Working with Beaver in Pataha Creek to Restore Salmon and Steelhead Habitat: Assessment, Design, and Construction Report

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INTRODUCTION

Pataha Creek is a tributary to the Tucannon River in southeast Washington. Much of Pataha Creek is dominated by loess soils and recent assessments of have identified a large portion of the mainstem as heavily incised (Beechie et al. 2008). The goal of this project is to test whether a restoration method developed and tested in Bridge Creek, Oregon will be suitable for restoring streams like Pataha Creek in southeast Washington. The Bridge Creek project is an Intensively Monitored Watershed (IMW; Bennett et al. 2015) that uses wooden fence posts driven into the stream to support existing beaver dams and/or simulate beavers dams to accelerate the recovery process from vertical channel incision. The Bridge Creek IMW is part of the Integrated Status and Effectiveness Monitoring Program (ISEMP) and the IMW has demonstrated that simulating beaver dams can reduce incision (Pollock et al. 2014) and increase the production of juvenile steelhead at the population level (ISEMP 2013). We also chose to use a restoration method that simulates beaver dams (and that can also support existing beaver dams) because it has a strong foundation in both ecological literature (Finnigan 1997, Pollock et al. 2004, Rosell et al. 2005, Nummi and Holopainen 2014) and fluvial geomorphology (Naiman et al. 1988, Pollock et al. 2007, Beechie et al. 2008, DeVries et al. 2012, Majerova et al. 2015). This method is called the beaver dam analog approach (BDA). The BDA approach can either simulate many of the benefits of natural beaver dams or help to promote beaver colonization of an area by providing stable structures to build dams on, especially when riparian areas have limited large woody debris available.

The Pataha Working with Beavers project is being implemented in two phases. Phase 1 includes the assessment of the Tucannon River watershed to support dam building beavers and the implementation of a trial of BDAs in Pataha Creek in 2015. Phase II includes the implementation of a larger BDA project based on the results of the assessment and trial in 2016-2017.

The specific objectives of the Pataha Creek project are to:

- Use the Beaver Restoration Assessment Tool (BRAT) developed by Dr. Joe Wheaton at Utah State (http://etal.usu.edu/BRAT/) to assess the potential of the Tucannon River to support dam building beaver,
- Conduct a trial of beaver dam support structures by building 2-3 complexes of beaver dam analog (BDA) structures in 2015, and based on the results of the trial structures
- Develop a more comprehensive plan and use BDAs to restore 2-3 km of stream habitat in 2016-2017.

Study Area

The study area for the project is the Tucannon River (Figure 1). However, in 2015 the field trial of BDAs will be in Pataha Creek. We selected Pataha Creek for the trial because a local landowner indicated they were interested in participating in a restoration project, the area appeared to have characteristics that were suitable for conducting a trial of simulated beaver dams (i.e., low gradient, high incision, current use by beavers in the immediate area), and the stream supports ESA listed steelhead (*Oncorhynchus omykiss*), Chinook salmon (*O. tshawytscha*), and Bull trout (*Salvelinus confluentus*). The location for the trial of BDAs is on the mainstem of Pataha Creek approximately 10 km upstream from the confluence of Pataha Creek with the Tucannon River (Figure 2).

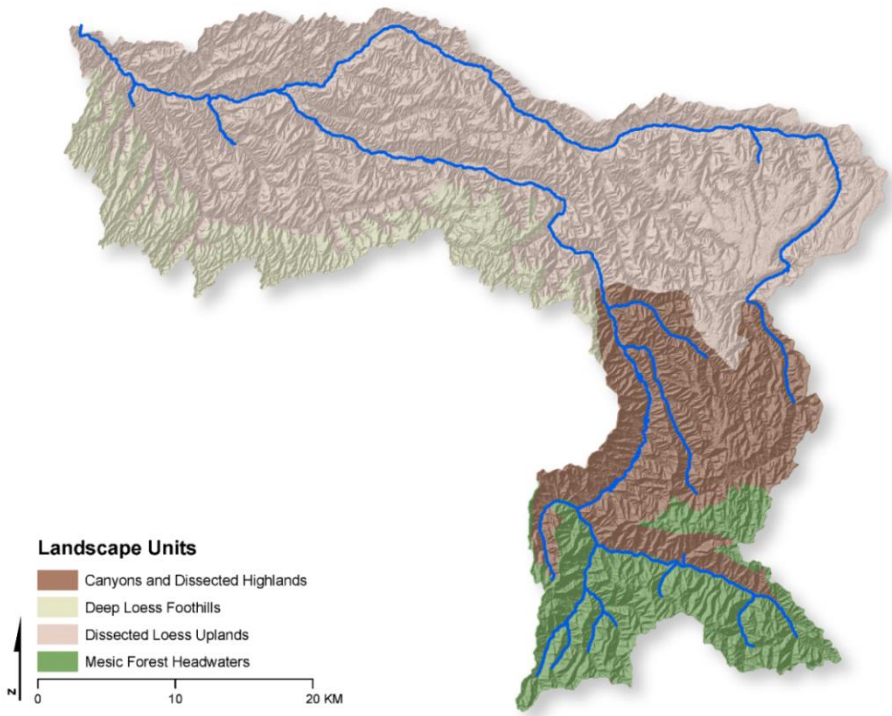

Figure 1. Broad landscape units within the Tucannon River watershed.

