Restoring Riparian Areas to Benefit Sage Grouse and Cattle on Working Lands Using Beaver in Box Elder County

A Demonstration Project in Partnership with Tanner Family

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PROJECT TITLE

Utah Watershed Restoration Initiative Project ID 3417 - Restoring Water, Trout, Sage Grouse and Riparian Areas on Working Lands Using Beaver in Box Elder County – A Demonstration Project in Partnership with Tanner Family

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EXECUTIVE SUMMARY

This 'research' proposal was requested by the UDWR director's office to support a subcontract to Utah State University associated with a Utah Watershed Restoration Initiative (WRI) Project (ID 3417). That project is in the first pilot year of a multi-year, phased implementation, demonstration restoration project. The restoration project is unique in a WRI context, as its aims extend beyond just the local restoration of an individual watershed. The project is aimed to demonstrate how beaver might be used as a restoration agent on working ranch lands and help to restore late season flows, which in turn support a host of knock-on restoration benefits. Those benefits include facilitating reintroduction of native cutthroat trout, improving brood rearing habitat for sage grouse, expanding mesic riparian habitats for the benefit of many upland species (including sage grouse) and improving forage production. The Tanner family are enthusiastic partners in this effort and want this project to act as a demonstration project to give other land-owners and wildlife managers confidence in proceeding with similar efforts. If the demonstration project is successful, the implications are huge for instream and riparian restoration throughout the state of Utah as beaver are potentially an extremely cost-effective form of restoration and instead of WRI's

investment in restoration just impacting 100's of miles, that investment could be expanded to 1000's of miles of streams. Recent work by USU researchers has shown tremendous capacity of Utah's rivers and streams to support beaver dam building activity and habitat is hugely under-seeded. However, building confidence in the restoration techniques using beaver and more realistic expectations about where such techniques are appropriate are urgently needed to help UDWR and other wildlife and land managers proceed with confidence.

From a research perspective, the purpose of this project is to test to what extent a) the hydrologic impacts of beaver dam building activity through late season baseflow augmentation produce the positive impacts project proponents hope they well, and b) track the extent to which such baseflow augmentation might improve instream and riparian habitats to the benefit of wildlife and range operations. By contrast, the primary WRI project goals are to accomplish specific restoration objectives, while at the same time investing in the research and monitoring to make the results transferable to other projects. In Year 1, USU will be responsible for developing the study design, designing and implementing a pilot restoration project, and establishing baseline monitoring as part of a longer term monitoring plan to test project effectiveness over time. In years 2, 3 and potentially beyond, USU will conduct the monitoring, perform analyses of monitoring data, and synthesize findings into both peer-reviewed scientific outputs, as well as simple management briefs and outreach materials (e.g. fact sheets and guidelines) for broader consumption by restoration practitioners. After a small-scale pilot implementation is built by USU in Year 1, the design and implementation will be handed off to other project partners and a design contractor. Our collaborator, Kent Sorensen with The Utah Division of Wildlife Resources (UDWR) will be responsible for conducting the beaver relocation efforts in accordance with the Utah Beaver Management Plan (UDWR, 2010).

INTRODUCTION/NEED

Historic local extirpation of beaver from the Grouse Creek watershed coupled with intensive land use practices have resulted in degraded instream and floodplain conditions throughout much of the watershed. The degraded conditions include impacts on hydrology: changes in the timing and delivery of water over the course of the annual hydrograph, decreased late season flows; impacts on habitat: a reduction in the area and quality of mesic riparian habitat, leading to decreased sage grouse brood rearing habitat, and a decrease in quality and extent of cattle forage production in the valley bottom, and a reduction in the quality of instream aquatic habitat.

Channel incision has been identified as a serious problem in many streams in semi-arid regions (Beechie et al., 2008) similar to the Grouse Creek watershed. Many of the streams comprising the Grouse Creek watershed are incised between 2-4 m, resulting in a current lack of historic floodplain connection. These degraded conditions will likely not recover naturally for decades or even centuries without restoration actions (e.g., Pollock et al. 2014). A lack of floodplain connection resulting from stream incision lowers the groundwater table, reduces the extent of historic wetlands and mesic areas critical for sage grouse brood survival (Donnely et al., 2015), lowers summer base flows, and generates loss of physical habitat diversity (Pollock et al., 2007). Additionally, incision causes significant loss of riparian vegetative communities, and population declines in fish and other aquatic organisms (Pollock et al., 2014). Incised stream conditions particularly impact sage grouse through the reduction in near riparian mesic areas which are critical for late season forage when sage grouse relocate their broods from the uplands to feed (Donnely et al., 2015).

The proposed WRI restoration project seeks to address the negative impacts of stream incision and degradation on water resources, sage grouse, and riparian areas through reintroduction of N. American Beaver (*Castor canadensis*) into their historical range over a multi-year, phased implementation project. Beaver are the main agent of restoration. However, Beaver Dam Analogs (BDAs) may be used strategically in some locations to improve habitat conditions for the reintroduction of beaver and encourage beaver to focus in key areas. We employ a variety of Beaver Dam Analog (BDAs) treatment types (Pollock et al., 2014), which are artificial structure types designed to achieve different functions. Some BDAs mimic the types of functions of natural beaver dams, and some create conditions that increase the probability that beaver dams and other BDAs will persist through typical floods. For a thorough description of BDAs see Appendix A.

