side channels typically exhibit a pool/riffle channel type (Montgomery and Buffington 1998), with scour pools typically forming adjacent to accumulations of LWD or along outside meander bends with bank hard points (natural or artificial). It is known that at least one major side channel and perhaps multiple minor side channels were excavated in the past for flood control or flow diversion purposes. The degree to which excavated channels were located in historical channel alignments is not known. The excavated channels appear to be functioning in a natural manner at this time, responding to natural changes in geomorphology.

While most side channel inlets were characterized by significant and persistent accumulations of LWD, the side channels themselves were lacking in LWD overall. With very few exceptions, side channel habitat was Not Properly Functioning for LWD (see Appendix A), with few large single pieces or accumulations of LWD away from the side channel inlets. However, the presence of mature cottonwood forests along much of the reach, combined with significant beaver activity, provide an active source of additional LWD recruitment.

Side channel stream habitat complexity was Fair trending towards Good (McBride 2001). As described earlier, scour pools typically exist adjacent to accumulations of LWD or along outside meander bends with bank hard points (natural or artificial). While there is reasonable variety in channel habitat units, the relatively uniform and small substrate provides very little in terms of microtopography and small-scale velocity refuges. Observed side channels were lacking in high quality resting habitat for adult salmonids and rearing habitat. This was primarily due to overall lack of LWD derived habitat complexity, high flow velocities, and lack of cover in most of the active channel. Edge habitat in the side channels appeared limited based on field observations and the results of 2D hydraulic modeling conducted by WSE. The model results show velocities over 1.5 fps and often over 4 fps at flows of 3,000 cfs, which, due to irrigation “flip flop” hydrology, are sustained or exceeded for much of the time from May through August.

Riparian habitat quality along the side channels was Moderate to High (see Appendix A). Buffer widths typically exceed 100 feet, and native woody plant species are dominating the canopy. However, as in the main stem, invasive reed canarygrass is ubiquitous as groundcover, and localized grazing and clearing has resulted in some areas of disturbed or highly compacted ground that is supporting little or no vegetation. On the narrower side channels, riparian canopy cover provides significant shading.

Fish access to side channel habitats varies with changing flow conditions in the river. The 2D modeling results produced by WSE indicate that three significant side channels at the upstream end of the project reach are connected to the main stem at 3,000 cfs but are disconnected or dry at low flows of 1,000 cfs. Nearly 7,000 linear feet of side channel habitat is not wetted at 1,000 cfs that is accessible at 3,000 cfs. The downstream 3.4 miles of the project reach do not experience significant disconnection of side channel habitat between 3,000 and 1,000 cfs.

Photos 3 through 7 show typical side channel habitat conditions within the project reach.

Photo 3. Low gradient and low velocity side channel habitat with bank vegetation dominated by invasive reed canarygrass.

Photo 4. Side channel with typical gravel and cobble bed conditions and relatively dense woody vegetation on banks. Multi stemmed tree physiology is common when plants are subjected to heavy deer, elk, and beaver browse.

Photo 5/ Typical side channel conditions with an accumulation of LWD at the side channel inlet from the main stem.

Braid Habitat Type

Definition

According to Lestelle et al. (2004), "a **braided channel (braids)** is one that typically has numerous branches, separated by exposed alluvial bars (Rosgen 1996). Bars tend to be transient, unvegetated and submerged at bankfull flow (Knighton 1988)."

Typical Habitat Conditions

Little or no braiding occurs within the project reach. Field crews observed the occasional small braid or flow split around small gravel islands when flows drop below approximately 2,000 cfs. However, those islands are typically inundated during the majority of the year, and they were considered to be part of the main stem channel for the purposes of habitat mapping.

Photo 8 shows typical habitat conditions of braids within the project reach.

Photo 6. Confluence of two active side channels. Note lack of LWD in most side channels as well as typical cobble and gravel substrate on the bar and riparian understory with ubiquitous reed canarygrass.

Off-Channel Habitat Types

According to Lestelle et al. (2004), "**Off-channel areas** are those not fed by surface water from the main river when flows are less than bankfull. They are fed by floodwaters, groundwater, and in some cases, by water sources from higher terraces." Off-channel habitat types include overflow channels, groundwater channels, and floodplain ponds. Herrera also included agricultural ditches in this category due to their lack of connectivity with typical riverine processes.

