Beaver Restoration on Thirtynine Mile Mountain

An experiment in restoring wetland and watershed functions on headwaters streams in the Upper South Platte

Mark Beardsley and Jessica Doran, EcoMetrics
Kristen Meyer, Pike National Forest, South Park Ranger District

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Introduction

Every student of ecology learns about the role that beavers play as a keystone species. They are effective "habitat engineers" in creating and maintaining wetlands. Regrettably, beavers have been largely extirpated from most of their previous range, resulting in widespread loss of wetlands and diminished watershed function. Reestablishing beavers to areas where they once occurred, and allowing them to restore and maintain the wetlands that were once present is a cost-effective and natural way to achieve watershed goals.

The purpose of this study is to determine the feasibility of using beavers (*Castor canadensis*) to restore wetland habitat within specific headwaters drainages in the Upper South Platte Watershed. The study area includes the drainages on the north side of Thirtynine Mile Mountain in eastern Park County, Colorado on the Pike National Forest. Thirtynine Mile Mountain is a volcanic ridge, aligned in an east/west direction, with Cross, Pruden, Union, Balm of Gilead, and Sims Creeks, descending its northern flanks about 2,500 vertical feet to Elevenmile Reservoir.

The creeks in these drainages are very small, and only certain segments actually have perennial flow. While the drainages can be followed all the way to their terminus at Elevenmile Reservoir, the upper and lower portions are intermittent or ephemeral. These dry conditions effectively isolate the middle portions of these watersheds from any downstream aquatic habitat.

Beavers were historically present in this area. There is evidence that beavers and beaver dams were once abundant on at least some of these creeks, but all traces of past beaver activity are very old. It is likely that beavers have been extinct from the north side of Thirtynine Mile Mountain for more than 100 years. As a result, the streams have become incised and simplified, and the drainages now support far fewer wetlands than they did historically. The isolation of these drainages from other aquatic habitat has prevented beaver from recolonizing the area, and because of this dry barrier it is unlikely that beaver will ever immigrate and become reestablished here on their own. This situation presents a potential opportunity for restoring wetlands by simply assisting migration of beavers to the area. Our aim is to determine the feasibility and potential outcomes of this strategy.

In this study, we surveyed Cross, Pruden, Union, Balm of Gilead, and Sims Creeks to identify evidence of past beaver activity and to assess beaver habitat suitability. In areas with suitable beaver habitat, we then assessed the existing and potential wetland condition to evaluate the potential for beavers to restore wetland and wetland functions. Ecological lift related to the restoration of wetland via beaver reestablishment is quantified in terms of wetland functional units. In addition to the feasibility study, the discussion section of this report includes a basic restoration plan and a monitoring strategy to track progress and evaluate effectiveness of restoring wetland function. If the project proceeds, it will also create an opportunity for research into the effects of beavers on basic hydrologic functions including water retention, flood attenuation, and base flow maintenance. These factors are critical to hydrologic resilience, which is increasingly important in the face of climate change. While we suspect that beaver-mediated wetlands are valuable for maintaining these functions, the effects have rarely been documented. The importance of beaver activity on amphibian distribution and habitat quality is another relevant research avenue, especially considering the importance of headwaters wetlands for the survival of declining populations. The small size, isolation, and remoteness of these sites, combined with the ability to set up a robust before-after control-impact (BACI) study design make this project area an excellent natural laboratory. These additional monitoring and research opportunities are briefly discussed.

Methods

The study area includes portions of six watersheds draining the north side of Thirtynine Mile Mountain on the Pike National Forest. We inventoried each of these by dividing them into individual stream reaches and assessing each for beaver habitat suitability, wetland extent, and wetland condition. For the wetland assessments, we considered both existing (baseline) condition as well as what the potential condition would likely be if beavers were fully re-established. Each reach was identified with a unique ID code and mapped on Google Earth as a path drawn along the centerline of the valley bottom. Reach length was measured using Google Earth tools along this path. Mean valley bottom width was calculated on Google Earth and checked for accuracy in the field, measured as the width of the historic active floodplain. We also noted areas where the present valley width has been significantly altered by human activity such as channelization or encroachment. Valley slope was estimated using elevation profiles on Google Earth for paths following centerline of the valley through each reach. Initial surveys were made remotely and then field checked over the course of four site visits by both EcoMetrics and USFS biologists.

Beaver habitat suitability

We assessed each reach for the potential to support active dam-building beaver colonies based on several factors.

- **Past beaver activity** - We walked the length of each reach and made note of any evidence of past beaver activity including relic dams, lodges, or chewed stumps. We made a rough estimate of the age of any identified beaver relics.
- **Stream channel presence** - Some of these valley segments have one or more stream channels, while others do not have a stream component at all. The non-stream reaches apparently convey most of their flows as diffuse groundwater and would be best

classified as wet meadow slope wetlands rather than riverine systems. Evidence of a stream channel was made by documenting the presence of identifiable bed and banks that would normally contain low to moderate flows.

- **Flow regime** - Field visits were timed both during runoff and at periods of low flow to observe the presence or absence of flowing water as evidence for a perennial versus intermittent or ephemeral flow regime. Reaches with steady flow estimated at greater than 0.5 cfs during the low-flow season were rated perennial; reaches that were dry during these periods but flowing during runoff season were rated intermittent; and reaches that were not flowing during either season were rated ephemeral.
- **Base flow conditions** - We estimated the approximate discharge at base flow for each reach using the following categories: Dry (no flow), 0.1 cfs (about the flow from a garden hose), 0.5 cfs (about the flow from a fire hose), 2.0 cfs, and 5.0 cfs.
- **Typical high flow (bankfull) conditions** - Field bankfull indicators were used to identify a rough idea of the magnitude of effective discharge and approximation of discharge with a roughly 2-year return interval. For this parameter, we simply rated the potential of this flow magnitude to have enough power to destroy a typical beaver dam.
- **Woody vegetation** - For each reach, we qualitatively described the condition of woody vegetation, noting the species, stature, size, cover/density, and proximity to the stream. Remote assessments made from Google Earth were field checked during site visits.
- **Availability of dam-building materials** - We separately assessed the availability of wood in the 1 to 6 inch diameter size range as potential building material for dams and lodges according to the categories abundant, limited, and none.
- **Herbaceous vegetation** - The availability of herbaceous vegetation was noted, with particular emphasis on species that would normally be used by beaver as food, including hydric grasses and sedges. Scoring categories are: abundant, limited, and none.
- **Site access** - We made general notes to rate the ease of site access for purposes of transporting beavers to the site and for future monitoring.
- **Existing cover** - This measure was meant to rate the ability of the site to accommodate released beavers with sufficient cover habitat. We qualitatively assessed the characteristics of existing cover based primarily on the area with water deeper than 1.0 ft.

These data were compiled into a spreadsheet and used to inform our rating of the habitat suitability for beavers. To aid in this decision, we employed two tools including Utah State's Beaver Restoration Assessment Tool (BRAT), and the Methow Beaver Project's release site scorecard.

Beaver Restoration Assessment Tool (BRAT) - This tool uses a fuzzy inference system to assess habitat suitability and predict the frequency of beaver dams (number of dams per km) based on the following lines of evidence:

- Evidence of a perennial water source. This factor was rated yes (1) or no (0).
- Evidence of stream bank vegetation to support dam-building activity and riparian/upland fringe vegetation to support expansion of dam complexes. This factor was rated on a scale of 0 to 4 based on the quantity, quality, and proximity of woody vegetation.
- Evidence that a beaver dam could physically be built across the channel during low flows based on estimated stream power during base flow, scored as "can build dam" (1) or "cannot build dam" (0). The tool allows for intermediate scores between 0 and 1 for the category "can possibly build dam" if there is uncertainty.
- Evidence that a beaver dam is likely to withstand typical floods based on estimated stream power at high flow (Q_2, or 2-year occurrence), scored as "dam persists" (1) and "blowout - peak flows certainly lead to dam blowout" (0). The tool also allows for intermediate scores between 0 and 1 for the categories "occasional breach" and "occasional blowout" if there is uncertainty.
- Evidence of high stream gradient that limits or eliminates dam building by beaver. Reaches steeper that 23% were scored as "beaver can't build a dam" (0), and reaches between 17% and 23% were scored as "dam building capacity is limited" with an intermediate score. It is assumed that dam building is not limited by stream gradient below 17%.

We applied these factors in straightforward manner that approximates the fuzzy inference system used in the model. The numerical scores of each factor are multiplied together to arrive at a score that indicates a particular category of predicted beaver dam frequency as described in the BRAT tool. Dam frequency categories are as follows:

- (0) None – 0 dams: segments deemed not capable of supporting dam building activity.
- (1) Rare – 1 dam/km: segments barely capable of supporting dam building activity; likely used by dispersing beaver.
- (2) Occasional – 2-4 dams/km: segments that are not ideal, but can support an occasional dam or even a small colony.
- (3) Frequent – 5-15 dams/km: segments that can support multiple colonies and dam complexes, but may be slightly resource limited.
- (4) Pervasive – 16-40 dams/km: segments that can support extensive dam complexes and many colonies.

Methow Beaver Project Release Site Scorecard - This tool was developed by the Methow Beaver Project, which has successfully transplanted hundreds of beavers to dozens of sites over the past seven years to study the effectiveness and effects of transplant beavers. The scorecard is used to rate the suitability of release sites using a point system based on several factors deemed relevant in their past monitoring studies.

Practical considerations - Finally, for each of the potential restoration and control sites, we made notes about specific practical considerations including access issues and site preparation needs, especially the need to provide temporary cover for introduced beavers.