Over the past several years, there has been a growing appreciation in the scientific, management, restoration and conservation communities about the importance of beaver as a keystone species in the long-term sustainable management of natural resources associated with riverine and riparian systems (DeVries et al., 2012; Pollock et al., 2012; Polvi and Wohl, 2013; Wohl, 2013). Beaver have actually been used as a conservation and restoration tool since the 1940's but their popularity as a conservation tool has grown dramatically in the past decade. The primary drivers for this interest have been: i) the ever increasing price tags of stream restoration when beaver can do better for virtually free once they are established, ii) their ability to create complex and dynamic stream habitats – thought to be a hallmark of a healthy stream ecosystem, and iii) their ability to potentially impact many more miles of stream and adjacent valley bottoms than traditional restoration projects. Amongst the many reasons managers are turning to beaver for help are the ecosystem services provided by their dam building activities (Hood, 2011). The following list highlights many of the feedbacks and services from beaver dam building that will benefit the degraded streams within the Grouse Creek watershed:

- Dam building slows the timing of delivery of water and increases the frequency and magnitude of overbank flows. This increases groundwater recharge (Westbrook et al., 2006) which can elevate summer baseflows, and the elevation of the water table (Woo and Waddington, 1990) which increases the size and quality of the riparian and near riparian mesic areas (Wright et al., 2002) critical for sage grouse habitat (Donnely et al., 2015).
- Beaver dam building enhances floodplain connectivity and floodplain creation (Westbrook et al., 2006).
- Sediment impoundment associated with dams accelerates the natural recovery of incised conditions (Pollock et al., 2014).

The potential for beaver reintroduction in Grouse Creek has been assessed using a previous investment from UDWR through the Beaver Restoration and Assessment Tool (BRAT) (Macfarlane et al., 2015) (Figure 1). The Beaver Restoration Assessment Tool (BRAT – http://brat.joewheaton.org) is a decision support and planning tool intended to help resource managers and researchers assess the potential for beaver as a stream conservation and restoration agent over large regions and watersheds (Macfarlane et al., 2015). The BRAT outputs for Grouse Creek presented in Figure 1 were run with widely available existing data sets (e.g., LANDFIRE vegetation layers, NHD stream layers, USGS regional hydrologic curves, NED DEMs) and used to identify opportunities, potential conflicts and constraints through a mix of assessment of existing resources and scenario-based assessment of potential futures. The primary backbone to BRAT is a spatially- explicit network model that predicts the capacity of riverscapes to support dam-building activity by beaver (Macfarlane et al., 2015). The model predicts the maximum density (in dams/km) of beaver dams the channel can support in each 250 m reach on the drainage network.

There are three main research questions that we seek to answer through the completion of the full –scale WRI restoration project. We do not expect to fully address these research objectives during the Year-1 pilot phase but we will be able to establish the longer-term study design (after Year 1) that will provide the framework to answer the following research questions.

1. How do baseflow augmentation benefits of beaver dams scale up? In other words, can the established hydrological benefits of beaver dams at local scales (cf. Woo and Waddington, 1990; Burns and McDonnell, 1998; Wright et al., 2002; Westbrook et al., 2006) of baseflow augmentation (e.g., decreasing peak flows and extending the magnitude and duration of late season flows, increased groundwater, elevation of water table) be scaled-up at the watershed scale to not only augment baseflows locally, but throughout the drainage network? The existing literature on the hydrological benefits of beaver dams have quantified these effects at the local scale (e.g., at the scale of an individual dam or a few dam complexes) but not at a larger scale, where the benefits (i.e. increased late season flows) could either positively or negatively impact downstream water users.

2. How will the assumed changes in hydrology effect the presence, extent or duration of mesic habitat identified as critical for late season forage for sage grouse (Donnely et al., 2015)? Existing literature (Wright et al., 2002) suggests that beaver dams can increase the diversity and areal extent of riparian areas but currently there are no studies that specifically assess the relationship between a beaver mediated increase in riparian habitat explicitly with potential benefits to sage grouse species.

3. Will the assumed changes in hydrology positively influence the presence, quality, extent or duration of forage for cattle?

4. Will the beaver reintroduction efforts be successful? If so, what are the most influential design considerations in their successful reintroduction (i.e., presence of a starter lodge, suitable existing riparian food resources, adequate base flow and non-excessive peak flows, family units reintroduced together, timing of relocation, etc.)? How transferable are the lessons learned from this project to other beaver reintroduction efforts elsewhere in Utah?