Photo 7. Side channel lacking LWD and woody bank vegetation.

Overflow Channel Habitat Type

Definition

According to Lestelle et al. (2004), "**Overflow channels** are flood swales, and often are relict mainstem channels (Dykaar 2000). Overflow channels are directly connected to the main river at their upstream end only when flows exceed bankfull. Like side channels, they are bordered partly or entirely by vegetated dry land. Overflow channels are often dynamic as a result of the periodic influx of water, sediment, wood, nutrients, and organic material from the main channel (Saldi-Caromile et al. 2004)."

Photo 8. Narrow braid of the main stem isolated at low to moderate flows by a low gravel bar.

Typical Habitat Conditions

The overflow channels observed during the March 2014 field assessment were characterized sometimes by bare ground but were primarily vegetated with dense mats of reed canarygrass, which is known to rapidly colonize such disturbed areas. Where the ground was exposed, substrate was typically a mix of gravel and sand/fines. Large woody debris was generally lacking in overflow channels and on adjacent floodplain surfaces, perhaps as a result of people using downed trees as firewood. Habitat complexity was poor on account of the generally homogenous cover of reed canarygrass and the lack of topographic and hydraulic roughness typically provided by woody vegetation and LWD.

Results of the WSE 2D hydraulic model for the project reach suggest that typical flow velocities in overflow channel areas during a 2-year return interval flow are typically less than 1.5 fps, with occasional channels or parts of channels seeing velocities between 1.5 and 4 fps. Observation of the size of bedload and suspended load material deposited in overflow channels (when compared to bedload size in the active channel) support these velocity estimates.

The downstream ends of overflow channels often form important off-channel alcove habitat, known to be used by a number of salmonids species and life stages. The banks and edges of alcoves observed during the field assessment were typically dominated by reed canarygrass.

Reed canarygrass provides little habitat value. It may provide some overhead cover and undercut banks for juvenile salmonids, but it provides almost no food sources (such as insects) for them. Native woody and herbaceous species along the banks would provide much higher quality habitat (for example, by providing shade and contributing LWD), but the reed canarygrass prevents them from colonizing the banks. Despite the prevalence of reed canarygrass, juvenile salmonids were observed in groundwater channels in the project reach. That may indicate a lack of better rearing habitat and high velocity refugia not only within the project reach but throughout a larger segment of the Yakima River.

Photos 9 through 12 show typical habitat conditions of overflow channels within the project reach.

Photo 9. Typical overflow channel inlet near the upstream end of the project reach.

Photo 10. Overflow channel swale dominated by invasive reed canarygrass.

Photo 11. Inlet area of a large overflow channel near the downstream end of the project reach.

Groundwater Channel Habitat Type

Definition

Photo 12. Downstream end of overflow channel providing alcove habitat. Bank vegetation dominated by invasive reed canarygrass.

According to Lestelle et al. (2004), "**Groundwater channels** are usually relict river and/or overflow channels fed by subsurface flow, though surface flow from higher terraces can also contribute. They can function as overflow channels at some flood stages, depending on their location on the floodplain. They include several subtypes of channels (Ward et al. 1999), including: (1) channels originating from the seepage of main channel surface water (i.e., very shallow groundwater closely associated with the main river), (2) channels fed by the larger floodplain aquifer (hyporheic zone), and (3) channels fed by lateral groundwater supplied from adjacent terraces."

Typical Habitat Conditions

Groundwater channels observed during the March 2014 field assessment varied widely in size. Bed material was typically fine grained, with a layer of silt and organics overlaying sand and gravel. Often, significant algae growths were present.

Large woody debris was generally lacking in the observed channels and on adjacent floodplain surfaces. Habitat complexity was poor to fair on account of the prolific reed canarygrass on the banks and the lack of complexity normally provided by woody riparian vegetation and LWD in the channel.

Riparian habitat quality along the groundwater channels was generally Poor (see Appendix A). While buffer widths typically exceed 80 feet, shading and overhead cover was typically less than 25 percent, and invasive reed canarygrass was the predominant vegetation species.