Wetland functions - potential for ecological lift

The primary goal for the project is to restore characteristic wetland functions to the Thirtynine Mile Mountain watersheds that were lost following the extirpation of beavers and other human impacts. We quantified wetland functions in terms of wetland functional units (WFUs), which are calculated as the product of wetland extent (acres) times its relative degree of functionality, or functional capacity index (FCI), which is a factor of condition. One WFU is equal to the amount of function provided by one acre of wetland in pristine, unimpaired condition. FCI is calculated directly from the condition score using FACWet (Functional Assessment of Colorado Wetlands) version 3.0 (Johnson, Beardsley, Doran 2013).

For potential restoration and control sites, we also predicted the potential future extent and condition of wetlands assuming successful beaver re-introduction. The difference in baseline WFUs and predicted post-project WFUs (ΔWFU) is a measure of the potential for ecological lift that could be expected from successful restoration in terms of wetland functions.

Wetland extent - Existing (baseline) wetland extent was determined by making a coarse delineation at potential restoration and control sites. The rough delineations were tracked using survey-grade (sub-decimeter) GPS and converted to polygon features in Google Earth KMZ files for mapping and aerial measurement. Potential extent of wetlands was determined by mapping polygons in Google Earth by tracing the lateral extent of the historic floodplain valley bottom, including the existing floodplain and wetland plus any abandoned terrace that would be charged by active, dam-building beavers. Only the abandoned terraces that are within about 1.0 ft of existing active floodplains (bankfull elevation) were included. Areas separated from the channel by natural or artificial dikes or levees were not included. Maps of potential wetland extent were then field-checked to assure accuracy.

Functional Condition - Wetland functional condition was determined using FACWet version 3.0 on all potential restoration and control sites. Each of the eight state variables and their supporting subvariables were scored according to FACWet guidelines on a scale of 50 to 100 that corresponds to the academic grading system, and the primary stressors responsible for impairment were identified and described. A weighted average of variable scores is then used to calculate an overall condition score and FCI according to the weightings provided in Table 1.

FACWet assessments were limited in this study to EPA level II (rapid field assessment) data, but the variable scores could be further tested and adjusted using quantitative level III methods in the future. Landscape variables were scored using Google Earth aerial imagery. Other variables were scored in the field.

Potential functional condition was predicted for selected restoration and control sites by adjusting FACWet variable scores to reflect future condition based on the assumption of successful beaver reestablishment at the site and sustainable beaver maintenance of the habitat. The prognosticated variable scores, therefore, reflect restoration target values or quantitative objectives, which can be used as success criteria for monitoring project effectiveness in the future. Predicted post-project variable scores are used to calculate a potential post-project condition score and FCI within FACWet via the same weighted average used to score existing condition. Thus, the change in condition predicted by the project is a direct reflection of practical expectations for individual state variable improvements.

Table 1: An outline of FACWet attributes, state variables, and subvariables. The right column indicates the weight that each variable has in calculating the overall functional condition score and FCI.

Attribute	Variable Number	State Variable Name	Sub-Variable Name	Total Weight of Variable in Composite FCI
Buffer & Landscape Context	V1	*Habitat Connectivity*	*SV 1.1 – Neighboring Wetland and Riparian Habitat Loss*	*0.04*
			SV 1.2 – Barriers to Migration and Dispersal	
	V2	*Contributing Area*	*SV 2.1 – Buffer Condition*	*0.11*
			SV 2.2 – Buffer Extent	
			SV 2.3 – Buffer Width	
			SV 2.4 – Surrounding Land Use	
Hydrology	V3	*Water Source*	*No sub-variables*	*0.13*
	V4	*Water Distribution*		*0.17*
	V5	*Water Outflow*		*0.17*
Abiotic & Biotic Habitat	V6	*Geomorphology*	*No sub-variables*	*0.15*
	V7	*Chemical Environment*	*SV 7.1 – Nutrient Enrichment*	*0.07*
			SV 7.2 – Sedimentation/turbidity	
			SV 7.3 – Toxic Contamination	
			SV 7.4 – Temperature	
			SV 7.5 – Soil Chemistry and Redox	
	V8	*Vegetation Structure and Complexity*	*SV 8.1 – Tree Stratum*	*0.16*
			SV 8.2 – Shrub Stratum	
			SV 8.3 – Herb Stratum	
			SV 8.4 – Aquatic Stratum	

Results

Beaver Habitat Suitability

The study area was divided into 30 assessment reaches. A summary of results for the beaver habitat suitability factors for each reach is provided in Table 2. These drainages vary in gradient from about 2% to 9%, and valley width varies from less than 20 ft to more than 200 ft. In general, the lower-gradient reaches in wider valleys have evidence of past or present wetlands and beavers. Steeper and narrowly confined valleys naturally support fewer beavers and much less functional wetland area. Our results generally follow this trend. We found good evidence of historic beaver activity on six reaches in the form of old dams and stumps of trees that were felled by beaver. None of the beaver evidence is recent, and the signs we observed appear to be at least 100 years old.

Table 2: Summary of beaver habitat suitability factors, by reach.

39-Mile Mountain Beaver Habitat Suitability Factors															
Drain-age	Reach ID	L_V (ft)	W_V (ft)	S_V (%)	Hx beaver evidence	Stream channel	Flow regime	Base flow (observed)	High flow	Woody vegetation notes	Dam mat.	Herb veg.	Access	Exist. cover
Cross	CC-1	3200	50-100	6	No	No	I	intermittent ~0.1 cfs	OK	Aspens present on hillside, cinquefoil is dominant on FP	Ltd	Abd	Easy	Poor
Cross	CC-2	3800	50-150	4	No	Yes	P	< 0.5 cfs	OK	Mixed forest near the road, willows dominant upstream	Abd	Abd	Easy	Poor
Cross	CC-3	700	100-150	8	Yes	Yes	P	< 0.5 cfs	OK	Aspen with current understory, more willows near the road	Abd	Abd	Easy	Poor
Cross	CC-4	700	50-100	7	No	Yes	I	intermittent ~0.1 cfs	OK	Mixed forest with aspen, current	Abd	Abd	Mod	Poor
Pruden	UP-1	1300	40-130	6	No	No	I	intermittent ~0.1 cfs	OK	Less shrub cover, willow and sparse aspen	Ltd	Abd	Easy	Poor
Pruden	UP-2	700	20-70	4	No	Yes	P	0.1 - 0.5 cfs (gaining)	OK	Willow and aspen in narrow band along stream, no large stands	Ltd	Ltd	Easy	Poor
Pruden	MP-1	920	50-75	2	No	Yes	P	~0.5 cfs	OK	Healthy willows, no aspen in the riparian area	Ltd	Abd	Easy	Poor
Pruden	MP-2	1200	60-100	5	No	Yes	P	~0.5 cfs	OK	Willows with increasing aspen on the hillsides	Ltd	Abd	Easy	Poor
Pruden	MP-3	630	100	3	Yes	Yes	P	~0.5 cfs	OK	Willows with aspens in riparian and on hillside	Abd	Abd	Easy	Poor
Pruden	MP-4	1200	70-80	5	No	Yes	P	~0.5 cfs	OK	Aspen forest with desnse willows	Abd	Abd	Easy	Poor
Pruden	MP-5	310	75	5	No	Yes	P	~0.5 cfs	OK	Willows, no aspen	Abd	Abd	Easy	Poor
Pruden	LP-1	880	≤ 40	3	No	Yes	P	~2 cfs	OK	Willows, no aspen	Abd	Abd	Easy	Poor
Pruden	LP-2	1100	exist < 40 hx ~ 200	2	Yes	Yes	P	~2 cfs	OK	Aspen, cottonwood, and willow	Abd	Abd	Mod	Poor
Pruden	LP-3	670	40-100	6	No	Yes	P	≥ 2 cfs	OK	Minimal at upper end with alders on lower end	Abd	Abd	Mod	Poor
Pruden	LP-4	1300	40	4	Yes	Yes	P	~2 cfs	OK	Thick willows, alder, cottonwood	Abd	Abd	Mod	Poor
Pruden	LP-5	300	n/a	6	No	Yes	I	Dry	OK	No woody vegetation	None	Ltd	Mod	Poor
Union	UC-1	2200		6	No	No	I	Dry	OK	No woody vegetation	None	None	Mod	Poor
Union	UC-2	970		5	No	No	I	intermittent ~0.1 cfs	OK	Aspen with willow and current	Abd	Ltd	Mod	Poor
Union	UC-3	350	exist < 40 hx ~ 300	4	Yes	Yes	I	intermittent ~0.1 cfs	OK	Decreased aspen, more willow and current	Abd	Abd	Dif	Poor
Union	UC-4	1650	20-80	2	No	Yes	I	intermittent ~0.1 cfs	OK	Aspen, abundant deadfall in the channel	Ltd	Abd	Dif	Poor
Union	UC-5	750	n/a	6	No	Yes	E	Dry	OK	No woody vegetation	None	Ltd	Dif	Poor
Balm of Gilead	BG-1	2300	30	5	No	No	P	~0.5 cfs	OK	Cinquifoil and current only	Ltd	Ltd	Mod	Poor
Balm of Gilead	BG-2	1800	20-100	2	No	No	P	~0.5 cfs	OK	Mix of cottonwood, aspen and alders, no willows.	Ltd	Ltd	Mod	Poor
Balm of Gilead	BG-3	1100	20	5	No	Yes	P	~0.5 cfs	OK	Cinquifoil and current only	Ltd	Ltd	Dif	Poor
Balm of Gilead	BG-4	1000	exist < 30 hx ~ 200	7	Yes	Yes	P	~0.5 cfs	OK	Alder and aspen on hillside, Cinquifoil and current, no willows	Ltd	Ltd	Dif	Poor
Balm of Gilead	BG-5	500	exist < 30 hx ~ 201	3	No	Yes	P	~0.5 cfs	OK	Mix of cottonwood, aspen and alders, no willows.	Ltd	Ltd	Dif	Poor
Balm of Gilead	BG-6	1280	exist < 30 hx ~ 202	5	No	Yes	P	0.5 - 2 cfs (gaining)	OK	Cinquifoil and current only	Ltd	Ltd	Mod	Poor
Balm of Gilead	BG-7	1380	exist < 30 hx ~ 202	5	No	Yes	P	~2 cfs	OK	Mix of cottonwood, aspen and alders, no willows.	Ltd	Ltd	Mod	Poor
Sims	SC-1	1730	15-50	4	No	No	E	Dry	OK	Mix of conifers and aspen, few riparian shrubs	Ltd	Ltd	Dif	Poor
Sims	SC-2	1380	15	9	No	No	E	Dry	OK	Mostly conifers, few riparian shrubs	Ltd	Ltd	Dif	Poor