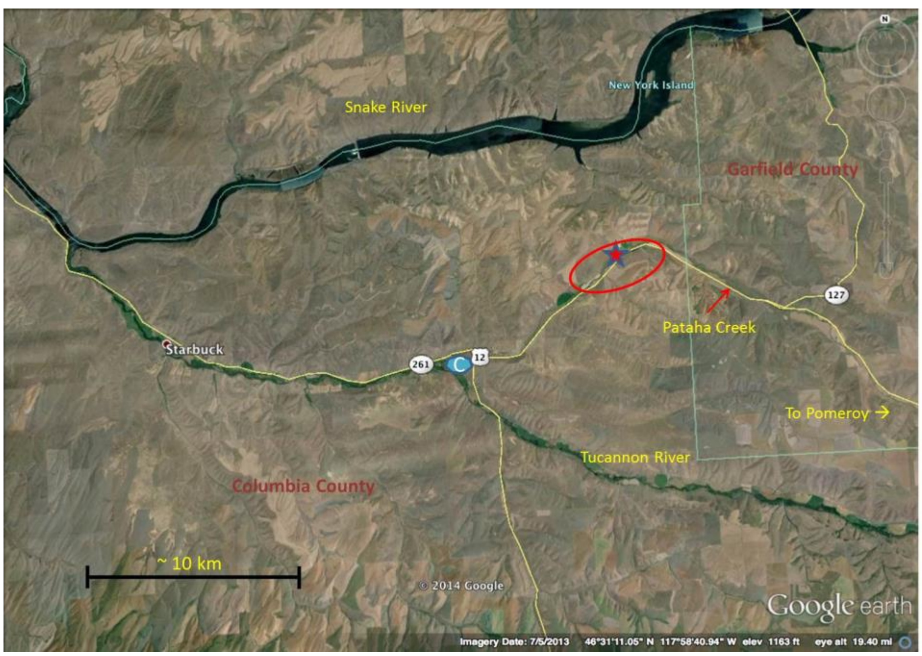

Figure 2. Lower Tucannon River and Pataha Creek and the location of the trial restoration area (red oval), the landowner (red star), and an existing Columbia Habitat Monitoring Program (CHaMP) site (blue C).

The Tucannon watershed is composed of four distinct Landscape Units: Mesic Forest Headwaters, Dissected Highlands, Dissected Loess Uplands and Deep Loess Foothills (Figure 1). Much of the lower portion of the watershed in dominated by deep loess foothills and dissected loess uplands. Loess soils are mostly absent from the mid and upper portions of the watershed which are dominated by mesic forest headwater and dissected highlands. The loess soils are highly erosive and prone to incision (Beechie et al. 2008). Much of Pataha Creek is within the loess uplands and has experienced significant (1-8 m) incision. The exact timing and causes of incision are not known but it is presumed that intensive grazing and farming beginning in the late 1800's caused increased erosion of loess soils from the hillsides and a loss of riparian vegetation along Pataha Creek which lead to down-cutting and the current incised nature of much of the mainstem (Duffin 2005, Beechie et al. 2008). Pataha Creek has incised the valley fill exposing 1-8 meters of heterogeneous sandy silt, evidently underlain by basal stream gravels. The stream is effectively disconnected from its floodplain for ~ 40 km upstream of its confluence with the Tucannon River. The incision trench has widened and the stream channel is now flowing within a floodplain that is inset within the incision trench. This situation is part of a natural evolution of incised channels and the current condition can be characterized as phase 2 – channel widening (Figure 3; Pollock et al. 2014). Recent changes in land-use practices have decreased the sediment delivery from the adjacent hillslopes but the stream channel and riparian habitat remain in a degraded state (SRSRB 2011). However, it will likely be several hundred years or more before the channel aggrades and riparian conditions return to a more historic state without active intervention.

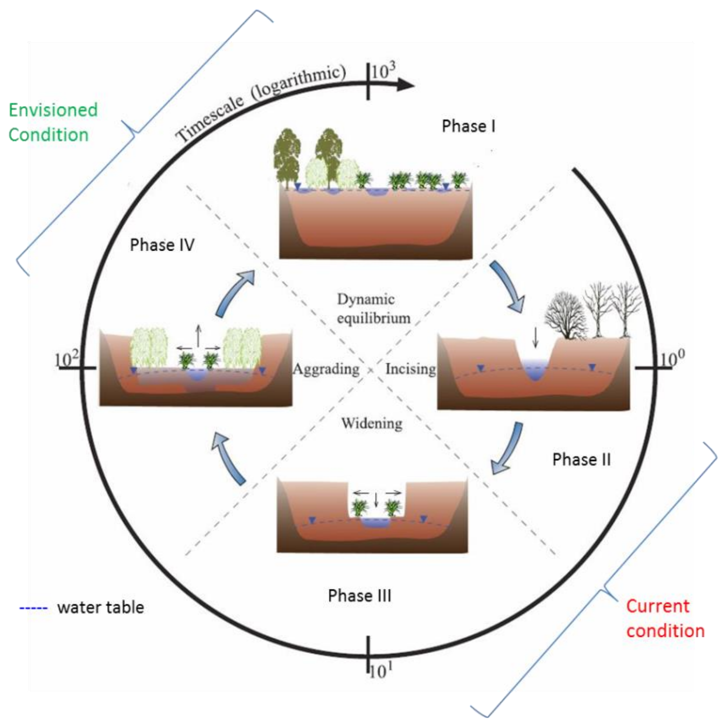

Figure 3. A simplified model of the evolution between typical conditions for incision-prone streams. Highlighted are the dominant physical processes forcing each phase and typical timescales of recovery. Small arrows illustrate the direction of erosion or deposition and the blue line signifies the water table elevation. Reproduced from Pollock et al. (2014) and Cluer and Thorne (2014).

The fisheries resources of Pataha Creek are primarily the Snake River steelhead distinct population segment (DPS). Recently the steelhead DPS in Pataha Creek was reclassified to a major spawning area (MaSA) from a minor spawning area (MiSA) due to the improvements in management practices in the watershed. Bull trout use the upper watershed and some rearing of juvenile Chinook salmon (Snake River ESU) occurs in the lower reaches of Pataha Creek (SRSRB 2011). Steelhead and Chinook also use the lower 20 km of Tucannon River downstream of the confluence with Pataha Creek and the lower portion of the Tucannon River has recently been reclassified as a priority restoration reach because of the improvements in water quality in Pataha Creek and the lower Tucannon River.

Pre-Construction Assessment and Design

We have reviewed several regional assessments of the Tucannon Watershed (USFS 2002, DOE 2010, AQEA 2011, SRSRB 2011) and literature related to land-use and erosion related issues in southeast Washington (Hecht et al. 1982, SCS 1984, Black et al. 1998, Duffin 2005, Beechie et al. 2008). These assessments confirm Pataha Creek has deep and easily erodible loess soils that are prone to incision, and historic land-use activities and sustained beaver trapping and dam removal likely caused rapid incision by increasing erosion rates and removing riparian vegetation. However, it appears land-use activities have improved and erosion rates have decreased.

Trial Beaver Dam Analog Assessment

We proposed to use a trial of the BDA approach on a small scale (i.e., reach scale) to inform a larger-scale restoration (Phase II). Using a trial is an inexpensive and safe approach to testing basic assumptions about a restoration approach and fits well within an adaptive management framework (Bouwes et al. 2015). The purpose of the trial structures were to i) test the feasibility of the installation of the treatment method and better constrain the time and costs associated with each structure, ii) highlight any unanticipated logistical constraints, and iii) ascertain how predictable the hydraulic and geomorphic responses associated with each structure were. We do not expect to learn about the broader restoration hypotheses associated with BDAs at the watershed scale or fish population response. However, we have collected aerial imagery of the trail study area and installed trail cameras and temperature loggers to provide a minimum level of monitoring to enhance learning from the trial.