The outlets groundwater channels often provide important off-channel alcove habitat, known to be used by a number of salmonids species and life stages. The banks and edges of alcoves observed during the field assessment were typically dominated by reed canarygrass.

As stated before, reed canarygrass provides little habitat value. It may provide some overhead cover and undercut banks for juvenile salmonids, but it provides almost no food sources (such as insects) for them. Native woody and herbaceous species along the banks would provide much higher quality habitat (for example, by providing shade and contributing LWD), but the reed canarygrass prevents them from colonizing the banks. Despite the prevalence of reed canarygrass, juvenile salmonids were observed in groundwater channels in the project reach. That may indicate a lack of better habitat not only within the project reach but throughout a larger segment of the Yakima River.

Photos 13 through 15 show typical habitat conditions of groundwater channels within the project reach.

Floodplain Pond Habitat Type

Definition

According to Lestelle, et al. (2004), "**Floodplain ponds** or crescentric lakes are water-filled depressions, partially or entirely filled with water year-round (Dykaar 2000). They are usually hydraulically isolated, although many have an egress channel to the main river that may dry up at low flows. Crescentric lakes form as cut-off oxbows or from the incomplete coalescence of an island with the river margin (Dykaar 2000). Floodplain ponds can also be man-made (e.g., floodplain gravel pits). Both natural and artificial ponds might be supplied by groundwater or surface water from streams or springs and may not be hydraulically connected to the river at all flows."

Typical Habitat Conditions

The vast majority of floodplain ponds in the project reach are manmade, constructed as either floodplain gravel pits, for stock watering or irrigation, or for recreational purposes.

During the March 2014 field assessment, LWD was typically lacking in floodplain pond habitat. Occasional logs were observed along the margins of ponds, but for the most part, LWD habitat and recruitment sources adjacent to ponds were lacking.

All of the floodplain ponds observed in the project reach, except one, appear to be connected to the main stem at only extremely high flows, greatly exceeding the 2-year return interval flow. The exception is one of the Hansen Pits that has become connected to the main river as a result of levee erosion.

Habitat complexity observed within the floodplain ponds was poor. Pond edges typically drop steeply into deeper water areas, providing little shallow water habitat or refuge. Personal accounts from local anglers

Photo 13. Groundwater channel outlet with banks dominated by invasive reed canarygrass.

Photo 14. Groundwater channel exhibiting both ideal bank vegetation (left) and poor vegetation conditions dominated by reed canarygrass (right).

Photo 15. Groundwater channel east of the main river. Water was extremely clear and cold despite lack of riparian shading, and numerous juvenile salmonids were observed around complex woody debris. Note encroachment of reed canarygrass degrading edge habitat in the right side of the photo.

suggest that water temperatures in most of the ponds reach levels generally considered too warm for native salmonids, and a number of the ponds within the project area are known to be inhabited by non-native, warm water species such as largemouth bass, bluegill sunfish, and common carp (David Child, personal communication, March 26, 2014).

Riparian vegetation associated with the floodplain ponds was typically of moderate to poor quality and density (see Appendix A). Riparian buffer widths were typically very narrow (less than 20 feet wide) and were confined primarily to the inner sloping banks of the ponds. Vegetation was either dense reed canarygrass or scrub-shrub vegetation.

Photos 16 through 18 show typical habitat conditions of floodplain ponds within the project reach.

Photo 16. Floodplains ponds in the project reach are virtually all man made, remnants of old gravel pits or irrigation ponds.

Photo 17. Typical vegetation conditions on all observed floodplain ponds were similar to those at the Hansen Pits.

Photo 18. View of the Hansen Pit that has been captured by the mainstem channel.

Ditch Habitat Type

Definition

A **ditch** is a manmade channel with or without full connectivity to the river that conveys water for the purpose of irrigation.

Typical Habitat Conditions

At the time of the field assessment in March 2014, ditches were non-operational and dry. Because of their ephemeral nature and simplistic geometric and geomorphology ditches are considered poor off-channel habitat.