All of the reaches where we found good evidence of past beaver activity have valley bottom widths that are or were greater than 100 ft. On Union Creek and Balm of Gilead Creek (UC-3 and BG-4) we found beaver evidence on reaches that historically had wide valley bottoms but have since become deeply incised due to artificial channelization and entrenchment. Valley width on these sites is now less than 40 ft, and the historic beaver dams are on abandoned terraces that are now perched up to ten feet above the level of the creek. Even though beavers clearly inhabited these reaches in the past, the impacts caused by channelization and entrenchment have severely limited their suitability today.

Hydrology and stream geomorphology on these drainages is interesting. The upper portions of the drainages contain no wetland or stream components. We did not assess these portions of the drainages because there is no aquatic habitat. Further down, the drainages tend to be fed by groundwater. These portions of the study area tend to be wet meadow habitat without a discernible stream channel and intermittent surface water. A noticeable stream channel, with a bed and banks, is present in all the drainages starting some distance downstream from the headwaters.

Once present, these stream traces tend to remain present in all of the drainages as they make their way through the study area. Downstream of the Forest boundary, some of these drainages lose their discernible stream component, and become wet meadows or uplands, while others maintain their identifiable bed and banks all the way to Elevenmile Reservoir. In all cases, the streams tend to lose hydrology as they reach the Forest Boundary and before they reach Elevenmile Reservoir. At the Forest boundary, which is the lowest point of the study area, none of the streams except Balm of Gilead show evidence of perennial flow. Even Balm of Gilead Creek apparently becomes ephemeral within a short distance downstream from Forest lands.

These drainages go through a pattern of having an increasing duration of surface flow as water accumulates and moves down-drainage. Once the drainages reach a certain point downstream, near the Forest boundary, another pattern of decreasing surface flow continues on to BLM and private land. The region with the most persistent flow is in the center portions of Pruden, Cross, and Balm of Gilead Creeks. On Union and Sims Creek, there is no evidence of perennial flow throughout the drainages. These drainages appear to be wholly ephemeral or intermittent and therefore unsuitable for beaver habitation; however, it is evident that beavers used to inhabit Union Creek when there historically was more water with a perennial flow. On the other hand, the drainages of Cross, Pruden, and Balm of Gilead Creeks have significant lengths of the drainages where there is evidence of the perennial flow regime that is needed for beavers to be able to persist.

Other stream flow factors important for beavers are related to stream power. Beavers are physically unable to build cross-channel dams on streams that have very high power at base flow, and if power is too high during seasonal peaks, then dams cannot persist. The small creeks in this study are nowhere near either of these stream power thresholds, and therefore suitable for persistent dams by these criteria.

Besides water, the other primary habitat need for beavers is wood. Wood is the beaver's main food source and the building material for their dams and lodges. On these streams, the native wood supply is aspen trees on the upland hillslopes and riparian shrubs such as willows and alders. On some sites, these native vegetation types are still prevalent. On other sites, the type and amount of woody vegetation has dramatically changed. On much of the uplands, conifer have encroached on areas that used to be dominated by aspens due to the lack of disturbance such as fire. On many riparian areas, willows and alders have become replaced by cinquefoil and currents due to drying (caused by channelization, entrenchment, and beaver loss) and grazing pressure. Aspen, willows and alder are the preferred food source for beaver. Conifers, cinquefoil, and currents, on the other hand, are not suitable food but can be used as building material.

The assessment of beaver habitat suitability with respect to woody vegetation is largely a matter of determining the extent to which the preferred native woody species (aspen, willows, and alder) have been lost or replaced by unusable species. Results of our surveys for woody vegetation are presented as short narrative descriptions in Table 2 along with an assessment of the availability of building materials. Suitability related to woody vegetation is assessed in more detail in the scoring of variables within the BRAT and Methow tools, where quantitative ratings are given based on the type, amount, and proximity of vegetation. Cross Creek and Pruden Creek both have areas where aspen, willows, and alder are plentiful.

While the beaver's preferred food for most of the year is wood, herbaceous vegetation such as hydric grasses and sedges can be an important part of their diet during certain seasons. Herbaceous vegetation was not found to be limiting on any of the sites that would otherwise be viable for beavers. It would only be limiting on sites that were already eliminated due to inadequate hydrology or valley width. Preferred herbaceous vegetation is abundant on most of the reaches of Cross Creek and Pruden Creek.

In addition to the beaver habitat suitability survey, we also rated several practical factors related to the difficulty for introducing and monitoring beavers. Site accessibility was assessed by considering the amount of time it takes to travel to the site on off-highway roads plus the distance of required off-road travel on foot. Cross creek and Pruden Creek generally have easy access on account of the proximity of the main forest roads, but the lower end of Pruden Creek does require a significant hike and access is rated as moderate. None of the sites presently have good cover habitat for beavers because there are no areas where surface water regularly exceeds one foot depth.

BRAT Results

The BRAT tool works essentially as a set of filters that separate suitable from unsuitable habitat according to set criteria. The first filter is evidence of perennial water. Of 30 reaches we assessed, 16 of them passed this filter, and 14 sites were eliminated. All of the Union and Sims Creek reaches were eliminated due to the lack of perennial flow. Reaches near the upper and lower ends of Cross and Pruden Creek and at the upper end of Balm of Gilead Creek were also eliminated on this basis. The next filter is evidence for required vegetation to support dam building and expansion. Vegetation is rated on a categorical scale from 0 (none) to 4 (abundant, unlimited). The reaches in this study spanned the entire range of vegetation condition, but most of the sites with poor vegetation corresponded with the lack of perennial water. All of the 16 sites with perennial water had some level of woody vegetation, but vegetation scores ranged from 1 (barely capable of supporting dam building and no more than an occasional dispersing beaver) to 4 (enough to support extensive dam complexes and many colonies). The other three filters are related to stream power and valley slope. All of the reaches in this study fell within the range of suitability for these criteria, so the additional filters did not change results based on the first two lines of evidence.

The output of the BRAT model is a categorical rating for each reach that indicates the frequency or density of beaver dams it could support. Both Cross Creek and Pruden Creek have reaches that rate in the "pervasive" (16-40 dams/km) and "frequent" (5-15 dams/km) categories. The model predicts no capacity for beaver dams on Union and Sims Creek and only "occasional" (2-4 dams/km) or "rare" (1-2 dams/km) on most of Balm of Gilead Creek, though the lower reach of Balm of Gilead may be able to support frequent dams. The suitability rating is derived directly from the overall score, which is simply the product of individual parameter scores. A map showing the results of the BRAT model evaluation is provided as Figure 1.

Table 3: Results of the BRAT (Beaver Restoration Assessment Tool).

39-Mile Mountain BRAT Results								
Drain-age	Reach ID	Perennial flow	Woody veg.	Dam possible	Dam persistent	Slope limitation	Combined score	Predicted dam freq.
Cross	CC-1	0	2	1	1	1	0	None
	CC-2	1	4	1	1	1	4	Pervasive
	CC-3	1	4	1	1	1	4	Pervasive
	CC-4	0	4	1	1	1	0	None
Pruden	UP-1	0	2	1	1	1	0	None
	UP-2	1	4	1	1	1	4	Pervasive
	MP-1	1	3	1	1	1	3	Frequent
	MP-2	1	3	1	1	1	3	Frequent
	MP-3	1	4	1	1	1	4	Pervasive
	MP-4	1	4	1	1	1	4	Pervasive
	MP-5	1	3	1	1	1	3	Frequent
	LP-1	1	2	1	1	1	2	Occasional
	LP-2	1	4	1	1	1	4	Pervasive
	LP-3	1	2	1	1	1	2	Occasional
	LP-4	1	4	1	1	1	4	Pervasive
	LP-5	0	0	1	1	1	0	None
Union	UC-1	0	0	1	1	1	0	None
	UC-2	0	1	1	1	1	0	None
	UC-3	0	4	1	1	1	0	None
	UC-4	0	3	1	1	1	0	None
	UC-5	0	0	1	1	1	0	None
Balm of Gilead	BG-1	0	1	1	1	1	0	None
	BG-2	0	2	1	1	1	0	None
	BG-3	0	2	1	1	1	0	None
	BG-4	1	2	1	1	1	2	Occasional
	BG-5	1	2	1	1	1	2	Occasional
	BG-6	1	1	1	1	1	1	Rare
	BG-7	1	3	1	1	1	3	Frequent
Sims	SC-1	0	2	1	1	1	0	None
	SC-2	0	2	1	1	1	0	None