OBJECTIVES AND GOALS

The primary goal of this restoration project is to **demonstrate that rangeland and riparian ecosystem health can be improved through beaver-assisted stream restoration**. While we have shown elsewhere the benefits of such beaver-assisted restoration to restoring incised streams (Pollock et al. 2014), invoking positive population responses in salmonids (Bouwes, 2015), improving stream hydrology locally (Majerova et al. 2015), and expanding wetlands (Wright et al., 2002), the benefits to upland game like sage grouse and improving forage production for livestock in the valley bottom have not been adequately documented and tested. If the restoration objectives are accomplished, this could benefit private landowners through increased forage production and elevated baseflows in perennial streams and/or extended duration of flow in intermittent streams. General project objectives include: 1) increase water storage behind beaver dams, thereby extending the duration of flow and/or increasing late summer flow, 2) improve forage for sage grouse, 3) increase forage production for cattle. Note, as this is Watershed Restoration Initiative project, the primary goal for the over-all project *is not* research.

The PI and Utah State University's primary goals for this scope of work in the first year are to assist UDWR in the creation of a scientifically defensible study design and monitoring plan (e.g. Bennett et al., 2016), produce an adaptive management plan (e.g. Bouwes et al., 2016), implement a pilot restoration treatment, and establish baseline monitoring. The synthesis of monitoring results over the course of the broader demonstration project will act as an experimental case study from which research findings will be published, synthesized and properly contextualized as to their broader applicability. Year 1 the project objectives are to:

- Establish baseline monitoring and conduct analyses of instream and floodplain habitat, hydrologic analysis, sage grouse brood rearing habitat, riparian resources, capacity of system to support dam building activity, and eventual capacity of the system to support reintroduction of native Bonneville cutthroat stocks. Deployment of baseline monitoring and instrumentation at treatment and control sites to establish effectiveness of restoration actions.
- Implement a Pilot Restoration and develop a broader Restoration and Adaptive Management Plan for all suitable streams on Tanner controlled properties in Grouse Creek Watershed. The intent will be to use the lessons learned from this Pilot implementation to inform the design process in Year 2 and deploy a staged treatment over Years 2 and 3.
- Design and install pilot treatments within suitable locations on tributaries to Grouse Creek. The pilot treatments will be used to test the efficacy and logistical feasibility of all proposed treatment types.
- Synthesis of the initial design, pilot installation and baseline monitoring results with design recommendations for full implementation in future years (develop longer term study design).

In order to contextualize the Pilot Year 1 objectives and goals into the longer-term WRI project objectives and goals we propose the following Years 2 and 3 objectives and goals for the portion of the project that will be carried out by USU (i.e., not construction implementation and beaver relocation).

Year 2

- Continue to monitor the response (hydrologically and to the riparian area) from the Pilot phase restoration treatments
- Refine initial adaptive management plan (inclusive of study design, monitoring methods) as needed based on lessons learned from Pilot
- Expand the scale of the pilot treatments based on initial results (actual implementation carried out by UDWR sub-contractor with assistance from USU)
- Expand the scale of the monitoring efforts as needed to accommodate the larger-scale restoration treatments
- Continue to relocate beaver as needed to develop a self-sustaining population within the treatment areas (to be carried out by UDWR)

Years 3 and beyond

- Continue to monitor the response (hydrologically and within the riparian area) from the larger-scale restoration treatments
- Refine adaptive management plan as needed
- Continue to relocate beaver as needed to develop a self-sustaining population within the treatment areas (to be carried out by UDWR)
- Synthesize and publish findings in peer-reviewed literature in appropriate journals. Distill research findings into management briefs, factsheets and best practice guidelines for restoration practitioners.

METHODS/APPROACH

Broadly, the WRI project will use an adaptive management approach (Bouwes et al., 2016) to learn from the implementation of the different phases of the project through monitoring and analysis. Project results will teach us about the utility of using beaver in rangelands to impact hydrology, and positively benefit sage grouse and cattle. Within this first scope of work, we are establishing the baseline monitoring, and initial pilot study design and implementation to eventually address those broader goals. Below we describe the techniques employed during this study to establish the study design and restoration design, as well as monitor hydrologic, riparian and vegetative responses. The monitoring methods described below will be employed throughout the life of the WRI project and the individual methods will not substantially change from Years 1 to 2, 3 and beyond.

Study Design

The majority of restoration projects suffer from a poorly articulated or non-existent study design which often does not include any form of monitoring (Palmer et al., 2005; Roni et al., 2008). Clearly, this limits the ability to draw any meaningful and transferable conclusions from restoration actions. In this project, we seek to learn as much as possible from each stage of the restoration. As such, we will implement a robust study design within an adaptive management framework that will include substantial monitoring efforts. The specifics of the study design for the longer-term project will be developed based on the results from the Year-1 Pilot implementation and will contain elements of the following.

The study design will likely contain aspects of a nested hierarchical staircase design (Walters et al., 1988; Loughin, 2006). We will compare treatment reaches with geomorphically and hydrologically similar, non-treated control reaches. Ideally, this accounts for the natural range of yearly variability associated with riverine systems while still being able to test hypotheses. The nested hierarchical approach allows us to expand the scale of the treatments over time (e.g. from pilot treatment reach to longer stream segments to the entire sub-watershed) while the staircase design incorporates multiple treatments through time. The staircase approach is beneficial in two main ways: 1) there are multiple treatment replicates throughout the different years of the project which helps to disentangle the year to year variability from the effects of the treatments and 2) by having multiple treatments over time less area has to be treated during each year which simplifies the implementation logistics.