Pataha Creek along the Archer property is essentially entrenched within two 'incision trenches' (Figure 4**Error! Reference source not found.**). The first incision trench is 5-8 m deep and approximately 10 m wide. The second incision trench is 1-1.5 m deep and 1-1.5 m wide and confines Pataha Creek into a relatively simple channel. On either side of the channel are high banks that are resistant to erosion because they are dominated by reed canary grass. A perched floodplain between the edge of the stream channel and the first incision trench is dominated by reed canary grass and slopes upwards away from the channel (Figure 4). This sloped floodplain is likely evidence that most high flow events lack sufficient stream power to evacuate material sluffing off the walls of the incision trench. This represents a modified version of the incision evolution model where small streams with deep incision trenches (incision depth ~ = bankfull width) lack the stream power to have a significant widening phase (see Beechie et al. 2008). Beaver dams would need to be $\geq$ 2 m high to flood water out onto this perched floodplain. We decided during this trial to build BDAs only 1.0-1.5 m high and flood a portion of the inset floodplain (i.e., proceed with caution). We selected areas with lower bank heights to maximize the amount of floodplain inundated.

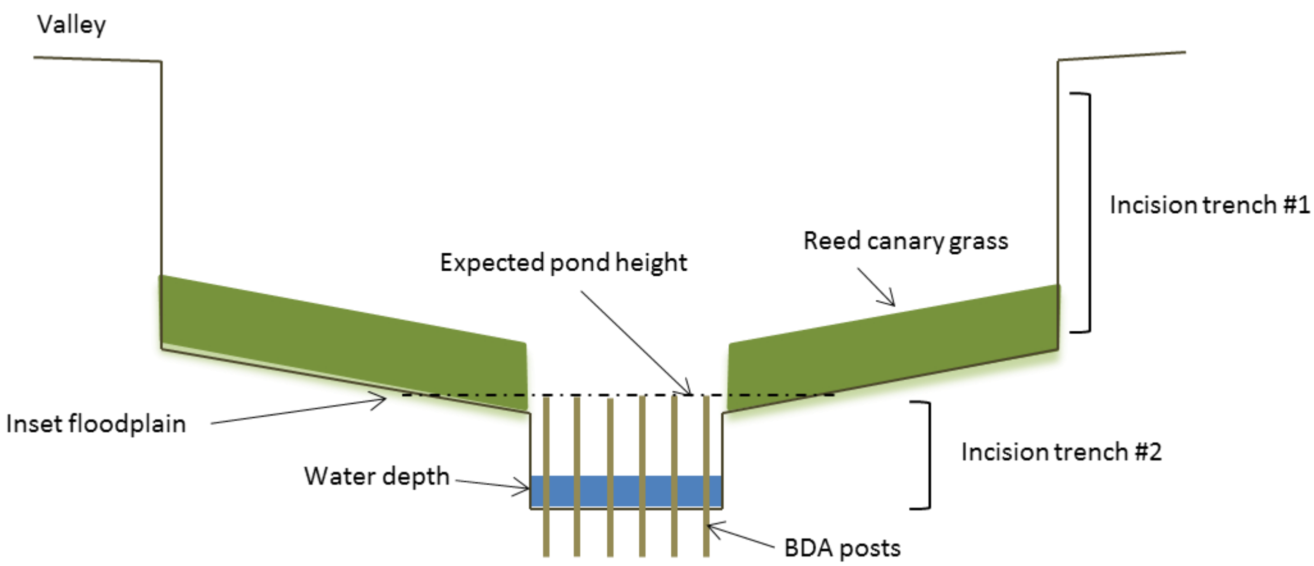

Figure 4. Schematic of incision trench in trial study area. Reed canary grass occupies an upward sloping inset floodplain and stream channel is trapped in a second trench 1-1.5 m deep.

Trial BDA Design

We designed eight beaver dam analogs (BDAs) grouped into four complexes (Figure 5). We found several areas of exposed bedrock throughout the study area and had to locate structures in areas where there was substrate deep enough to drive a post into (i.e., ≥ 1.0 m). We built three types of BDAs: primary, secondary, and reinforcing (Table 1). Complex 1, 3, and 4 each had at least one secondary and one primary dam whereas complex 2 consisted of a single reinforcement structure (Table 2). Complex 1 is located in a more complex section of the study area where the channel and incision trench were wider and some braiding of the channel was present. There was also a large deposit of gravel exposed in the wall of the incision trench which is rare along this portion Pataha Creek. We anticipate complex 1 flooding more of the inset floodplain due to lower bank heights and having the potential to deposit sediment onto the inset floodplain and create or maintain multiple channels. Complex 2-4 are all located in sections of the study area where there is a single channel that is confined by high banks reinforced with reed canary so the design is focused more on aggrading the channel upstream of the BDAs. Complex 2 was designed as a single reinforcement BDA (Table 2). The beginning of a natural beaver dam was found at this site. We added posts along the dam to act as a support and left a large pile of willow cuttings to provide building material. Complex 3 and 4 were designed to test how fast aggradation can occur upstream of BDAs in this very incised section of stream. We do not expect to flood large areas upstream of the dams until 1.0-1.5 of aggradation has occurred.

Figure 5. Location of three beaver dam analog complexes and eight total beaver dam analogs (BDAs) along Pataha Creek on the Archer property. “B” = location of individual BDAs, numbers indicate BDA complexes (groups of ≥ 1 BDAs designed to function as a group), Pataha BS = bottom of study area.

Table 1. Types of beaver dam analogs (BDAs), intended function, design, and construction methods.