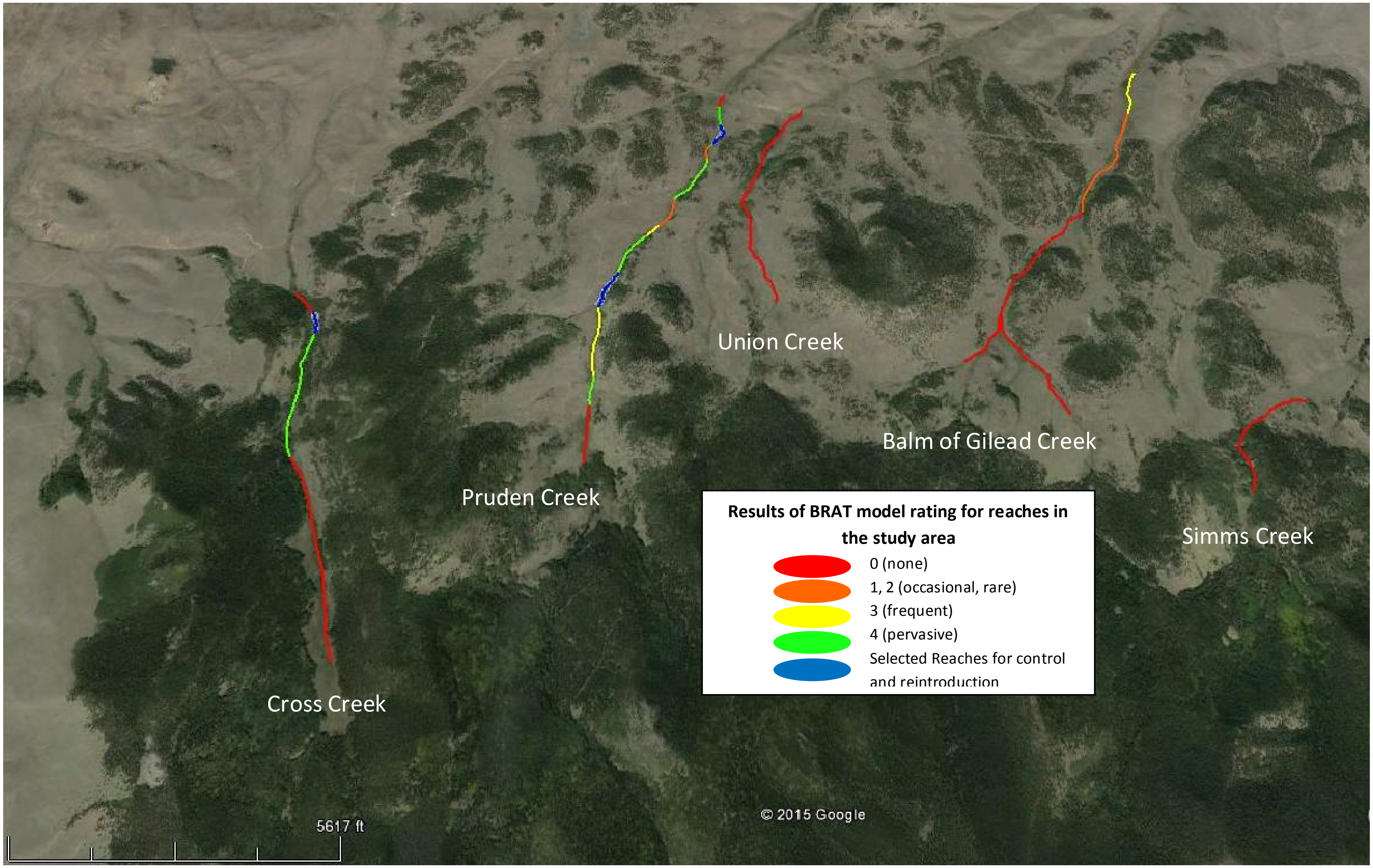

Figure 1: Results of the BRAT model, by reach.

Table 4: Capacity estimates for number of beaver dams per km based on the BRAT model.

39-Mile Mountain BRAT Beaver Dam Capacity Estimates						
Drain-age	Reach ID	BRAT	dams/km	Length (km)	dams/reach	dams/stream
Cross	CC-1	None	0	0.98	**0**	**34**
	CC-2	Pervasive	25	1.16	**29**	
	CC-3	Pervasive	25	0.21	**5**	
	CC-4	None	0	0.21	**0**	
Pruden	UP-1	None	0	0.40	**0**	**46**
	UP-2	Pervasive	25	0.21	**5**	
	MP-1	Frequent	10	0.28	**3**	
	MP-2	Frequent	10	0.37	**4**	
	MP-3	Pervasive	25	0.19	**5**	
	MP-4	Pervasive	25	0.37	**9**	
	MP-5	Frequent	10	0.09	**1**	
	LP-1	Occasional	3	0.27	**1**	
	LP-2	Pervasive	25	0.34	**8**	
	LP-3	Occasional	3	0.20	**1**	
	LP-4	Pervasive	25	0.40	**10**	
	LP-5	None	0	0.09	**0**	
Union	UC-1	None	0	0.67	**0**	**0**
	UC-2	None	0	0.30	**0**	
	UC-3	None	0	0.11	**0**	
	UC-4	None	0	0.50	**0**	
	UC-5	None	0	0.23	**0**	
Balm of Gilead	BG-1	None	0	0.70	**0**	**6**
	BG-2	None	0	0.55	**0**	
	BG-3	None	0	0.34	**0**	
	BG-4	Occasional	3	0.30	**1**	
	BG-5	Occasional	3	0.15	**0**	
	BG-6	Rare	1	0.39	**0**	
	BG-7	Frequent	10	0.42	**4**	
Sims	SC-1	None	0	0.53	**0**	**0**
	SC-2	None	0	0.42	**0**	

The BRAT model output can also be used to estimate the number of potential beaver dams that each reach and drainage can support. To make this rough estimate, we used the mid-point dam frequency value in the range given by BRAT for each category. This value, multiplied by the length of each reach (in km) provides an estimated capacity for the number of dams. These data are shown in Table 4. The model predicts a capacity of 34 dams on Cross creek, 46 dams on Pruden, six on Balm of Gilead, and none on Union or Sims.

Methow Scorecard results

The Methow Beaver Project Release Site Scorecard is a much more in-depth site-scale look at beaver habitat suitability, specifically for the purpose of supporting transplanted beavers. Like BRAT, the Methow tool heavily weights the primary beaver habitat requirements of water and wood, with the availability of woody vegetation being the most important factor determining the quality of the site. The Methow tool takes into account additional factors including additional physical and biological habitat factors plus practical aspects related to potential for successful beaver release. The output is a numerical score that can be used to compare potential release sites to each other. We used our survey data to complete the scorecard on the 16 reaches for which there was evidence of perennial water (See Appendix A). Scores ranged from 30 to 89. Four reaches scored greater than or equal to 75, eight scored between 50 and 75, and four scored less than 50. All four of the reaches scoring less than 50 are on Balm of Gilead Creek. The reaches scoring 50 or greater are on Cross and Pruden Creeks.

Table 5: Results of the Methow Beaver Project Release Site Scorecard.

39-Mile Mountain Methow Scorecard Results																	
Drain-age	Reach ID	Stream Grad.	Stream flow	Habitat size	Food		FP width	sub-strate	Historic use	Bldg. mat.	Grazing use	Bonus					Score
					Woody	Herbs						Access	Fire	Conflict	Cover	Owner	
Cross	CC-1	Not scored															**N/A**
Cross	CC-2	3	4	5	27	3	2	5	0	5	0	0	0	5	0	5	**64**
Cross	CC-3	1	5	5	27	3	5	5	10	5	0	5	0	0	5	5	**81**
Cross	CC-4	Not scored															**N/A**
Pruden	UP-1	Not scored															**N/A**
Pruden	UP-2	3	3	5	27	3	0	5	0	0	0	0	0	5	0	5	**56**
Pruden	MP-1	5	4	5	18	3	2	5	0	0	0	0	0	5	0	5	**52**
Pruden	MP-2	3	4	5	18	3	2	5	0	0	0	5	0	5	0	5	**55**
Pruden	MP-3	5	4	5	27	3	5	5	10	5	0	5	0	5	5	5	**89**
Pruden	MP-4	3	4	5	27	3	2	5	0	5	0	5	0	5	0	5	**69**
Pruden	MP-5	3	4	5	18	3	2	5	0	0	0	5	0	0	0	5	**50**
Pruden	LP-1	5	5	5	18	3	2	5	0	0	0	5	0	0	0	5	**53**
Pruden	LP-2	5	5	5	27	3	2	5	10	5	0	0	0	5	0	5	**77**
Pruden	LP-3	3	5	5	18	3	2	5	0	5	0	0	0	5	0	5	**56**
Pruden	LP-4	3	5	5	27	3	5	5	10	5	0	0	0	5	0	5	**78**
Pruden	LP-5	Not scored															**N/A**
Union	UC-1	Not scored															**N/A**
Union	UC-2	Not scored															**N/A**
Union	UC-3	Not scored															**N/A**
Union	UC-4	Not scored															**N/A**
Union	UC-5	Not scored															**N/A**
Balm of Gilead	BG-1	Not scored															**N/A**
Balm of Gilead	BG-2	Not scored															**N/A**
Balm of Gilead	BG-3	Not scored															**N/A**
Balm of Gilead	BG-4	1	3	5	6	3	0	5	10	0	0	0	0	5	0	5	**43**
Balm of Gilead	BG-5	5	3	5	9	3	0	5	0	-10	0	0	0	5	0	5	**30**
Balm of Gilead	BG-6	3	3	5	3	3	0	5	0	0	0	0	0	5	0	5	**32**
Balm of Gilead	BG-7	3	3	5	8	3	0	5	0	0	0	0	0	5	0	5	**37**
Sims	SC-1	Not scored															**N/A**
Sims	SC-2	Not scored															**N/A**

Site selection

Our initial site selection is made by identifying reaches that maximize the probability of success by making sure that we would be relocating beavers to areas that will be immediately suitable and capable of sustaining expanding populations. We used the combined results from the beaver habitat suitability tools to guide our appraisal of each reach for this purpose and to select priority sites for restoration, with sites scoring greater than 75 on the Methow scorecard rated excellent candidates for reintroduction (see Table 6). These methods identify four high priority reaches, including three on Pruden Creek (MP-3, LP-2, and LP-4) and one on Cross Creek (CC-3).