For analysis of the hydrological monitoring results, the study design will draw largely on a physical/hydrological model under development by USU personnel (Konrad Haffen) within the Fluvial Habitat Center. The model will be used in part, to predict water storage capacity behind natural beaver dams and BDAs. We will use hydrologic data from the Grouse Creek treatment reaches to calibrate the model. The model will also be used to analyze the potential changes in the timing and delivery of water through treatment reaches. This model will ultimately allow us to make predictions about the changes in hydrology associated with beaver dams at the scale of the entire Grouse creek watershed.

Pilot Implementation Design

Stream segments designated for treatment during the Year-1 Pilot phase were identified for restoration potential by a combination of BRAT outputs, remotely sensed data and site visits. In order to be selected for treatment in Year 1, consideration was given to the following variables:

- Land ownership (stream segment must be owned/associated with the Tanner family)
- Sufficient conditions to support dam building by beaver (informed by BRAT and field visits)
- Perennial flow (Year 1 beaver reintroduction will not take place in intermittent or ephemeral streams)
- Current geomorphic and riparian condition and estimates of recovery potential
- Proximity of treatment reach to potential high quality sage grouse habitat

Year 1 Restoration Treatments

Suitable stream segments were located within portions of Kimball, Pine and SF Pine Creeks for Year 1 treatment. Treatments will include:

- Construction of one pilot BDA complex (3-8 individual structures) within SF Pine
- Construction of a BDA starter dam and lodge on mainstem Pine to support beaver reintroduction of 1 colony of beaver (5-8 related individuals)
- Construction of one pilot BDA complex (3-8 individual structures) and a starter lodge within Kimball Creek to support reintroduction of 1 colony of beaver.
- Reintroduction of colonies of beaver into the pilot treatment reaches. The beaver relocation will be carried out by UDWR personal and will follow the recommendations from the Utah's Beaver Management Plan (UDWR, 2010).

Note that due to contracting delays, the beaver translocations will not take place during FY16 (i.e. in Spring 2016) and will instead take place in Fall 2016. Beaver translocation should only take place in the fall. This should not be problematic from a contracting perspective, as UDWR will be undertaking the translocation work.

In Years 2, 3 and beyond, the full implementation restoration treatments will be carried out by qualified sub-contractor (e.g. Anabranch Solutions, LLC) instead of USU. The implementation shall be based on the Restoration and Adaptive Management Plan developed at the end of Year 1 by USU and informed by the experience of preparing the pilot. Monitoring efforts by USU will continue throughout the course of the WRI project.

MONITORING METHODS

Hydrology

We will evaluate the effects of beaver and beaver dam analogues (BDAs) on i) magnitude and timing of peak discharge, ii) magnitude of late summer discharge (baseflow), iii) frequency and extent of overbank flows, iv) changes in flow duration in intermittent streams, and v) groundwater levels in unconfined alluvial settings. Pressure transducers will be installed above and below all proposed treatment reaches in Winter/Spring 2016 in order to establish baseline data. Discharge measurements will be taken manually using either a flowmeter or salt-dilution gaging methods in order to establish a rating curve at each pressure transducer allowing continuous discharge measurements. Groundwater levels will be inferred from water surface elevation profiles conducted before and after treatments (Volk, 2015) to record changes in groundwater levels associated with ponding and overbank flows associated with beaver dams. Overbank flows will be assessed in the field based on flood indicators (e.g. overbank sediment deposition, flattened vegetation etc.), crest gages and mapped using the GISPro application on an iPAD.

Monitoring discharge upstream and downstream of treatment areas will allow us to evaluate the effects of specific treatments on the magnitude and timing of discharge in perennial streams and changes in the duration of flow in intermittent streams. Assessing groundwater levels will allow us to investigate the influence of treatments on the extent (both laterally and vertically) on groundwater levels due to overbank flows and ponding behind beaver dams and/or BDAs. The influence of changes in groundwater levels on riparian and mesic vegetation will be monitored as described in following sections. Mapping the spatial extent of overbank flows will allow us to assess the influence of overbank vs. subsurface flows on changes in groundwater level and riparian and mesic vegetation. In addition, flow gages installed on downstream, non-treated reaches will help assess the cumulative impact of a full implementing. This data will be used to develop and calibrate numerical hydrologic model. The model will help explore tradeoffs in different weather scenarios, beaver dam density scenarios and isolate the influence of year effects.

Sage grouse foraging habitat

Vegetation surveys (Eric Thacker) will be conducted in areas adjacent to treatment reaches in order to assess the influence of natural beaver dams and BDAs on forage quantity and quality for livestock, sage-grouse and big game. We will also assess vegetation structure and composition with methods commonly used by sage-grouse biologists. Assessment of groundwater and soil moisture will permit a mechanistic, process-based linkage between discharge and storage associated with BDAs and forage response. Transects (20 m) will be placed parallel to streams in riparian zones adjacent to treatments areas. Transects will be placed at increasing distances starting at the green line and moving away from the stream. We will use Daubenmire for species composition and cover of herbaceous species. Line intercept will be used to quantify shrub cover. To assess forage quality and quantity we will collect forage samples by functional group (forbs and grasses) bimonthly April through September. We will assess forage quality at each transect by clipping five .25 m^2 quadrats at each sampling site (transect). A composite of forage samples will be analyzed for quality (crude protein and digestibility).