Structure Type	Function	Design	Construction
Primary Dam	Primary flow impounding structures maximize pond extent, water storage, channel aggradation, flow dispersion, and groundwater exchange	Channel spanning dams built adjacent to and extending laterally onto floodplains, benches, and terraces. Crest elevation greater than bankfull	Convex post-line with wicker weave. Upstream impermeable sediment wedge for pond creation, downstream willow mattressing scour prevention
Secondary Dam	Downstream gradient control and return flow capture of primary dams. Increase extent of ponding, aggradation, and habitat complexity	Channel spanning dams installed downstream of primary dams. Crest elevation at or below bankfull	Post-line with wicker weave. Less extensive upstream sediment wedge and little to no downstream mattressing
Constriction Dam	Creation of hydraulic jet to increase capacity for geomorphic work of bank erosion, sediment recruitment, pool and bar formation	Partial channel spanning dam oriented downstream and at an angle to flow. Enhance flow constrictions at meanders and in-channel structural elements	Staggered post-line securing locally available fill material such as LWD, cobbles, gravels, sand, and/or willow weave
Reinforced Existing Dam	Increase resistance of dams to high flow events and extend functional life of abandoned dams. Increase likelihood of stable colony establishment	Active and abandoned dams in areas lacking established beaver colonies	Post-line installation extending along the width of and just downstream of natural dam crest

Table 2. Summary of beaver dam analog design characteristics for trial project on Pataha Creek, 2015.

Complex #	Trial #	Number Posts	Structure Type	Hydraulic and Geomorphic Response Hypotheses	Installation Completed	Latitude	longitude
01	1	11	Secondary	aggradation and dam pool upstream; plunge pool, deposition, and channel widening downstream	07/22/2015	46.54765	-117.87789
01	2	29	Primary	overbank deposition, aggradation and dam pool upstream; develop multi-channel	07/22/2015	46.54768	-117.87775
02	3	9	Reinforce	beaver uses posts and willows to create dam, aggradation and dam pool upstream	07/23/2015	46.54582	-117.87092
03	4	14	Secondary	aggradation and dam pool upstream; plunge pool, deposition, and channel widening downstream	07/23/2015	46.54521	-117.87002
03	5	10	Primary	aggradation and dam pool upstream	07/23/2015	46.54499	-117.86978
04	6	13	Secondary	aggradation and dam pool upstream; plunge pool, deposition, and channel widening downstream	07/22/2015	46.54457	-117.86899
04	7	15	Secondary	aggradation and dam pool upstream; plunge pool, deposition, and channel widening downstream	07/22/2015	46.54443	-117.86877
04	8	12	Primary	aggradation and dam pool upstream	07/22/2015	46.54426	-117.86850

Beaver Restoration Assessment Tool (BRAT)

BRAT Methods

Prior to construction of the trial we visited the proposed restoration site on the Archer property several times and confirmed the site was suitable for a trial of the BDA approach. We conducted an assessment of the Tucannon watershed to support dam building beaver using the Beaver Restoration Assessment Tool (Macfarlane et al. 2014). We present results of the BRAT assessment here including a brief description of the model, inputs required, and preliminary results. A digital copy of the BRAT output will also be uploaded to PRISM.

The BRAT tool is used to assess the existing and potential (i.e., historic) capacity of riverscapes to support beaver dam building activities as measured in dams/km. Capacity is evaluated in GIS using readily available spatial datasets that provide the following lines of evidence (Macfarlane and Wheaton 2013):

1. Evidence of a perennial water source,
2. Evidence of riparian vegetation to support dam building activity,
3. Evidence of adjacent vegetation (on riparian/upland fringe) that could support expansion and establishment of larger colonies,

4. Evidence that a beaver dam could physically be built across the channel during low flows, and
5. Evidence that a beaver dam is likely to withstand typical floods.

The analyses are performed on 300 m stream segments using data available from the National Hydrography dataset (nhd.usgs.gov). Vegetation structure and composition data is acquired form from LANDFIRE (http://www.landfire.gov). Discharge estimates and stream power were calculated using USGS regional regression equations and calibrated to determine where dams could be built based on base flow stream power and persist from year-to-year based on two-year recurrence interval stream power. Gradient is estimated using 10 m digital elevation models available from the National Elevation Dataset (ned.usgs.gov). Fuzzy inference systems were used to assess the relative importance of these inputs which allowed explicit incorporation of uncertainty resulting from categorical ambiguity of inputs into the capacity model (Bangen et al. 2015).

Factors that can potentially limit beaver from realizing the full capacity such as landuse activities (e.g., roads or farming) and potential human conflicts (e.g., irrigation diversions, settlements) were also incorporated into the assessment by including available GIS layers on land ownership, roads, and infrastructure. Rules in BRAT assume that the closer the stream is to roads and infrastructure the higher the probability of conflict. The final output from the BRAT model is Beaver Management, Conservation, and Restoration Zone Model (hereafter Management Model). The Management Model incorporates the potential and existing capacity model and the conflict model and categorizes the watershed based on seven specific conservation and restoration objectives: 1) currently inhabited by beaver or in good shape but under-occupied (Low Hanging Fruit), 2) lack riparian vegetation but can recover quickly if management is changed (Quick Return), 3) low current use but potential sites (Long-term Possibility), 4) Unsuitable: Naturally limiting, 5) Unsuitable: Anthropogenically Limiting, 6) High potential to support beavers but potential conflicts (Living with beaver high source), and 7) Low potential to support beavers but potential conflicts (Living with beaver low source). See brat.joewheaton.org for more details on the BRAT modeling process.

BRAT Results

BRAT produces many GIS layers that can be useful for managers including existing and potential vegetation, beaver dam density, conflict, and management layers. We have not field verified the BRAT findings for the entire Tucannon watershed because it is beyond the scope of this study, so these layers should be considered preliminary. We have attached the full BRAT results to PRISM in a kmz format viewable in Google Earth. See Appendix I for a description of the different outputs of BRAT.

We ran the BRAT model on approximately 327 km of perennial stream. The potential for the perennial streams in the Tucannon River to support appears to be relatively high with the majority (74.1%) of the streams being able to historically support frequent (5-15 beaver dams/km) to pervasive (> 15 beaver dams/km) densities of beaver dams (Figure 6). By summing up the potential capacity of each stream segment we estimated that the Tucannon River could historically support 3,660 beaver dams.