The LP-2 reach apparently has good potential, but the stream is deeply incised on this reach. Some of the historic beaver dams on this reach are, in fact, now perched 5-10 feet above the present elevation of the creek. Some more recent relic dams were observed along the creek at its present elevation within the entrenched channel, which is a strong indication that beavers could gain a foothold on this site and succeed in building dams. Nevertheless, the depth of entrenchment would probably severely limit the potential for expanding wetland area laterally, since hydrologic effects of the dams would be confined within the entrenched channel (see Figure 2).

Therefore, while the LP-2 reach does offer potential beaver habitat, it is given a lower priority than the other three potential reaches. The three highest priority restoration reaches are MP-3 and LP-4 on Pruden Creek and CC-3 on Cross Creek.

39-Mile Mountain Suitability Summary				
Drain-age	Reach ID	BRAT	Methow	Suitability rating
Cross	CC-1	None	N/A	None
	CC-2	Pervasive	64	Good
	CC-3	Pervasive	81	Excellent
	CC-4	None	N/A	None
Pruden	UP-1	None	N/A	None
	UP-2	Pervasive	56	Good
	MP-1	Frequent	52	Good
	MP-2	Frequent	55	Good
	MP-3	Pervasive	89	Excellent
	MP-4	Pervasive	69	Good
	MP-5	Frequent	50	Good
	LP-1	Occasional	53	Good
	LP-2	Pervasive	77	Excellent
	LP-3	Occasional	56	Good
	LP-4	Pervasive	78	Excellent
	LP-5	None	N/A	None
Union	UC-1	None	N/A	None
	UC-2	None	N/A	None
	UC-3	None	N/A	None
	UC-4	None	N/A	None
	UC-5	None	N/A	None
Balm of Gilead	BG-1	None	N/A	None
	BG-2	None	N/A	None
	BG-3	None	N/A	None
	BG-4	Occasional	43	Poor
	BG-5	Occasional	30	Poor
	BG-6	Rare	32	Poor
	BG-7	Frequent	37	Poor
Sims	SC-1	None	N/A	None
	SC-2	None	N/A	None

Table 6: Summary of site suitability incorporating the BRAT and Methow models.

Figure 2: On artificially channelized reaches, the stream is entrenched and dissociated from its historic floodplain. Deeply entrenched segments such as this have limited wetland restoration potential as bank heights exceed the height of typical stable beaver dams.

Wetland Functional Condition

The overarching goal of this project is to increase wetland function, and the means to this end is re-establishment of beavers. The ultimate measure of success is, therefore, a demonstrable increase in wetland functions, which is expressed by the combined effect of expanded wetland area and improved wetland condition. In a project of this sort, improvements are made gradually. If beavers are successfully relocated on priority sites, we expect benefits will be detectable locally on the relocation reaches within a few years. If the populations are sustainable and expanding, we expect the benefits to spread further throughout the watershed as beavers expand their range. Expansion of beavers and the wetland benefits beyond the initial release sites may take years to decades. In this study, we focused our assessment on the priority reaches, and while our discussion of the potential for ecological lift is therefore limited to the target reaches, it should be understood that if the project is successful then wetland benefits will spread through the watersheds over time. Expansion to other reaches and overall watershed benefits could be tracked by future monitoring efforts.

In this section of the report, we describe the existing extent and condition of wetland on the three priority reaches. For each reach, we also provide a prediction of the future extent and condition assuming the full recovery of sustainable beaver populations to calculate the potential for ecological lift in terms of wetland functional units (WFU).

Existing (pre-project) wetland area was estimated for each of the three priority reaches. On all three sites, wetlands are presently limited to a narrow strip along the active channel. Existing values are 0.08 acres at MP-3, 0.04 acres LP-4, and 0.01 acres at CC-3. Predicted maximum (post-project) wetland extent is estimated to be 2.34, 1.10, and 1.14 acres for the MP-3, LP-4, and CC-3, respectively. Pre-project FACWet condition scores are 75 (C)[1] for the two reaches on Pruden Creek, and 77 (C) for CC-4, and predicted scores are 87 (B) for the Pruden reaches and 88 (B+) for the reach on Cross Creek. All of these values are compiled in Table 7 which calculates the potential ecological lift in terms of wetland functional units.

Table 7: Calculation of wetland functional units and the potential lift for each of the selected reaches.

39-Mile Mountain Predicted Lift				
Reach		**MP-3**	**LP-4**	**CC-3**
Existing	Wetland area (ac)	0.08	0.04	0.01
	Condition	75 (C)	75 (C)	77 (C)
	FCI	0.50	0.50	0.54
	WFU (fctn. ac)	**0.040**	**0.020**	**0.005**
Predicted	Wetland area (ac)	2.34	1.10	1.14
	Condition	87 (B)	87 (B)	88 (B+)
	FCI	0.74	0.74	0.76
	WFU (fctn. ac)	**1.73**	**0.81**	**0.87**
Predicted lift (Δ WFU)		**1.69**	**0.79**	**0.86**
Combined		**2.49**		**0.86**

Table 8 shows FACWet scores for the assessed reaches. The sites are similar, differing slightly in scores for habitat connectivity, hydrology variables, and vegetation. Water distribution and outflow are the most impaired variables in all cases. The native condition is one in which beaver dams, ponds and channels would naturally retain water and spread out laterally, maintaining a high water table with water storage in ponds and a saturated alluvial aquifer. In the absence of beaver dams, however, flows in the drainage are rapidly transmitted through the system. The prognosis scores are based on the effects of a restored water distribution system that that would result from the successful reintroduction of beaver and the construction of beaver dams on the sites. We set the target score for water distribution at 85 (B) which is lower than reference condition due to the effects of channel incision and enlargement which may not be fully overcome by beaver activity for a long time. Improvements to other variables such as chemical environment and vegetation are secondary effects of restored hydrology and a disturbance regime that is characteristic of beaver-mediated streams.

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[1] FACWet scores correspond to letter grades according to the academic grading scale: A = 90-100, B = 80-89, C = 70-79, D = 60 - 69, F = 50-59. 50 is the lowest numerical score in FACWet, indicating complete impairment or conversion to upland. In this report, the numerical score is followed by the letter grade in parentheses.

Table 8: Summary of FACWet scoring for existing wetland condition and predicted condition following beaver restoration at the three priority sites.

39-Mile Mountain FACWet Scores						
State Variables	MP-3		LP-4		CC-3	
	Existing	Prognosis	Existing	Prognosis	Existing	Prognosis
V1 - Habitat Connectivity	82 (B)	82 (B)	82 (B)	82 (B)	86 (B)	86 (B)
V2 - Contributing Area	95 (A)	95 (A)	95 (A)	95 (A)	95 (A)	95 (A)
V3 - Water Source	88 (B+)	88 (B+)	88 (B+)	88 (B+)	94 (A)	94 (A)
V4 - Water Distribution	58 (F+)	85 (B)	58 (F+)	85 (B)	62 (D)	85 (B)
V5 - Water Outflow	58 (F+)	85 (B)	58 (F+)	85 (B)	62 (D)	85 (B)
V6 - Geomorphology	75 (C)	85 (B)	75 (C)	85 (B)	75 (C)	85 (B)
V7 - Chemical Environment	87 (B)	89 (B+)	87 (B)	89 (B+)	87 (B)	89 (B+)
V8 - Vegetation	77 (C)	85 (B)	81 (B-)	85 (B)	77 (C)	86 (B)
Cond.	**75 (C)**	**87 (B)**	**75 (C)**	**87 (B)**	**77 (C)**	**88 (B+)**
FCI	**0.50**	**0.74**	**0.50**	**0.74**	**0.54**	**0.76**

The most important result of beaver loss on these sites has been has been a decrease in wetland area, much more than a decrease in condition. The hydrologic impairment is severe enough that most of the historic natural wetland area has been converted to upland. In other words, the problem is not so much that the condition of wetland has suffered, but rather that wetland area has been lost altogether. Looking back at Table 7, the combined wetland area for both sites on Pruden Creek is estimated to be about 0.12 acres which is about 3% of its estimated historic potential of 3.44 acres. The 0.1 acres of existing wetland on the site at Cross Creek is less than 1% of the potential 1.14 acres at that site. Regaining wetland function in these watersheds is largely a matter of recovering this area that has been lost.