Riparian condition

Changes in riparian condition associated with reintroduction of beaver and/or BDAs will be assessed primarily using free, publicly available LandSat data with field verification. Calculating a Normalized Difference Vegetation Index (NDVI) will allow us to evaluate changes to riparian extent and condition, as well as compare to current riparian conditions. A further advantage of using LandSat data rather than field assessments is the ability to assess longer stream lengths as future treatments expand in future years.

Geomorphic change

Changes in water surface elevation through ponding and bed aggradation associated with beaver dam building or the use of Beaver Dam Analogs (BDAs) will be assessed using longitudinal profiles collected using a combination of Digital Elevation Model (DEM) analysis and field-based rtkGPS surveys of the channel bed pre and post treatment.

Beaver

Beaver trapping and relocation efforts will be led by Kent Sorenson (UDWR) and assisted by personnel from Utah State University. Trapping and relocation will be done in accordance with the protocol outlined in the Utah Beaver Management Plan (UDWR, 2010). Individual beavers will be marked with ear tags, and beaver activity will be tracked along the study streams to determine to what extent beaver utilize the structures built for them or whether they build more dams in the areas released, or whether they build new dams in the vicinity or leave the area. It is outside the scope of this project to radio-tag beaver and track their movements, so inferences will be made from activity signs (e.g. fresh cuttings, dam construction and/or maintenance, lodge construction and winter food caching).

Study Duration

This proposal is specific to Year 1 of a multi-year effort but also outlines the activities by USU personal for Years 2 and 3. See Project Schedule for the proposed timeline of activities.

STUDY AREA

Portions of three streams in the Grouse Creek Watershed, located in Western Box Elder County, UT have been identified for restoration in Year 1: Kimball Creek, Pine Creek, and South Fork Pine Creek (Figure 1). Each stream has unique hydrologic and geomorphic features which allow us to test the efficacy of beaver-assisted restoration in multiple settings. Over the course of the project (Years 2, 3) it may become necessary to expand the scope of the treatment to other suitable portions of Grouse Creek owned by the Tanner family.