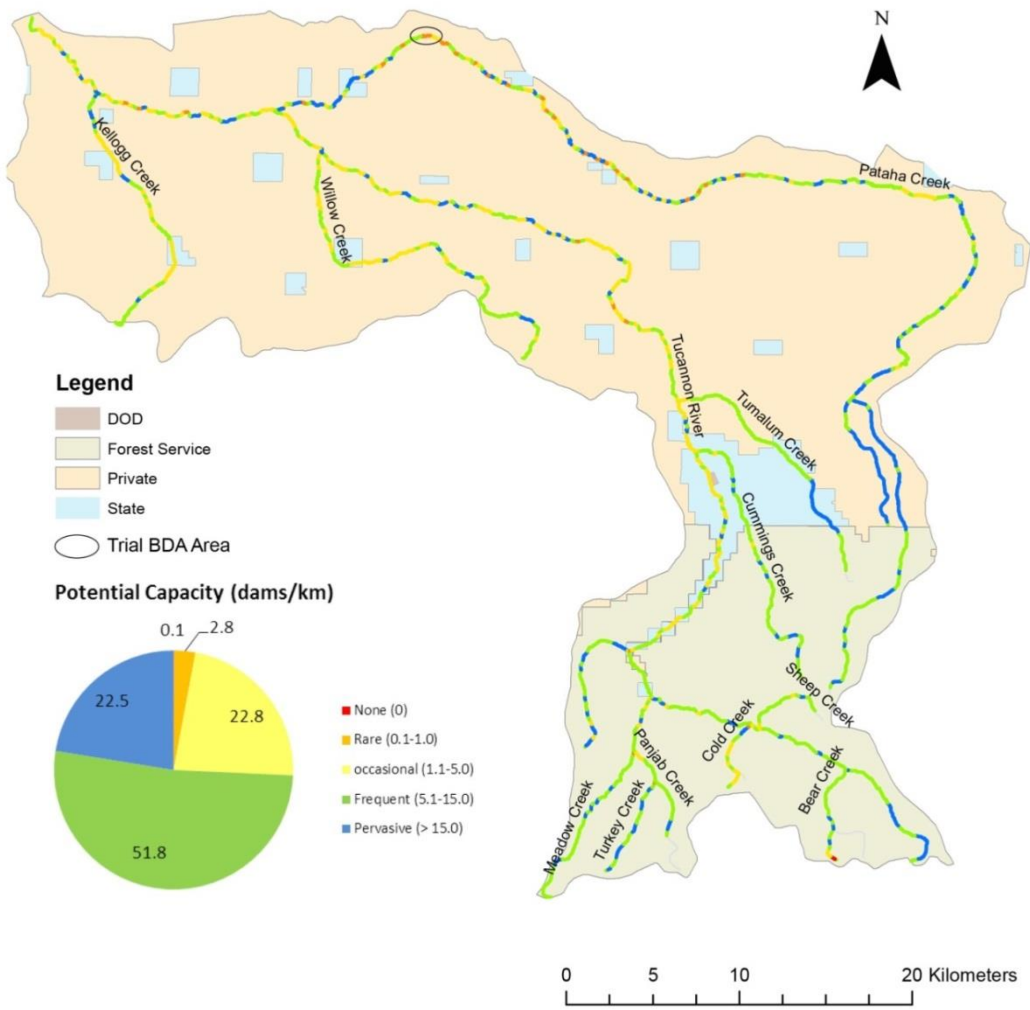

Figure 6. Potential capacity of Tucannon River to support dam building beavers based on output from the Beaver Restoration Assessment Tool (BRAT). Output is measured in potential beaver dams/km.

However, based on the current status of vegetation in the watershed the existing capacity to support beaver dams appears to have decreased such that 57.6% of the watershed can only support occasional (1.0-5.0) or less (Rare or None) beaver dams (Figure 7). By summing up the existing capacity of each stream segment we estimated that the Tucannon River could currently support 1,950 dams. This represents a decrease in capacity to 53% of historic conditions.

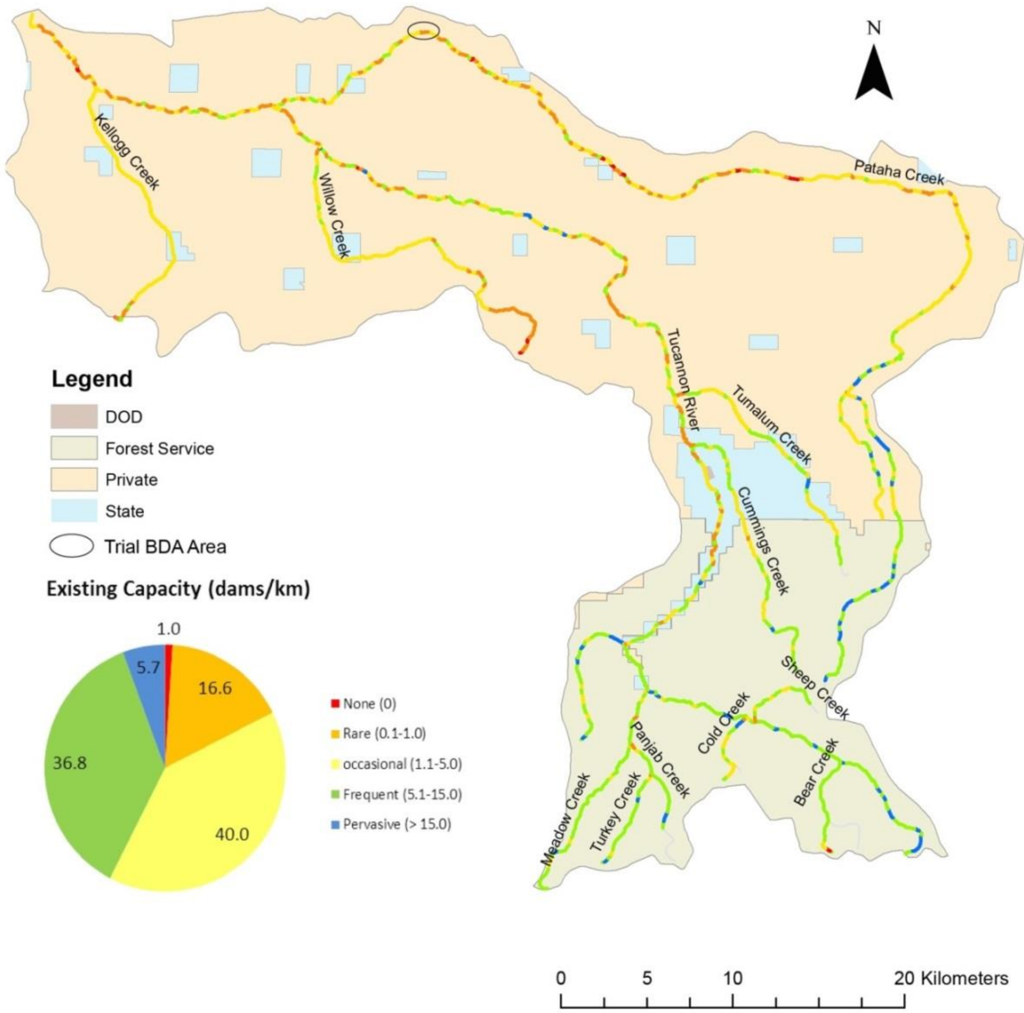

Figure 7. Existing capacity of Tucannon River to support dam building beavers based on output from the Beaver Restoration Assessment Tool (BRAT). Output is measured in potential beaver dams/km.