We predict a lift of about 2.5 WFU on the combined Pruden Creek sites and about 0.9 WFU on Cross creek based on the restoration of these priority sites to the expected level of B (87) or B+ (88). A rating in the high B category for restored wetland area may seem optimistic, but these predicted values follow directly from the primary and secondary effects of beaver presence. Moreover, these reaches are excellent candidates for restoration because, apart from beaver loss, they are otherwise minimally impacted. The sites have excellent buffers and no major harmful land use practices. They also have an unimpaired water source, excellent water quality, and reasonably intact vegetation structure. Restoring wetland area to these sites may be as simple as replacing the natural components, such as beavers, that are currently missing from the system. Unlike most restoration scenarios, success does not require any artificial or engineered solutions. Be this what it may, even if the condition of restored wetland is more marginal (lower FACWet scores) the gains in wetland function would still be great since there is so much potential to increase wetland acreage.

Discussion

Feasibility Summary

The conclusion of our reconnaissance is that wetland restoration via beaver reintroduction is feasible on specific reaches of Pruden and Cross Creek. There appears to be little or no opportunity, however, on Union, Sims, or Balm of Gideon Creek. The Union and Sims Creek drainages probably do not have adequate perennial hydrology to support beaver-mediated wetlands; and while Balm of Gilead Creek could probably support occasional beavers and beaver dams, the stream is so altered by channelization and entrenchment that only a small amount of wetland area is reasonably recoverable.

Pruden and Cross Creeks offer good potential for restoration of wetland functions by reintroducing beavers. About 8900 ft of the Pruden Creek drainage and 4500 ft on Cross Creek have good or excellent habitat suitability for beavers. From these suitable reaches, we identified two priority sites on Pruden Creek (about 1900 ft) and one site on Cross Creek (about 700 ft) where beaver reintroduction is predicted to result in the restoration of about 2.5 and 0.9 acres worth of wetland functional units, respectively. (These are the blue segments in Figure 1). Figure 3 is a photo of the selected Middle Pruden Creek restoration site taken in September of 2014.

Figure 3: The single thread channel of Pruden Creek is visible on the right side of the image running through a historically active floodplain. Relic beaver dams are identified by the dashed lines.

If beavers are successfully transplanted on these priority reaches, we anticipate them to spread up and down the drainages and eventually reoccupy suitable habitat within the project area. A long term goal for the project is the recovery of lost wetlands and improvement of hydrological conditions throughout the watershed.

The remainder of this report describes a restoration plan that is initially focused on these priority reaches. The plan is a general outline for how to implement the project; including practical considerations for obtaining and translocating beavers, site preparation to assure survivability of transplants, site protection needs, and monitoring. This project presents an excellent opportunity for studying the effects of wetland restoration and the importance of beavers on small headwaters watersheds. The proposed restoration plan therefore includes a detailed monitoring plan and a study design that could be used to track the effectiveness of the project and to support basic scientific research. We recommend targeting the Pruden Creek watershed for restoration, and using Cross creek as a control. This approach allows us to focus restoration efforts in one area initially, while providing the opportunity for a BACI (Before-After Control-Impact) study design.

Restoration plan

It would be ideal to implement all monitoring prior to the relocation of beavers to any of the sites. If this is possible, quantitative pre-project data can be collected to establish base line conditions. However, we realize that the timeline of the project may have to be flexible to accommodate the availability and condition of the beaver that are being relocated. If monitoring is not completely established prior to the arrival of beaver, it should be implemented as soon as possible after the beaver are relocated to facilitate the BACI design.

The two sites on Pruden Creek (MP-3, LP-4) will be the beaver family translocation sites. The first site to receive beavers will be MP-3; the second will be LP-4. MP-3 is selected as the first site because it offers the most wetland improvement potential and is more easily accessible. It is desirable to keep both relocation sites in the same drainage to improve the chances that the populations will eventually be able to interact and potentially cross breed. Cross Creek was selected as the control site because the site conditions closely resemble the relocation sites. Additionally, CC-3 is just downstream of a road crossing which may lead to conflict if beavers are relocated there first.

General considerations for transplanting beavers

We consulted with Kent Woodruff, leader of the Methow Beaver Project, and his team of beaver biologists and made a visit to the Methow Valley to witness their beaver trapping and transportation methods, see their holding facilities, and to observe both successful and unsuccessful release sites. The following recommendations came from our discussions with him and his team:

<u>Site Assessment</u>

- Careful assessment of potential release sites is critical to verify habitat suitability. Site assessment was carefully planned in this study.

Trapping and transport

- While live-trapping beaver is not an especially difficult or complicated procedure, working with an experienced and reputable trapper could provide a more dependable source of beaver. Using an experienced trapper would expedite the process and reduce or streamline permitting obligations related to trapping and transport of wildlife.
- Trapping should occur after the young are born and are moving around out of the den. This is to ensure a mating pair is not captured and moved without dependent young.
- The logistics of transporting the beaver from the holding site to the relocation site should be well planned. Considerations should include the general comfort of the animal to minimize stress with a specific focus on temperature.

Release

- Beavers should be released in groups that contain compatible male and female pairs, and the optimal situation is releasing compatible two-year old sub-adults. This is especially important in this project since the relocation sites are geographically isolated from any other beaver populations.
    - Trapping and relocating beaver families together is one strategy for meeting the requirement of a compatible male-female pair, but capturing family groups together may be difficult in practice. Wildlife 2000, a private beaver relocation service in run by Sherrie Tippie in Denver, primarily uses this strategy and may have special ways of assuring that beavers are trapped as family units.
    - Another strategy is to hold captured beavers in a facility for several weeks to let them sort themselves out into compatible groups. The Methow project uses this approach. Their facilities contain several artificial lodge options for the held beavers, and individuals tend to group together by electing to sleep together in a one lodge even when other lodges are available. Beavers paired this way tend to bond within several days, and presumably any pairs that were bonded prior to capture (any families trapped together) reconnect in the facility.
    - A third strategy is to simply capture and release as many beavers to a site as possible, and hope that compatible pairs will unite and bond at the release site. This is the least efficient and therefore least preferable option
- Accurately sexing beavers after capture and prior to release is important for assuring that males-female pairs are released. Sexing beavers is a difficult technique that has historically involved DNA testing. The Methow project recently developed field techniques based on the observation of oil gland secretions. Training and application of these techniques will help assure appropriate pairs are released in the field.

- Release of beavers to the site should probably be made no later than mid-August to allow enough time for the relocated beavers to prepare for winter and to minimize disturbance from hunters. This is particularly important in South Park where winter starts early and lasts well into April.
- Limiting predation early on is a very important consideration. Newly released beavers are very vulnerable to predation, and all beaver restoration projects have noted the impact of predation in this vulnerable stage. Post-release mortality can be significantly reduced by providing adequate escape cover in the form of deep water and physical structure.
    - Aquatic cover - Constructing brush dams or other beaver dam analogs (BDAs) to create pools with water depth exceeding 1.0 ft is critical for release sites on small streams. These temporary structures would be necessary on any of the sites within this project since there is virtually no water deeper than 1.0 ft and little structural cover. Small temporary structures are preferred due to the ease of construction, minimal impact, and lack of permitting requirements.
    - Artificial lodges - Constructing one or more temporary artificial lodges at release sites is a low cost method that assures appropriate physical escape cover is present. Physical structure of this sort provides newly released beavers with a much-needed feeling of security at the release site where they can hide and gradually venture out. The Methow group reports that the use of artificial lodges tends to be heavy for the first few days or more after release, as beavers frequently return after venturing out. Artificial lodges appear function mostly by supplying temporary cover while the beavers get used to their new surroundings. In one case, released beavers adopted the artificial structure as their permanent lodge, but in most cases they tend to build a new habitation on their own.
    - Additional structural cover - Other simple ways to reduce predation and to provide security for released beavers with structural escape cover is to build pools or select sites such that there is plenty of area where vegetation or stream banks overhang over deep water.
- Providing supplemental food at the time of release can improve success in keeping beaver at the drop site.
- Avoid potential human conflicts by selecting sites in secluded areas or where there is full disclosure and willingly participating landowners. The potential for costly management efforts may be avoided by choosing beaver restoration sites that are not near infrastructure that could be impacted by flooding or stream alteration such as roads, culverts, buildings, diversions, etc. or by planning for the management of these structures ahead of time.

Further consultation with Sherri Tippie of Wildlife 2000, Trish Neekin of Latah Soil and Water Conservation District of Idaho, Janet Hohle of Idaho Office of Species Conservation, and our local Colorado Parks and Wildlife (CPW) representatives corroborated these recommendations.

Possible sources for beavers

We researched the local availability and process of obtaining candidate beavers for relocation and found there to be several possible avenues. A commonly utilized local source is Wildlife 2000; a non-profit organization in Denver operated by Sherri Tippie (pers. comm.). She begins trapping around July and continues into September depending on fall conditions, and commonly has beavers available during that time. We described this project to Mrs. Tippie, and she expressed an interest and willingness to provide beavers. A second potential source is the local CPW. Nuisance beaver are regularly reported to CPW, and they have staff may be available to trap these beavers for use in this project. The CPW source may be less predictable, however, because CPW does not routinely trap nuisance beavers or maintain a facility for holding them. A third option would be to utilize an alternative private source. EcoMetrics is available and willing to take on the role of trapping, holding, and releasing beavers for this project. The cost for trapping and relocating beaver will vary depending on the source. Because of permitting issues and costs associated with private trappers, the CPW source will probably be the most cost effective alternative if they are willing and able to assist. Wildlife 2000 was unable to provide a specific cost estimate, but given their experience and dependability, this is likely the most practical option. EcoMetrics could likely provide the service for a similar cost, but we lack the experience and dependability of Wildlife 2000.