Terrestrial/Floodplain Habitat and Land Use Types

Deciduous Forest Floodplain Habitat Type

Definition

For the purposes of this project, **deciduous forest habitat** is defined as deciduous-tree-dominated forested areas where canopy cover is over 60 percent. Within the project reach, most observed deciduous forest canopy cover was in the range of 80 to 100 percent.

Typical Habitat Conditions

Forested floodplain habitats in the project reach were dominated by deciduous tree species, such as black cottonwood and willow. Cottonwoods were the larger tree species forming the canopy, typically 65 to 100 feet tall and 16 to over 30 inches diameter at breast height (dbh). Other common woody plant species included alder and red osier dogwood. Groundcover was dominated by reed canarygrass in areas where extremely dense scrub/shrub understory was not present. Plant assemblage was not particularly diverse in species or age class, and new cottonwood recruitment appeared to be limited by dense reed canarygrass and by deer and elk browse. Occasional, and isolated instances of single, large ponderosa pine trees (24-inch dbh or greater) were observed. The pines were primarily associated with localized areas of higher, drier ground on the floodplain.

Photos 19 and 20 show typical habitat conditions of deciduous forest within the project reach.

Photo 19. Deciduous forest habitat type with large mature cottonwoods dominating the canopy and understory dominated by reed canarygrass.

Photo 20. Deciduous forest habitat type with understory dominated by red osier dogwood and other shrubs. Reed canarygrass is predominant in the foreground of the photo on the river banks.

Woodland Floodplain Habitat Type

Definition

For the purposes of this project, **woodland habitat** is defined as areas where canopy cover ranges from approximately 20 to 60 percent.

Typical Habitat Conditions

In the project reach, woodland habitat areas were dominated by deciduous tree species, such as black cottonwood and alder. Red osier dogwood and willow were also observed. Cottonwoods were the large tree species forming the canopy, typically 65 to 100 feet tall and 16 to over 30 inches diameter at breast height (dbh). Groundcover was dominated by reed canarygrass. Occasionally, large (24-inch dbh or greater) single ponderosa pine trees were observed, primarily in localized areas of higher, drier ground on the floodplain.

Photos 21 and 22 show typical habitat conditions of woodlands within the project reach.

Scrub-Shrub Floodplain Habitat Type

Definition

For the purposes of this project, **scrub-shrub habitat** is defined as areas dominated by shrubs and small trees.

Typical Habitat Conditions

Within the project reach, scrub-shrub habitat was vegetated with species tolerant of floodplain soil conditions, such as alder, red osier dogwood, and willow. Scrub-shrub habitats also included young willow and black cottonwood, less than approximately 15 feet tall. Throughout the project reach, the understory and open areas of this habitat type were dominated by dense reed canarygrass.

Photos 23 and 24 show typical habitat conditions of scrub-shrub areas within the project reach.

Prairie Floodplain Habitat Type

Definition

For the purposes of this project, **prairie habitat** is defined as vegetated open areas with a tree canopy cover less than 20 percent.

Photo 21. Woodland habitat type with primarily midsized deciduous trees widely spaced and understory dominated by reed canarygrass.

Photo 22. Woodland habitat type with understory dominated by reed canarygrass. Sparse tree canopy made up of large cottonwoods and the occasional ponderosa pine.

Photo 23 Sparse scrub-shrub habitat on a small island separating a side channel from the main channel.

Photo 24. Dense scrub-shrub habitat lining a groundwater channel.

Typical Habitat Conditions

Within the project reach, prairie habitats were consistently dominated by reed canarygrass. Virtually no other vegetation was observed in these areas during the field assessment.

Photos 25 and 26 show typical habitat conditions of prairie areas within the project reach.

Photo 25. Prairie habitat type in the foreground is dominated by invasive reed canarygrass. Habitat type transitions to deciduous forest in the background.

Bare Ground Floodplain Habitat Type

Definition

Bare ground areas are unvegetated areas not related to overflow channels or active gravel bars in the main stem or side channels.

Typical Habitat Conditions

Bare ground conditions persist in places where significant soil impact has resulted from cattle grazing, grading, filling, gravel mining, or repeated use by vehicles forming makeshift dirt and gravel roads (Photo 27). Bare ground areas provide little to no off-channel or floodplain habitat when inundated, and they provide limited terrestrial habitat due to their lack of vegetation.