The potential for conflict between beaver activity and human infrastructure is high with 51.5% of the perennial stream length having a 50% or greater probability of some type of conflict (Figure 8Figure 7Figure 8). The probability for conflict is higher on private land compared to public land in most cases.

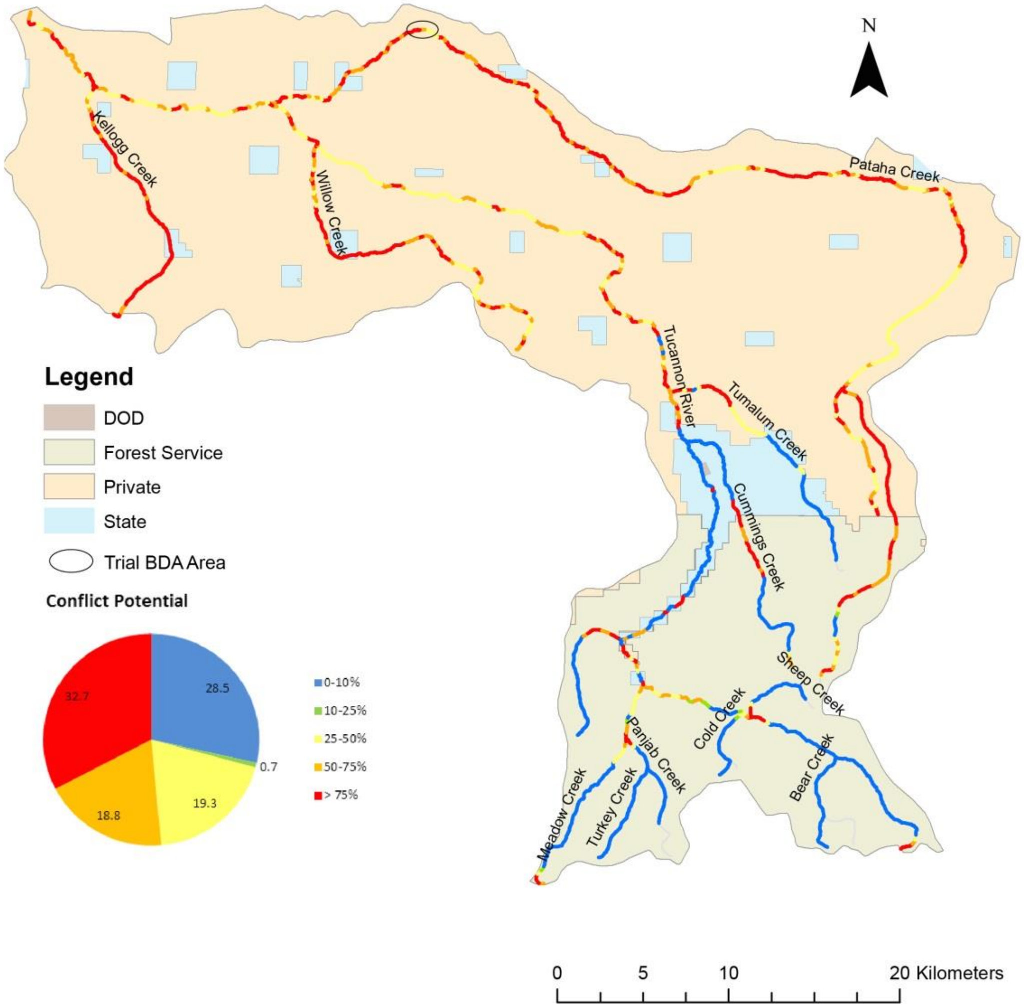

Figure 8. Conflict potential between beaver dams and human infrastructure in the Tucannon based on output from the Beaver Restoration Assessment Tool (BRAT). Conflict potential presented as a probability. A high percent probability equals a high conflict potential.

We combined the results of the conflict potential model with the beaver dam capacity models (Figure 6 and Figure 7) to create a management model that is an initial estimate of how to manage beavers and beaver related restoration activities in the Tucannon River (Figure 9Figure 9). From the management model we determined that there are very few perennial streams naturally unsuitable for beavers in the Tucannon River (5%) and these areas are mostly restricted to small tributaries with low flows in the lower watershed (e.g., Kellogg and Willow Creeks). Almost a third (30.3%) of the watershed appears to be unsuitable because of anthropogenic constraints (e.g., roads and farming activities). Almost a third (28.6%) of the watershed was ranked as “Low hanging fruit” for either conservation or restoration. Conservation sites would be sites with existing beaver populations and potential restoration sites would be sites that have high capacity to support beavers but are currently under seeded. The low hanging fruit category is mostly on public land (WDFW or USFS). Another almost third of the watershed (29.5%)

could be areas where beavers have some potential to cause harm but the sites have a relatively high capacity to support beavers. These sites could act as sources of beavers to transplant to other areas.