Regardless of the source, every effort should be made to assure that beavers are released to the sites as intact compatible groups (male-female pairs or family units). While there is no complete assurance that any group of beavers released will cohabitate and ultimately form a healthy breeding pair or family, certain measures should be taken to provide the best possible chances for success. Activities such as sexing the animals prior to release, observing them in a holding facility for two to three weeks prior to release to assure good health, and allowing them to self select their mates will help to achieve the best results. If all of these conditions cannot be met then beaver translocation may still proceed, but we should expect a greatly reduced rate of success.

Site preparation needs

Prior to the arrival of the beaver, site preparations will be necessary at the relocation sites selected for this project to create adequate aquatic escape cover and supplemental food.

Aquatic escape cover - The construction of temporary brush dams or other types of BDAs are recommended to create pools that provide aquatic escape cover for beavers by impounding water along these tiny creeks. BDAs should be constructed to produce at least 500 sq. ft of standing water at least 1.0 ft deep. At the selected sites on Pruden Creek, a series of two or three BDAs will be necessary to create an adequate area of standing water. Multiple BDAs also gives the beavers options while allowing them to move about the site with more comfort and safety from predators. The structures should be located to create situations where impounded water exists under overhanging vegetation, and as close as possible to food sources.

Figure 4: Example brush dam beaver dam analogs on Tarryall Creek .

We recommend using brush dams (Figure 4) as the select BDA structure where possible since they are simple and easy to construct using small diameter wood, rock, and sod mats that are available on site. They are also low impact, temporary, and generally passable by most aquatic organisms including fish. Relict beaver dams are present at both of the recommended release sites, and an ideal strategy would be to utilize these existing dams by simply plugging the areas that are breached with constructed brush dams. Brush dams about five feet wide and one to two feet tall will be sufficient at most locations for this purpose.

Physical escape cover - In addition to aquatic cover, we recommend providing physical cover at the release sites in the form of temporary artificial lodges. Artificial lodges may be constructed using native materials such as logs, rocks, and woody debris to provide an enclosure large enough to house several adult beavers and a small opening that is accessible from the water. Additional overhead cover spanning aquatic cover may be provided in the form of overhanging or floating woody debris, logs, etc.

Supplemental feeding – Fresh willow and aspen cuttings should be brought to the site on the day when beavers are released to provide a readily available choice food source, even when native food supplies are abundant. The purpose is to maximize chances that beavers will remain at the relocation site, and the reasoning is that if there is preferred food available close to aquatic escape cover, then the released beavers will be less likely to wander away from the site in the early days after relocation. This makes them less susceptible to predation and more likely to settle at the selected site for the long term. Beyond the initial placement of fresh aspen or willow cuttings, supplemental feeding should not be necessary at the relocation sites since native sources of select woody and herbaceous vegetation are abundant.

Minimizing beaver-human conflict

The major impediment to using beavers as a restoration tool, is the pervasive public perception that beavers are pests. This project is particularly sensitive to the issue. While it is clear that that beaver activity in the natural setting is both valuable and necessary for maintaining streams, wetlands and riparian habitats; in areas where beavers interfere with human infrastructure problems may arise that require difficult and sometimes costly management solutions. Beaver conflicts should be minimal on this project due to the fact that there is little human infrastructure and generally compatible land uses in place. The study area was selected to be remote and relatively isolated on public land with little risk of future beaver-human conflicts. Moreover, this restoration approach also has the potential for addressing the problem of nuisance beaver in other nearby areas. By creating a demand for beaver and a program for trapping and relocating them, the project opens up an opportunity where beavers could be removed from areas where there are conflicts. The Methow Beaver Restoration Program provides an example of how successful this approach can be. In about six years, they captured 181 "nuisance" beavers from 54 locations and released 163 beavers to 35 restoration sites. The effects are positive on both ends[2].

While the potential for conflicts in this watershed are probably about as low as they could be anywhere, some issues could still arise and ought to be planned for. Impacts to roads can be anticipated and treated, if necessary, with simple mechanical solutions such as fencing and beaver deceivers to prevent flooding and blocked culverts. Temporary cattle fencing around

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[2] See (http://www.rco.wa.gov/documents/SalmonConference/presentations/WednesdayAMWoodruffMeyer.pdf).

the release sites during 20-day grazing rotations is also recommended to reduce potential conflict with livestock and lessees. Finally, marking beavers with visible tags could also be considered as a way to identify individuals released as part of the project. This way, if there are beaver nuisance becomes on a neighboring properties, it can be determined whether the individuals came from a release site or not.

Monitoring, evaluation, and research opportunities

Evaluating success - Beaver establishment and wetland restoration

The core goals of this project are to reestablish beavers and to restore wetland. Success may be generally defined by these criteria and a basic monitoring project to evaluate success on these two factors is described here. This represents the minimum amount of monitoring that should be completed with implementation of this project. We assume, however, that successful reestablishment of beavers and restoration of wetlands will bring about certain specific benefits related to wetland functioning. More detailed monitoring opportunities aimed at testing the response of these assumed benefits and quantifying additional measureable outcomes is described later.

Beaver activity monitoring

The objective of beaver monitoring is to determine whether beavers are successfully reestablished and active in the watershed. This can be quantified by documenting the amount of observable beaver activity at each site. At the basic level, the simple presence or absence of beaver activity can be documented. Beaver activity is monitored by having trained biologists walk the reach to observe and record signs. Signs that indicate positive presence of beaver activity include dam building, lodge building, woody vegetation harvest (chewed stumps, felled trees, or caches), slides or tracks, scat, chewed sticks, and the direct observation of beavers. If all of these signs are absent at a site, it is interpreted as a lack of beaver activity. Monitoring should be done along both the restoration and control sites, and also up and down the Pruden and Cross Creek drainages where perennial water is present to document the full range of beaver activity. If relocated beavers do not remain at the sites where they are released but do establish in the watershed, this represents some level of success that can be documented. If beavers die or leave the study area altogether, then reestablishment has failed.

Monitoring beaver activity for this project involves reconnaissance missions by a pair of qualified beaver biologists to cover the entire perennial reaches of Pruden and Cross Creeks three times per year for at least three years. The reconnaissance trips should be spaced through the season, specifically targeting spring, summer, and fall. The type and location of beaver sign should be documented in field notes and mapped. Ideally each observation should also be photographed and identified with a GPS point where possible. The cost for three years of beaver activity monitoring via this schedule is estimated at $9,000 to cover time and travel expenses for biologists, recording data, and analysis.

Wetland monitoring

If the reintroduction of beaver is successful, we expect changes in the wetland extent and condition to be immediately evident and to be sustained as long as beavers are present. The extent of wetland area is also expected to expand up and down the drainages as the range of beavers expand. Monitoring success at wetland restoration is accomplished by tracking the number of wetland functional units (WFUs) in the study area. This involves delineating the wetland boundary (extent) and performing a functional assessment (condition) using FACWet. The ultimate goal of the project is to restore wetland functions in the watershed using beavers, so the number of increased WFUs is the ultimate measure of project success. For the purposes of appraisal, a rough delineation and level two rapid assessment of FACWet variables is sufficient, but any of these variables can be further tested using more robust level three techniques if reported success or failure is questioned. Wetland surveys should be made annually during the growing season.

In the results section of this study, we determined the practical maximum potential values for wetland extent, condition, and number of WFUs for the treatment and control sites (Table 7). These values can serve as targets for evaluating success. That is, while any increase in WFUs caused by reestablished beavers can be considered a success, the degree of success at specific restoration sites can better quantified by the increase in WFU relative to these target values. Maximum success at the select sites is would constitute recovery of the full 1.69 and 0.79 WFUs at the MP-3 and LP-4 restoration sites, respectively. We suspect that reaching this maximum potential will take at least several years.

In addition to monitoring wetland restoration on the select sites, it is also important to document the recovery of wetland throughout the study area in case beavers move or expand their range and start restoring wetland areas outside the selected release sites. In addition to site evaluations of wetland extent and condition, any additional off-site wetland improvements can be documented across the Pruden and Cross Creek drainages during beaver monitoring trips. The estimated cost for three years of wetland monitoring using the methods outlined above is $6,000 including the field assessments, rough delineation, FACWet assessments, and analysis.

Monitoring watershed services and specific measureable outcomes

One impetus for this project and subsequent studies is to begin to understand the role of beavers in basic headwaters watershed functions and the potential for using beaver relocation as a tool for recovering lost ecosystem services. If this project ultimately succeeds in reestablishing beavers and restoring wetlands within this small test watershed, we can expect improved water quality and a more favorable hydrologic regime. Water quality, particularly temperature, could also be improved due to longer retention time and groundwater interaction. Soil saturation and groundwater processes also affect rates of nutrient processing and metal and carbon sequestration in the familiar process of "wetland filtration."

By impounding water in ponds and saturated floodplain wetland areas, beaver systems store water during high flow periods (typically summer thunderstorm events in this country) and release it slowly to downstream reaches. This acts to attenuate floods during peak flows and to maintain higher base flow between storms and in drought. In its present degraded condition, the study watershed is very flashy because the streams are incised gullies that are efficient at water transport but poor at storage. Presumably, the reconnected floodplains and wetland area restored by beaver activity would provide essentially the same hydrologic function as artificial reservoirs, which is to store water during high flow events and release it gradually to maintain base flows.