Photo 26. Prairie habitat type in the foreground on both sides of a groundwater channel is dominated by invasive reed canarygrass and other non-native species including tansy ragwort and woolly mullen. Habitat type transitions to scrub-shrub and deciduous forest in the background.

Agricultural Land Floodplain Land Use Type

Definition

The **agricultural land** use/habitat type includes areas of the project reach currently used for agricultural production of alfalfa or timothy hay, or dedicated specifically to livestock pasture.

Photo 27. Typical bare ground habitat type along a heavily used 2 track unimproved road.

Typical Habitat Conditions

Agricultural areas provide poor floodplain habitat conditions with low hydraulic roughness when inundated during overbank flow events. Such areas may also act as a source of runoff, sediment, and nutrients to the river. Hay fields and pastures in the project reach (Photo 28) are used by wild ungulates (deer and elk) for grazing.

Developed Land Floodplain Land Use Type

Definition

For the purposes of this project, the **developed** land use type is defined as areas of significant residential or commercial building development. Developed areas in the project reach include groupings of buildings such as homes, agricultural buildings, or shops and associated driveways, parking areas, and yards.

Photo 28. Typical agricultural land conditions within the project reach.

Typical Habitat Conditions

Developed areas provide poor floodplain habitat conditions and may act as a source of runoff, sediment, and nutrients or other pollutants to the river. They typically provide little or no benefit to fish and wildlife and can result in complex social dynamics regarding river and floodplain management. Developed areas in the active floodplain are also at serious risk of flooding.

Major Road Floodplain Land Use Type

Definition

A **major road** is defined for this project as a paved road elevated significantly above the native floodplain surface and creating a clear hydraulic boundary between portions of the landscape. Within the project reach, the following roads are considered major roads:

- Canyon Road, Stone Road, and Ringer Loop Road on river left
- Riverbottom Road on river right

SUMMARY OF KEY LIMITING FACTORS

The main factors limiting habitat quantity and quality for key salmonid species in the project reach are:

- *Reduction in overall quantity of off-channel habitat as a result of roads, levees, and channel filling* — The reduction in overall floodplain and off-channel habitat in the project reach has not been affected as dramatically as it was upstream, where I-90 cut off nearly the entire historic floodplain. Still, multiple public and private levee projects, as well as the construction of Canyon Road and the railroad, and numerous small-scale channel filling projects have resulted in a significant decrease in off-channel habitat relative to historical conditions. These cut-off areas have the potential to be extremely productive due to the significant groundwater upwelling within the project reach.

- Degradation of site-scale habitat complexity in existing main stem and off-channel habitats due to presence of invasive vegetation such as reed canarygrass and lack of overhead cover, large and small woody debris in off-channel habitats — While many off-channel habitat areas still exist within the project reach, the quality of the small-scale habitat in those areas has been degraded due to a shift towards dominance by non-native plan species that do not provide the degree of cover, complexity, and food (insects) that native wood vegetation provides. The vegetation shift, along with physical removal of woody debris in some areas, has resulted in a decrease in shading and cover for juvenile salmonids, and increases in summer water temperatures.

- *Elimination of normative flow hydrology in the watershed* — Alteration of natural flow regimes and adoption of the "flip-flop" flow regime has had a severe impact on habitat in the project reach in a number of ways. Reducing the regularity of overbank flows has resulted in decreased groundwater recharge that historically provided cooler water conditions during the summer. Also, the reduction of peak flow volume and alteration of runoff timing has decreased the effectiveness of anadromous smolt outmigration. Lastly, extended periods of high flows through the summer months have significantly reduced the quality and quantity of available summer rearing habitat for juvenile salmonids. Under current conditions, high velocities that exceed the limits of juvenile fish swimming ability exist in most areas of the main stem and side channels, even up the edges in many locations.