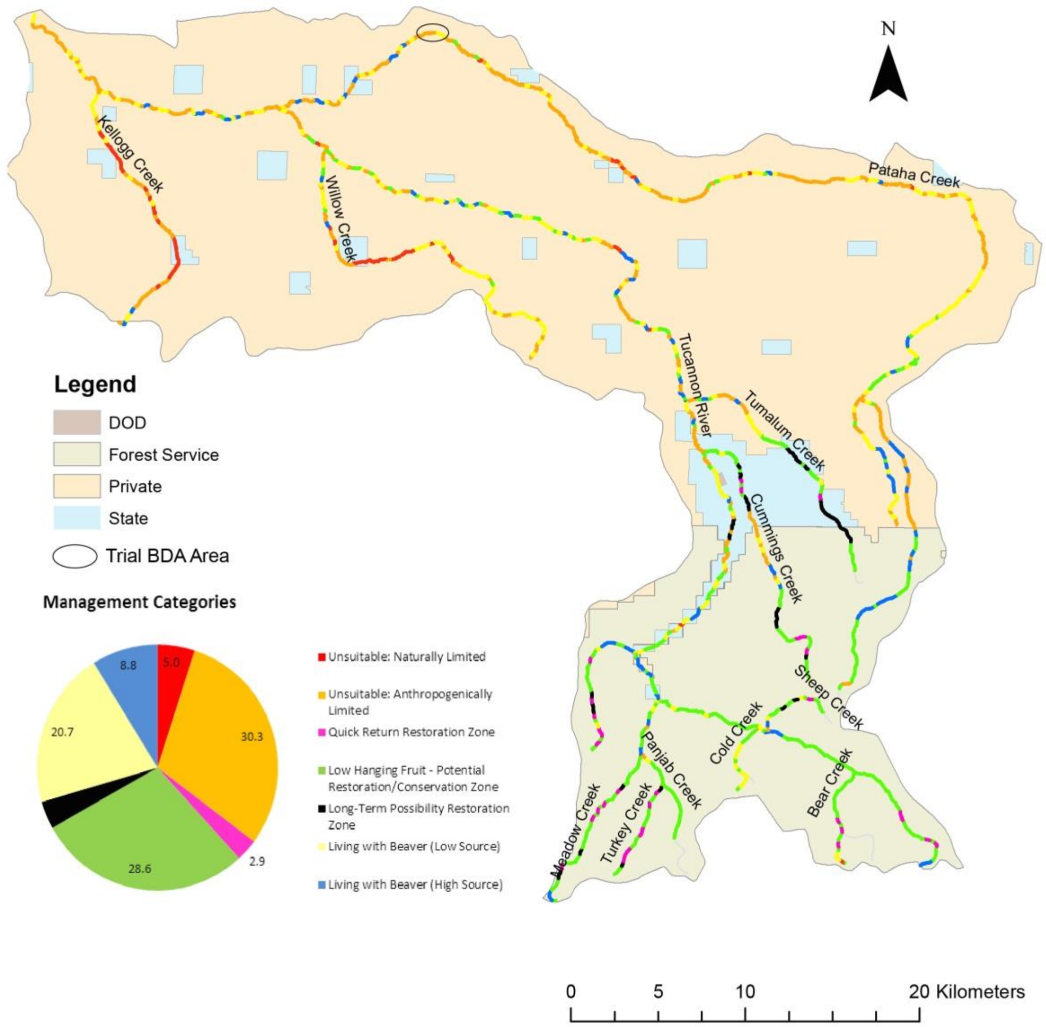

Figure 9. Management categories based on the existing and potential capacity and conflict potential in the Tucannon based on output from the Beaver Restoration Assessment Tool (BRAT). See text or (Macfarlane et al. 2014) for more description on management categories.

Beaver Dam Analog Construction

We build the eight BDAs as designed during the week of July 20th, 2015. Willows were donated by the Columbia Conservation District and harvested from the Hartsock property along the Tucannon River mainstem. We used coyote, Drummond, and Mackenzie willow to build BDAs and estimate we used approximately 50-70/BDA (or ~ 500 in total).

BDA structures were constructed of untreated, sharpened lodgepole fence posts, approximately 5-12 cm diameter, driven into the active channel and inset floodplain using a hydraulic post pounder. Posts extended no more than 1 m above the active channel bed, which is within the 0.5 to 1.5 m typical height range of natural beaver dams. Posts were spaced approximately 0.5 - 0.8 m apart, and driven to a depth of approximately 1 m into the streambed. Following installation of the post line, willow stems were woven in between the posts to create a semipermeable structure that closely resembles a natural beaver dam. The willow weaving acts as a dam, but is also designed to be passable to fish, and is consistent with the adult and juvenile fish passage criteria provided in NOAA's Anadromous Salmonid Passage Facility Guidelines (NMFS 2008) and consistent with the Aquatic Resources Biological Opinion for restoration actions on federal lands in Oregon and Washington (NMFS 2013). In addition to weaving willow among the post line, BDA structures were manually reinforced by placing cobble, gravel, and fine sediment at the base of the structure, a technique very similar to the way beavers build natural dams (these materials were available onsite). Reinforcing the base of BDA structures prevents flow from scouring under the dam, and speeds up pond formation and associated processes.

We planted some willows on and around the BDAs to promote the establishment of willows and to enhance the BDA structures. We will also come back in the fall and plant more willows in the inset floodplain dominated by reed canary grass to test if willows can survive in this habitat and eventually shade out the reed canary grass. See Appendix I for pictures of each structure and Table 2. Summary of beaver dam analog design characteristics for trial project on Pataha Creek, 2015. for GPS location and structure number.

Discussion and Recommendations

Trial of Beaver Dam Analogs

The presence of numerous bedrock outcrops suggests the incision trench is roughly as low as it will go. It also appears that there may not be much widening of the incision trench due to size of Pataha Creek and depth of the incision trench. If this is the case, then BDAs could be an effective way to increase aggradation and create a more diverse inset floodplain eventually leading to benefits for fish rearing and spawning. However, because of the dense growth of reed canary grass, geomorphic changes could be difficult to create. This trial may provide insight into the ability of BDAs to flood reed canary grass and or willow plantings to take and eventually shade out reed canary grass.

Beaver Restoration Assessment Tool

We found much of the Tucannon River perennial streams had moderate to high potential capacity to support beaver dams but the existing capacity is considerably lower than historic conditions. The management model suggests that almost a third of the watershed is anthropogenically unsuitable for beaver conservation or restoration actions but these results are likely overly conservative. The management model uses results from the capacity and conflict models to assess suitable management actions. The conflict model rates the probability of conflict using road layers but does not distinguish between road types. For example, the model predicts the same potential level of conflict from a small unimproved dirt road compared to a large paved highway. Also, if there are willing landowners in a section with potentially high conflict due to human infrastructure the conflict probability could be lowered. This is similar to the situation along much of Pataha Creek where there is high potential capacity, low existing capacity, and high potential conflict. If there are willing landowners and the conflict to infrastructure is lower than model predicts, then these areas are potentially areas of high restoration potential. In contrast, the public lands generally have high potential and existing capacity and are therefore good areas for conservation if beavers are present, or the reintroduction of problem beavers if the areas are underseeded (i.e., lack beaver populations). We will work with the Snake River Salmon Recovery Board and the Pomeroy Conservation District to further assess and refine and interpret the BRAT results.

Recommendations

Prior to implementation of Phase II of the project we recommend:

- review effect of BDAs after spring 2016 high flows

- review effect of willow planting

- field verifying the results of BRAT throughout the watershed

- refine and further assess BRAT results to identify sites for more BDAs

- continue to assess the historic incision evolution (i.e., what are the “natural” incision processes)

Appendix I. Description of the Beaver Restoration Assessment Tool output. See the kmz layer attached in PRISM for the model results.