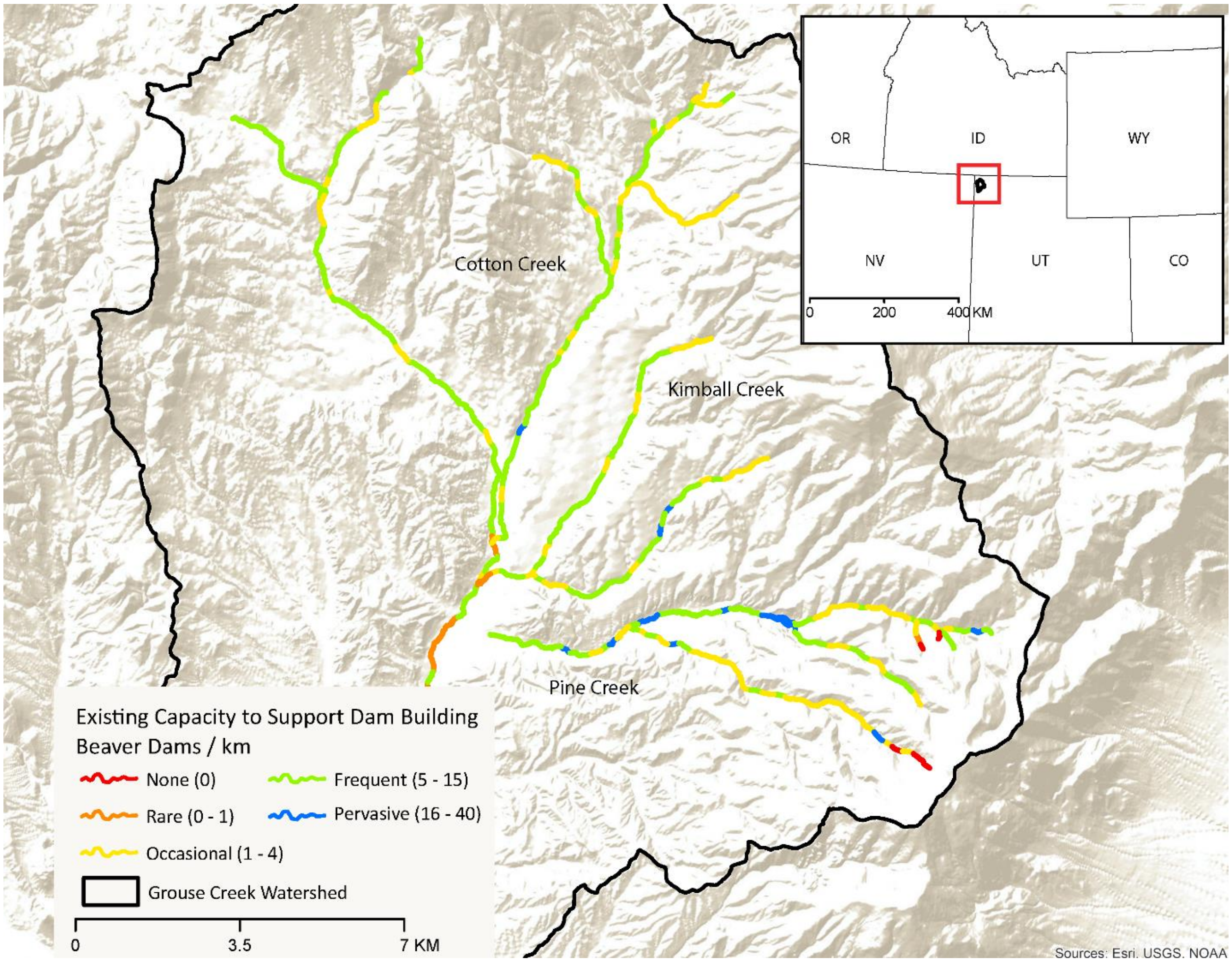

Figure 1 – Map of study area showing the Grouse Creek Watershed outlined in black. BRAT dam building capacity estimates are shown along the perennial stream network.

EXPECTED RESULTS AND BENEFITS

Year 1 is considered a pilot year, in that we are exploring and testing the feasibility of the restoration methods in Grouse Creek specifically, collecting baseline monitoring information and establishing the adaptive management framework for monitoring the effectiveness of the restoration actions through time. Additionally, we are testing the range of treatment options at a number of reaches within the larger treatment area representing the range of geomorphic, hydrologic and ecologic conditions present in the Grouse Creek Watershed. As such, we do not expect to accomplish the broader, and longer-term restoration goals within Year 1. Rather we will learn as much as possible from the pilot treatments to then inform the implementation actions during Years 2 and 3. Despite this, we do expect some level of results moving towards the broader restoration objectives. The list below is separated into probable short-term (i.e., the short-term outcomes may include results from the year-1 pilot phase) and longer term expected outcomes from the restoration actions. The spatial extent of these results will expand with the expansion of the treatments over the course of the project. Because implementation will be Spring and Fall of 2016, only baseline monitoring will be done and the longer term responses will be documented in the next phase of the project

Short-term (Year 1):

- Pilot installation of BDAs
- Successful reintroduction of beaver and successful colonization manifest as multiple beaver dam complexes
- Increased water storage (i.e. water immediately backed up by natural and artificial beaver dams)
- Elevated water tables

Longer-term (Years 2, 3 and beyond):

- Decreased peak flows
- Elevated base flows
- Longer duration of flow in intermittent streams
- Increase in riparian extent
- Increase in forage quality (forbs and grasses)
- Increase in forage quantity (protein and digestibility)
- Increase in spatio-temporal extent of mesic areas
- Increase in sage grouse population
- Increase in habitat complexity and thermal refugia for trout

Unlike traditional stream restoration measures that impose immediate change in stream conditions over a small scale, beaver- assisted restoration seeks to restore a suite of hydrologic, geomorphic processes that promote the ecological health and productivity of aquatic, riparian, and mesic environments, potentially at the watershed scale. It is important to recognize that the benefits of such an approach, unlike more conventional and expensive engineering solutions, may not be realized immediately. Reversing and restoring processes that have been altered over the course of many decades may require multiple years to fully realize restoration objectives. One of the main benefits of beaver-assisted restoration is that it attempts to restore historic conditions through a process-based approach that, once begun, requires little intervention over time.

PROJECT SCHEDULE

The project schedule has been altered because the contract was supposed to be awarded in July of 2015 and the pilot was initially planned for a Fall 2015 installation. If the project is awarded by end of February, there is still time to complete the Year 1 scope of work according to the schedule proposed below. This restoration project is anticipated to be a multi-year project with the vast majority of implementation being carried out in years 2 and 3. If our past experience with such projects is any indication, some of the physical hydrologic and biotic responses may be quite rapid and take place over this 1-3 year time frame, whereas others may take longer to track. However, this specific proposal is for the Year 1 USU design, pilot implementation and baseline monitoring component of that broader project to take place in the first year. The schedule for these components are anticipated as follows. We also include the USU monitoring component for Years 2 and 3.

Winter/Spring 2016:

1. Remote sensing and GIS-based hydrologic, geomorphic and ecological analysis, BRAT analysis. Field-assessments to inform restoration planning, permitting
2. Installation of stream flow gauging network, additional habitat and physical condition assessments
3. Initial pilot treatments will be installed using Utah Conservation Corps (UCC labor) within suitable locations on tributaries (i.e., Kimball, Pine and SF Pine Creeks) to Grouse Creek. The pilot treatments will be used to test the efficacy and logistical feasibility of all proposed treatment types.