Improved water storage within the riparian system is also the key to habitat improvement goals. In their present state, most of these streams no longer have perennial flow all the way to the reservoir. Lower reaches of these streams are ephemeral or seasonal because the water from source springs is not sufficient to keep the existing single-thread and gully stream types wet all year long. By storing storm flows in naturally restored beaver ponds and wetlands upstream, we can expect an extended flow season, and perhaps an extension of the range of perennial flows. Dry streams are a potential limiting factor for many important species including amphibians, fish, and waterfowl. Moreover, reestablishing these aquatic and wetland areas could also provide potential new habitat for threatened species such as the greenback cutthroat trout and the Colorado state-endangered boreal toad, which is also under review for federal listing under the Endangered Species Act.

An improved hydrology and a disturbance regime characteristic of beaver activity is critical for recovering and maintaining native vegetation. Riparian vegetation, particularly deciduous woody trees and shrubs, such as willow, cottonwood, birch, and aspen, are important as food and cover for many South Park wildlife species. The health of these communities could be bolstered significantly buy reintroduction of beavers.

Each of these functional categories offers a potential research opportunity for studying the effects of beaver restoration on specific ecosystem service benefits. The Upper South Platte Watershed is replete with opportunities for restoring wetlands that had historically been maintained by beavers (but are now non-functional due to beaver loss). A motivation for additional research on this project is that if we can document the efficacy of beaver restoration in terms of real watershed benefits, these methods will eventually become more widely accepted.

Research Opportunities

The basic monitoring and evaluation plan we previously described is sufficient for describing the effectiveness of this project in meeting its stated general goals of beaver reestablishment and wetlands restoration. Below we offer ideas on studies to further investigate the effects on specific watershed functions and values described above. While there is widespread belief and expectation that beaver complexes improve theses specific functions, demonstration of these improvements with scientific data would be especially useful. This project is specifically designed so that level three quantitative data can be collected on specific hydrologic, water quality, vegetation, and amphibian/wildlife habitat parameters to determine the effectiveness of beaver restoration at improving these key functions. The following discussion describes a three year monitoring program with individual studies aimed at addressing each of these key factors. All, some, or none of these studies could be undertaken as part of this project for three or more years to test specific hypotheses and to quantify measureable results.

Hydrologic response

The expected hydrologic response of beaver activity and wetland restoration in the watershed includes increased water retention, peak flow attenuation, delayed release, increased base flow discharge, and a more uniform hydrograph. The combination of these factors is summarized by the term "hydrologic resilience" which is the ability of the watershed to maintain a characteristic flow regime in the face of environmental stochasticity, disturbance, or change. Each of these factors could be monitored as response variables to quantify specific hydrologic effects of beaver reintroduction.

A working hypothesis is that areas with beaver-restored wetlands have increased water retention. Increased water retention is qualitatively evident by the observation of ponds (surface water storage) and expanded wetlands (ground water storage), but this study offers an opportunity to actually quantify these increased storage volumes by comparing changes to water surface elevation (ponds) and water table depths (groundwater) on treated versus untreated sites. Datalogging water level recorders in ponds and monitoring wells would be set up on both the restoration and control sites to carefully monitor water level changes through time, documenting the response to treatment. By using arrays of these devices at each site, we would be able to map the water table elevation at each location to quantify the volume of water stored over time in units of acre-feet, cubic feet, or gallons.

In addition to quantifying water storage volume, these data could also be used to compare the response in terms of lateral extent of saturation, frequency of saturation, and duration of consecutive saturation. The lateral extent of saturation is simply the amount of physical area that is saturated to a specific soil depth (*e.g.* 1.0 ft) typically measured in acres. Frequency of saturation is a similar measure but with an added time component. It compares the area for which water table meets certain depth requirements for certain amount of time in the season. (*e.g.* area that has water table depth less than 1.0 ft. for at least 20 days per season). This parameter is also referred to as THD (total hydric days). Consecutive hydric days (CHD) is another metric that is commonly used relating hydrology to wetlands which is the number of consecutive days per season that that the water table meets certain depth criteria.

Approximately 12 dataloggers and water level sensors would be required for this study, and commitment to at least three years of study would be necessary to adequately develop trends. Three years of water table monitoring including instrumentation, technical labor for installation, maintenance, and data collection, plus data analysis to evaluate changes to water storage volume would cost approximately $36,000.

A second hydrologic monitoring approach involves discharge measurements to compare changes to the hydrograph following beaver reestablishment including peak flow attenuation and base flow maintenance. The object of these measurements is to develop a hydrograph (discharge over time) at locations upstream and downstream from relocation and control sites. One could then compare restoration and control sites with respect to the amount of difference between the upstream and downstream hydrographs to determine the effects of beavers and restored wetlands. There are two primary hypotheses that would be tested in this experiment:

1. *Peak flow discharge is attenuated by the beaver wetlands.* This hypothesis is tested by comparing the difference in discharge between up- and downstream stations at peak flow periods. If that difference is greater (more negative) for the restoration site than it is for the control site, then that is evidence in favor of the hypothesis. That is, the magnitude of peak flows in the hydrograph downstream from treatment sites would be depressed, or lessened if the effect is positive. One could also evaluate the length of the peak discharge period with respect to this hypothesis. If the treatment is having an attenuating effect on peak flows, the duration of peaks may be longer. This would be evidence that the sites are absorbing water during peak flows.
2. *Beaver wetlands maintain greater base flow.* This hypothesis is tested by comparing the difference in discharge between up- and downstream stations during periods of base flow. If that difference is greater (more positive) for the restoration site than it is for the control site, then that is evidence in favor of the hypothesis. If the hypothesis is true, we would see greater discharge during base flow periods and/or longer periods with more flow. This is would be evidence that the sites are slowly releasing stored water to maintain base flows.

This study would require the installation of four stream discharge gauge stations, one each upstream and downstream of the restoration and control sites. Developing discharge rating curves on a natural stream channel can be a relatively expensive proposition, and for this reason we recommend the installation of Parshall flumes or V-notch weirs that have known rating curves. Because these creeks are so small, the flumes or weirs would be small enough to install by hand at locations where the creeks are already confined, and the installations could be temporary. An estimated cost for three years of hydrograph monitoring for the project is about $40,000 including the installation of flumes and gauges, instrumentation, maintenance, data collection and analysis to quantify the appropriate metrics.

Water quality response

Water temperature is one water quality parameter that would be especially interesting to study. There are conflicting thoughts about the effect of beavers on water temperature. A popular notion is that beaver dams increase water temperature by increasing the surface area of water exposed to sunlight. On the other hand, improved groundwater exchange and hyporheic flow could act to decrease water temperatures during critical times in summer, and several recent studies actually have documented decreased summer water temperatures on reaches immediately downstream from beaver complexes. A water temperature monitoring study would test the hypothesis that restored beaver wetlands have an effect on water temperature. To accomplish this, datalogging water temperature sensors would be placed in the stream upstream and downstream from the control and restoration sites. If the hypothesis is true, we would expect to see more difference in temperature between sensors upstream and downstream of the restoration site compared to the control site. The cost of three years of temperature monitoring including four temperature loggers, installation, maintenance, data collection, and analysis is estimated at $4000. Other water quality parameters of interest could also be monitored.

Vegetation response

Restoring the hydrology to the currently dry historic floodplain should have a dramatic effect on the riparian vegetation community. We hypothesize that the vegetation will shift from drought tolerant upland species to hydric species as the wetland becomes reestablished and expanded on treated sites. These changes can be documented to test the hypothesis by quantifying plant species composition across established cross-valley transects and test plots to calculate specific metrics determined by the relative abundance of different vegetation classes (obligate wetland, facultative, obligate upland, *etc.*). The study design includes two transects and four plots at each restoration and control site that would be surveyed annually during the growing season. Three years of vegetation monitoring including establishing transects and plots, annual surveys, and data analysis to calculate parameters has an estimated cost of $7,000.

Amphibians and other fish and wildlife response

One of the many important functions that beavers provide is a dynamic and complex wetland habitat that is critical for many native species. Additionally, the specific aquatic habitat types created by beaver dams on headwaters systems can support amphibian species that cannot survive elsewhere on this landscape. We predict an increase in habitat suitability for amphibians and a positive response in local amphibian populations following treatment at restoration sites. A study of this type would have to be specifically designed by a qualified biologist, but it would not necessarily need to be especially detailed or costly. Basically, the study would need to identify critical limiting habitat factors for amphibian species of interest and track these parameters spatially on both the restoration and control sites. These data could then be used to test the first hypothesis (increase in habitat). Actual amphibian sampling and population estimates would be necessary to test the second (positive population response). The study also offers the potential to track any other specific parameters of fish or wildlife habitat that are expected to change with the introduction of beavers and restoration of wetland area.

Conclusion

Beaver reintroduction to the drainages on the north side of Thirtynine Mile Mountain is feasible and likely to be an effective means of restoring lost wetland function within this watershed. A basic restoration plan defines general considerations for transplanting beavers, possible sources for beaver transplants, site preparation, and the importance for avoiding human-beaver conflicts. Success of the project can be easily evaluated by tracking beaver activity in the host drainages and quantifying wetland restoration in terms of wetland functional units. The study would be an excellent natural laboratory, presenting a unique opportunity for a controlled BACI study to quantify specific hydrologic, water quality, vegetation, amphibian and other wildlife habitat responses to the reestablishment of beavers.