This habitat assessment study and numerous other studies conclude that, while degraded relative to historical conditions, the project reach contains some of the best remaining floodplain and off-channel habitat in the Yakima River watershed. For example, the Kittitas Valley Reach (which includes the project reach) was ranked #2 by Snyder and Stanford (2001) for priority of conservation actions, only behind the Upper Yakima-Teanaway reach. As a baseline, conservation and protection of existing habitats should be prioritized as a key component of the restoration planning effort for the project reach.

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APPENDIX A

Habitat Assessment Metric Details

HABITAT ASSESSMENT METRIC DETAILS

This appendix describes the specific metrics used to assess and describe conditions in the Hansen Pits to Yakima Canyon reach of the Yakima River. The specific metrics were used to map and describe existing conditions within the project area.

Channel Type

Channel morphologic reach types were classified referencing the channel-process-based classification system developed by Montgomery and Buffington (1997). Additional reach types were used to describe channel and reach types that do not fit well into that classification system. Defining the overarching morphology of the reach enables a comparison of observed channel conditions and response to the natural geomorphic ability of the reach to resist or respond to changes in hydrology or sediment supply.

Montgomery and Buffington (1997) channel types included: cascade, step pool, plane-bed, pool-riffle, dune-ripple, bedrock, and colluvial. An additional channel type, excavated/constructed is defined as:

- **Excavated/constructed.** This is a channel reach that has been mechanically altered or constructed. It has not been formed by natural processes of erosion and deposition. This channel type may or may not be engineered, and bed/bank material may consist of anything from natural material (fines, sand, gravel, cobble, etc.) to imported riprap, blasted bedrock, gabions, or concrete. This type typically consists of highly simplified planform (straight, with clear angle changes) and cross-sectional geometry (rectangular or trapezoidal). Constructed channels are not necessarily stable.

Forced channel types, such as pool-riffle or step pool forced by large woody debris (LWD) in the channel were classified as that basic channel type, with notes added describing the significant morphological influence of the LWD or other forcing factor.

The classifications used to describe the reach and channel types in the project reach are listed and described in Table A-1.

Functional Large Woody Debris

The function of each reach was rated based on the amount and type of LWD in the channel as approximated from aerial photos and global information system (GIS) data. Reaches were described using a protocol that combines components of existing LWD protocols from the National Marine Fisheries Service (NMFS 1996) Matrix of Pathways and Indicators and research published by (Ralph et al. 1994; Beechie and Sibley 1997; Fox and Bolton 2007).

Habitat types were categorized based on the functional LWD criteria listed in Table A-2.

Fox and Bolton (2007) provide baseline information for an alternative means to assess LWD stability. Fox and Bolton surveyed and cataloged a number of Cascade Range river systems and compiled information from existing research that documented the volume of individual key log members. Key log members are defined as "proportionately large individual logs" that are "independently stable and resist entrainment by moderate floods." These logs "function to provide the primary catalysts for smaller wood retention and jam formation." Their summary of key member size is shown in Table A-3.

Table A-1. Reach and Channel Type Classifications.

Reach Type	Channel Type	Description
Source	Colluvial	Headwater, colluvial channels; act as transport-limited; sediment storage locations subject to debris flow scour
Transport	Bedrock	Morphologically resilient, supply-limited reaches; rapidly convey increased sediment inputs
	Cascade	
	Step pool	
Response	Plane-bed	Lower gradient, alluvial, transport-limited reaches; morphological adjustments occur in response to increased sediment supply
	Pool-riffle	
	Dune-ripple	
Additional (not discussed in Montgomery and Buffington 1997)	Excavated / constructed	A channel reach that has been mechanically altered or constructed, often to convey surface runoff; has not been formed by natural processes of erosion and deposition. Bed/bank material may consist of anything from natural material (fines, sand, gravel, cobble, etc.) to imported riprap, blasted bedrock, gabions, or concrete. Typically consists of highly simplified planform (straight, with clear angle changes) and cross-sectional geometry (rectangular or trapezoidal). Constructed channels are not necessarily stable.

Table A-2. Functional LWD Criteria Ratings.