Fall 2016

1. UDWR personal will relocate beaver to the pilot treatment reaches
2. Produce a comprehensive initial Restoration Design and Adaptive Management Plan and effectiveness monitoring recommendations for all suitable Tanner land in Grouse Creek Watershed. The intent will be to modify this design slightly in Year 2 based on response to Year 1 Pilot and deploy a staged treatment over Year 2 and 3.

Subsequent specific stages of this project will be informed by results from year one in accordance with the principles of adaptive management and will likely include the following:

2017

1. Expand the scale of the restoration treatments (e.g., BDAs and beaver relocation) in phase 1 of full implementation in accordance with the Restoration and Adaptive Management Plan (implementation carried out by sub-contractor – e.g. Anabranch Solutions LLC)
2. Expand the scale of the monitoring effort to accommodate the increase in size of the restoration treatments

2018

1. Continue effectiveness monitoring of restoration treatments
2. Maintain and or complete phase 2 of full implementation treatments.
3. Publish findings as technical reports and peer-reviewed primary literature.

2019

Seek other continuing funding (non-WRI if possible; e.g. Federal Partners or USU matches) to support long-term monitoring. Minimal maintenance as part of the adaptive management may be warranted as well.

BUDGET/COMPLIANCE DOCUMENTATION

The budget for USU for Year 1 has already been approved in the Scope of Work document on file with the WRI. Here we present a proposed budget for USU's monitoring efforts for Years 2 and 3.

The PI will work with Kent Sorensen from Utah Division of Wildlife Resources and personnel from UDWR's sub-contractor to coordinate USU's monitoring effort with the implementation and beaver relocation efforts (Kent Sorensen, UDWR).

YEAR 1

A total of $91,909 will be requested to support Utah State University technicians and researchers to complete this work.

Budget Performance Period: July 1, 2015 to June 30, 2016

LABOR & FRINGE BENEFITS:

$5575

- **Principle Investigator** (Wheaton) - $2968 for one week of PI's time to supervise and lead the project ($2051 Salary)
    - **Fringe Benefits**: $917 fringe (@ 44.7%)
- **Co-Op Outreach Specialist** - $2607 for Co-Op agreed 3% for outreach from project ($1802 Salary)
    - **Fringe Benefits:** $805 fringe (@ 44.7%)

TRAVEL:

$7057

- **Field Work & Meetings**: - $7057 for site visits and USU motor pool when lab rigs are unavailable, travel accounts primarily (85%) for Box Elder County, but also accounts for UDWR meetings, NRCS meetings, CMU meetings etc.).

OTHER DIRECT COSTS

$74,900

Demonstration Project Monitoring & Research: $42,160

- **Monitoring Equipment:** $6000 for ten streamflow weir gaging stations @ $600 each
- **ETAL Research Associate:** $8,300 for 20 days of research associate time to develop research study design (@$415/day**)**
- **ETAL Field Technicians:** $23,460 for 137 days of field technician time (2-4 person crews) to install monitoring equipment and conduct baseline hydrologic, instream, riparian, vegetation surveys and sage grouse monitoring (@ $170/day).

- **ETAL Senior GIS Technician:** $4400 for updating BRAT, VBET and Riparian Condition models to support development of study design and Restoration and Adaptive Management Plan (12 Days @ $370/day).

Pilot Project Implementation: $32,700

- **ETAL Research Associate:** $16,600 for 40 days of research associate time to prepare pilot design and prepare broader Restoration and Adaptive Management Plan (@$415/day**)**
- **ETAL Senior Field Technicians:** $1000 for 5 days of senior field technician time (2-4 person crews) to oversee construction (@ $200/day).
- **Pilot Restoration Materials & Equipment Rental** - $10,600 for rental of equipment, posts, and other construction materials (note any materials not used will be stock-piled for use in Years 2 and 3).
    - **Poles, straw, cages, construction materials for starter lodges** - $6200
    - **Saw, waders, boots, flagging, traps** - $2100
    - **Hydraulic post pounder rental for 2 to 3 weeks** - $2300
- **CCC Installation Crew** – $4,500 for one week of Utah Civilian Conservation Corps crew for installation of BDAs for pilot.

F&A

$4377 - As per the Cooperative Agreement, a 5% F&A is charged (representing a 38.11% F& A waiver of $33,359)

YEAR 2 (2017) AND YEAR 3 (2018) BUDGET ESTIMATES

Budgets have not been finalized for Years 2 and 3 of the project, but we anticipate the budget will be roughly the same (c. $90K-$100K excluding partner match). What will change is the relative proportion that goes to USU. The pilot implementation in Year 1 is being undertaken by USU for roughly $35K, with a significant portion (roughly $50K) going to research. We anticipate that in years 2 and 3, the implementation costs will go up ($40K to $60K), and the portion going to monitoring should decrease somewhat ($35K to $40K). When implementation is complete, ongoing monitoring and analysis should be possible for roughly $35K to $40K per year, with a slight bump (c. $50K) in the last year for synthesis, publication and synthesis efforts. These budget requests are not yet requested or approved by WRI. Utah State Universities continued effectiveness monitoring of the Tanner demonstration stream restoration project using beaver-assisted restoration treatments within the Tanner properties in the Grouse Creek watershed is not intended to cover all of the components of the WRI restoration project (i.e., continued restoration treatment implementation, beaver relocation).