% The tool requires a *.csv file to run with following columns:

% 1: iGeo_ElMin: Minimum Segment Elevation - Extracted from 10m NED DEM [meters ABMS]

% 2: iGeo_ElMax: Maximum Segment Elevation - Extracted from 10m NED DEM [meters ABMS]

% 3: iGeo_ElBeg: Elevation at Segment Beginning- Extracted from 10m NED DEM [meters ABMS]

% 4: iGeo_ElEnd: Elevation at Segment End - Extracted from 10m NED DEM [meters ABMS]

% 5: iGeo_Length Segment Length: Derived from NHD 24K geometry; typically 250 m [meters]

% 6: iGeo_Slope: Segment Slope - Derived from elevations and segment length [percent slope - dimensionless]

% 7: iveg_VT100EX Existing Vegetation Type Beaver Suitability Adjacent to Stream - Classified from existing LANDFIRE as Beaver Vegetation Suitability using Zonal Stat Average within 100 m buffer [Suitability Value between 0 & 4]

% 8: iveg_VT30EX Existing Vegetation Type Beaver Suitability Near Stream(Riparian)

% 9: iveg_VT100PT:Potential Vegetation Type Beaver Suitability Adjacent to Stream

% 10: iveg_VT30PT: Potential Vegetation Type Beaver Suitability Near Stream

% 11: iGeo_DA: Upslope Drainage Area - SqMi - Derived from flow accumulation calculated on 10m NHD DEM [square miles]

% 12: iPC_UDotX: Distance to UDoT Culvert - Euclidian distance to nearest UDoT Culvert [meters]

% 13: iPC_RoadX: Distance to Road Crossing - Euclidian distance to nearest road crossing excluding UDot Culverts [meters]

% 14: IPC_RoadAdj: Distance to Road - Euclidian distance to nearest Road [meters]

% 15: IPC_RR: Distance to Railroad - Euclidian distance to nearest Railroad [meters]

% 16: IPC_Canal: Distance to Canal - Euclidian distance to nearest Canal [meters]

% The model outputs the above inputs as well as:

% iHyd_QLow - iHyd: Low Flow - CFS - Estimated by USGS Regional Curves [cfs]

% iHyd_Q2 - iHyd: 2 Year RI Flow - CFS - Estimated by USGS Regional Curves [cfs]

% iHyd_Q25 - iHyd: 25 Year RI Flow - CFS - Estimated by USGS Regional Curves [cfs]

% iHyd_SPLow - iHyd: Low Flow Stream Power - Calculated by Slope & Q estimate [Watts]

% iHyd_SP2 - iHyd: 2 Year RI Stream Power- Calculated by Slope & Q estimate [Watts]

% iHyd_SP25 - iHyd: 25 Year RI Stream Power - Calculated by Slope & Q estimate [Watts]

% oVC_EX - oVC: Modeled Vegetation Existing Beaver Dam Capacity Density - FIS modelled output of beaver dam density based only on existing vegetation [dams/km]

% oVC_PT - oVC: Modeled Vegetation Potential Beaver Dam Capacity Density - FIS modelled output of beaver dam density based only on potential vegetation [dams/km]

% oCC_EX - oDC: Modeled Combined Existing Beaver Dam Capacity Density - Final FIS modelled output of existing beaver dam density based on all combined inputs [dams/km]

% oCC_PT - oCC: Modeled Combined Potential Beaver Dam Capacity Density - Final FIS modelled output of potential beaver dam density based on all combined inputs [dams/km]

% mCC_EX_Ct - mCC: Existing Capacity Dam Count - Product of oCC_EX and Segment length [dams]

% mCC_PT_Ct - mCC: Potential Capacity Dam Count - Product of oCC_PT and Segment length [dams]

% mCC_EX-PT - mCC: Existing to Potential Capacity Ratio - Ratio of actual to potential dam densities [dimensionless ratio between 0 and 1]

% e_DamCt - Empirical: Actual Dam Count - These are the adjusted flow types by FHC [dams: optionally NA]

% e_DamDens - Empirical: Actual Dam Density - These are the adjusted flow types by FHC [dams/km; Optionally NA]

% e_DamPcC - Empirical: Actual Percent of Existing Capacity Ratio - A ratio comparing actual dam count to capacity estimate for segment [ratio between 0 & 1; Optionally NA]

% oPC_Prob - oPC: Potential for Beaver Conflict Probability - These are the adjusted flow types by FHC [Probability]

%oPC_BRC: Beaver management, conservation, and restoration potential model

Appendix II – Photo documentation of beaver dam support structures built along Pataha Creek.

 Complex 1. BDA trial # 1. Secondary dam. From river right.	 Complex 1. BDA trial # 1. Secondary dam. Overview from river right.
 Complex 1. BDA trial # 2. Primary dam. Note large gravel deposit on river right. Looking downstream.	 Complex 1. BDA trial # 2. Primary dam. Overview looking downstream.

Complex 1. BDA trial # 2. Primary dam.
Pond upstream of BDA.

Complex 1. BDA trial # 2. Primary dam.
Mowed reed canary and willow planting upstream of dam – from river right.

Complex 2. BDA # 3. Reinforcement of the start of a natural dam.

Complex 2. BDA # 3. Reinforcement of the start of a natural dam.

<table>
<tr><td>Looking downstream.</td><td>Looking upstream.</td></tr>
<tr><td>
Complex 3. BDA # 4. Secondary dam.
From river right.</td><td>
Complex 3. BDA # 4. Secondary dam.
Overview from river right.</td></tr>
<tr><td>
Complex 3. BDA trial # 5. Primary dam.
Looking upstream prior to adding willow.</td><td>
Complex 3. BDA trial # 5. Primary dam.
Looking downstream from pond.</td></tr>
</table>

 Complex 4. BDA trial # 6. Secondary dam. Looking upstream.	 Complex 4. BDA trial # 6. Secondary dam. From river right (downstream on left).


Complex 4. BDA trial # 7. Secondary dam. From river right.


Complex 4. BDA trial # 7. Secondary dam. Overview from river right.


Complex 4. BDA trial # 8. Primary dam. From river right.


Complex 4. BDA trial # 7 and 8. Secondary dam (7 – downstream) and Primary dam (8 upstream). Overview looking downstream.

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