Rating	Criteria
Properly Functioning	Bankfull width 0-6m – Approximately one piece every 8to 9 feet of channel. Bankfull width 6-30m – Approximately one piece every 5 to 6 feet of channel. To classify as LWD, pieces must exceed 10 cm (4 in) in diameter and 2 m (6 ft) in length. In addition, the reach must have an adequate source for LWD recruitment in the adjacent riparian area.
At Risk	Meets LWD quantity requirements for classification as Properly Functioning but lacks adequate sources of LWD recruitment in adjacent riparian areas to maintain the standard.
Not Properly Functioning	Does not meet LWD quantity requirements for classification as Properly Functioning or At Risk. Reach may or may not have an adequate source for LWD recruitment in the adjacent riparian areas Where sources for LWD recruitment were present, it was recorded in the notes.

Sources: NMFS (1996); Ralph et al. (1994); Beechie and Sibley (1997); Fox and Bolton (2007)

Table A-3. Key Wood Member Definitions from Fox and Bolton (2007).	
Minimum Piece Volume to Define Key Pieces (all regions)	
Bankfull Width Class	**Minimum Piece Volume (m^3)**
0-5 m	1*
>5-10 m	2.5*
>10-15 m	6*
>15-20 m	9*

Substrate Material

Primary and secondary stream bed substrate were classified for all geomorphic reaches based on field observations. Visual estimates were based on relative surface area covered by different size classes of sediment. Primary substrate refers to the most common size class, and secondary substrate refers to the second most common size class. In certain instances, the presence of a third size class was observed and documented in the notes. Primary and secondary stream bed substrate were classified using the categories listed in Table A-4.

Table A-4. Substrate Material Categories.	
Category	**Size Class**
Fines	<63 microns (0.063 mm) estimated
Sand	63 microns – 2 mm
Gravel	2 mm – 32 mm
Cobble	32 mm – 256 mm
Boulder	>256 mm (approximately 10 inches)
Bedrock	Non-alluvial bedrock
Cohesive fines	Non-alluvial erosion resistant clays
Other	

Stream Habitat Complexity

Stream habitat complexity is a metric used to distinguish between a channel that is naturally diverse with riffles and pools and one that has become uniform and simplified through natural or anthropogenic influences. A quantitative field method that is both quick and comprehensive was not available for assessing stream channel complexity. Therefore, a qualitative metric with specific guidelines for visible assessments of channel topography and habitat diversity (McBride 2001) was used. The metric was determined to provide the most rapid and complete method for assessing whether the physical channel conditions were consistent with the existing and designated beneficial uses, which include salmonid spawning and rearing habitat. Although the metric is qualitative and subjective, the same observers applied the metric to all sites; therefore, the results should be consistent for use in this analysis. The channel characteristics used for classifying stream habitat complexity are shown in Table A-5.

Riparian Habitat Quality

The habitat quality of the riparian buffer was determined by combining individual rankings for the width and integrity of the riparian zone into one multivariable metric. This metric provides a general description of the width of the riparian zone and an estimate of the disturbance from nearby development. It also provides insight into whether and how the existing conditions are supportive of their existing and beneficial uses, given established relationships between riparian conditions and both habitat and water quality (May et al. 1997). Overall riparian habitat quality was noted as *high, moderate*, or *low* according to the guidelines presented in Table A-6.

Table A-5. Stream Habitat Complexity Classifications.

Classification	Channel Characteristics
Excellent	Diverse and complex structure Variety in channel units (pools, riffles, glides) Side channels and/or debris jams present Diverse microtopography Variable channel geometry
Good	Less diverse and complex structure Some variety in channel units Side channels and/or debris jams less frequent Some heterogeneity in microtopography and channel geometry
Fair	Little diversity or complexity in structure Little variety in channel units Very few side channels and/or debris jams Little heterogeneity in microtopography and channel geometry
Poor	Simple structure No variety in channel units No side channels or debris jams present Very little variety in channel geometry Homogeneous microtopography

Source: McBride (2001)

Table A-6. Riparian Habitat Quality Classifications.

Overall Riparian Habitat Quality	Width of Riparian Buffer (approximate feet)	Riparian Cover Over Stream Channel/Shading (average %)	Native Plant Species Dominance (average %)
High	>80 feet	>75%	>80%
Moderate	20 – 80 feet	75 – 25%	80 – 50%
Low	<20 feet	<25%	<50%