DELIVERABLES

Year 1 deliverables include:

- Actions:
    - Establish and conduct baseline monitoring and analysis within the instream and floodplain habitat, hydrologic analysis, sage grouse brood rearing habitat, riparian resources, capacity of system to support dam building activity, and eventual capacity of the system to support reintroduction of native Bonneville cutthroat stocks. Deployment of baseline monitoring and instrumentation at treatment and control sites to establish effectiveness of restoration actions.
    - Develop a study design that will facilitate the documentation of hydrologic, riparian and vegetative responses to beaver treatments that fits within an adaptive management framework.
    - Develop a comprehensive initial Restoration and Adaptive Management Plan and effectiveness monitoring recommendations (specifically tailored for the UDWR) for all suitable Tanner land in Grouse Creek Watershed.
    - Design and install pilot treatments within suitable locations on tributaries to Grouse Creek.

- Reporting:
    - Restoration & Adaptive Management Plan
        - Includes the Study Design Report
    - Pilot Design & Implementation Vignette

Specific deliverables for USU's portion of the project activities for Years 2 and 3 are outside the scope of this document but will generally include reporting on the ongoing effectiveness monitoring efforts, which will ultimately be published as a peer-reviewed scientific article and a technical report for UDWR. The USU deliverables for Year 2 and 3 will likely include:

Year 2

- Continued effectiveness monitoring and analysis of changes to hydrology, sage grouse foraging habitat, cattle forage, riparian condition and geomorphic change associated with natural and artificial beaver dams
- Synthesis of Year 2 monitoring results with recommendations for future years

Year 3

- Continued effectiveness monitoring and analysis of changes to hydrology, sage grouse foraging habitat, cattle forage, riparian condition and geomorphic change associated with natural and artificial beaver dams
- Synthesis of Year 3 monitoring results with recommendations for future years
- Publication of peer-reviewed primary literature and a technical report based on analysis of effectiveness monitoring

DWR PERSONNEL REQUIREMENTS AND FUNDING

Kent Sorensen (UDWR) will provide the time necessary to conduct the beaver trapping relocation necessary for project success. All beaver relocation efforts will be undertaken following the guidelines in Utah's Beaver Management Plan (2010).

COLLABORATORS/RESEARCHERS ON INTERNAL DWR PROJECTS

Tanner family, Utah State Universities' Watershed Sciences Department (Fluvial Habitat Center) and the Department of Wildland Resources Range Management (Extension), Box Elder County Coordinated Resource Management Group, and Anabranch Solutions LLC.

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APPENDIX: BEAVER DAM ANALOGS

The general goal of a beaver-assisted restoration project is to broadly mimic the dam building activities of beaver to then restore hydrological and geomorphic processes. However, there is a deliberate strategy in how and where structures are built to most effectively induce these processes that may be beyond the strategies by which beavers build dams and dam complexes. We employ a variety of Beaver Dam Analogs (BDAs) (Pollock et al., 2014) structure types to achieve different functions, some of which mimic the types of functions of natural beaver dams, and some which create conditions that increase the probability that beaver dams and other BDAs will persist. Individual BDA structures used in isolation are unlikely to achieve a goal of restoring a process that is self-sustaining and must be used in concert with other BDAs to form a complex. Finally, for the larger restoration effort, the family of complexes must be viewed at even coarser resolution such as the reach or watershed scale to ensure that non-localized processes do not prevent localized goals (e.g. sediment delivery, discharge, vegetation communities etc.).

In general, the design and installation of BDA structures is a relatively simple, cost effective, and non-destructive restoration approach. BDA structures are constructed of untreated, sharpened lodge pole fence posts, approximately 3-4" diameter, driven into the active channel and inset floodplain using a hydraulic post pounder. Posts extend 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. For a single structure posts will be 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 are generally 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 (2004) and consistent with the Aquatic Resources Biological Opinion for restoration actions on federal lands in Oregon and Washington. In addition to weaving willow among the post line, BDA structures will be 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. Reinforcing the base of BDA structures prevents flow from scouring under the dam, and speeds up pond formation and associated processes. Beaver Dam Analogues should last until the pool behind the dam fills with sediment and is colonized by woody riparian vegetation (< 5 yr.). The spacing between structures will be consistent with the dam layout of a natural beaver colony, which is approximately 30 - 100 m apart, depending on stream gradient and width.

There are four major BDA structure types:

- Primary Dams
- Secondary Dams
- Constriction Dams
- Reinforced Existing Dams

While not always mutually exclusive, specific structure types vary with respect to their function, design, and construction, and are strategically placed to mimic the form and function of beaver dam complexes. Each structure is designed with defined objectives for triggering and/or maintaining geomorphic and hydraulic processes leading to channel and floodplain rehabilitation.

Table 1 – Four major restoration structure types. Constriction dams are classified as both BDA and PALs structure types

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 natural 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 active 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