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The Economic Value of Beaver Ecosystem Services

Escalante River Basin, Utah

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Table of Contents

EXECUTIVE SUMMARY

Figure ES1. Beavers' Potential Impacts on Streams and Related Ecosystems

	Upstream Impacts	Downstream Impacts
Water Quantity	↑Precipitation Storage ↑Water Depth	↓Velocity ↓Flooding Severity ↑Consistency of Flow ↑Groundwater Recharge ↑Late Season Flow
Water Quality	↑Methane Production ↑Carbon Production ↑Aerobic Respiration ↓Oxygen Concentration ↑Other Nutrients ↑Sediment Retention	↓Sediment Retention ↓Temperature
Ecosystems	↑Wetland Area ↑Riparian Area ↑Open Canopy Area	↑Riparian Area ↑Open Canopy Area
Habitat	↑Big Game Habitat ↑Fish Habitat ↑Insect Habitat ↑Bird Habitat ↑Small Mammal Habitat ↑Amphibian Habitat	↑Big Game Habitat ↑Fish Habitat ↑Insect Habitat ↑Bird Habitat

Source: ECONorthwest with data from: Gurnell, A. 1998. "The Hydrogeomorphological effects of Beaver Dam-Building Activity." *Progress in Physical Geography*. 22(12):167-189; Naiman, R., J. Melillo, and J. Hobbie. 2986. "Ecosystem Alteration of Boreal Forest Streams by Beaver." *Ecology*. 67(5):1254-1269; Naiman, R., C. Johnston, and J. Kelley. 1988. "Alteration of North American Streams by Beaver." *Bioscience*. 38(11):753-762; Rosell, F., O. Bozser, P. Collen, and H. Parker. 2005. "Ecological Impact of Beavers *Castor fiber and Castor canadensis* and their Ability to Modify Ecosystems." *Mammal Review*. 35(3):248-276.

The Escalante River Basin in southern Utah historically supported beaver (*Castor canadensis*), which are now relatively rare in the region. Restoring healthy populations of dam-building beaver can potentially impact ecological structures and processes in the basin of high and growing economic importance (Figure ES1). In particular, beaver activity can potentially substantially increase the area of aquatic and wetland habitat, increase base streamflow, and recharge aquifers. Improved baseflows and habitat structure would contribute to improving the temperature conditions the Utah Department of Water Quality identifies as constraining fish populations in the basin. Limited surface water supplies and storage options lead to high economic values for improved accessible streamflow. Streamflow and habitat improvements would likely benefit the primary regional industries of agriculture and ranching, recreation, and tourism. Increased water storage and habitat would also provide valuable buffers against expected increases in temperature and decreases in snowpack storage for the basin as a result of climate change.

The ecosystem services that could be provided by increased dam-building beaver populations in the Escalante Basin would provide benefits in the form of avoided costs for water storage, habitat restoration, and water quality treatment (Table ES1). The services would also supply a number of other identified and demonstrated direct and indirect benefits in the basin. Based on beaver population densities observed elsewhere in Utah under similar conditions, beaver could provide benefits to local residents and visitors well into the millions of dollars per year.

Table ES1. Ecosystem Services Potentially Provided by Beaver in the Escalante Basin, and Per-Unit Values

Ecosystem Service Provided	Per-unit value for service
Sediment Retention	$2 per cubic yard
Delayed Water Flow upstream of Reservoirs	$520 per acre–foot
Riparian Habitat	$1,000 per acre per year
Wetland Habitat	$8,000 per acre per year
Aquatic Habitat	$4,000 per acre per year
Pollutant Removal through Sediment Capture	$100,000 per year per percent improvement
Water Temperature	$74,000–$411,000 per river mile
Recreation	$75–$375 per recreation day
Aesthetic Benefits	Qualitative Description
Existence Value	Qualitative Description
Sensitive Species Habitat	$9–$256 per household per year
Flood Resilience	Qualitative Description

Source: ECONorthwest with data from a number of sources (see report)

I. BACKGROUND AND CONTEXT

Beaver (*Castor canadensis*) likely historically numbered in the hundreds of millions and ranged across most landscapes in North America. Demand for beaver pelts drove much of the early exploration into the West following depletion of eastern beaver populations.[1] Consequently, by the time communities developed and general memory and record of landscape conditions began to develop for the West, beaver populations were often well below the levels at which the ecosystems developed. The Escalante River Basin, part of the Colorado River watershed, is an area with historically abundant beaver depleted by trapping.

Beavers and their dams impact the structure and function of ecosystems in ways that can contribute valuable ecosystem goods and services for human communities. Restoring their populations holds the potential to significantly improve a range of natural systems that are particularly scarce and valuable in the West. Managing the Escalante Basin for beaver restoration holds the potential to improve several ecosystem functions that residents, businesses, and visitors rely upon, particularly in terms of water availability, water quality, instream flows, and habitat. In this analysis, we consider the potential impacts of restored beaver populations in the Escalante Basin and the values that beaver restoration would provide to local communities and beyond.

We begin by providing the economic framework for considering the value of ecosystem services provided by beavers. We then describe the biophysical structures and processes in the Escalante Basin that potentially would be affected by beaver restoration. Next, we characterize the local community, economy, and visitors that rely upon the Escalante landscape. We then review the literature on the effects of beavers and their dams on a landscape, and apply the observed impacts from elsewhere to the Escalante context. We provide quantitative estimates of these structural and process changes. Finally, we utilize cost, benefit, and expenditure data local to the Escalante region, as well as peer-reviewed literature to estimate the economic value of these benefits.

A. Background on Ecosystem Services and their Economic Value

Ecosystem services are the benefits to humans derived from functional ecosystems. In this section we first describe the conceptual framework for ecosystem services, then we describe the techniques used to value them.

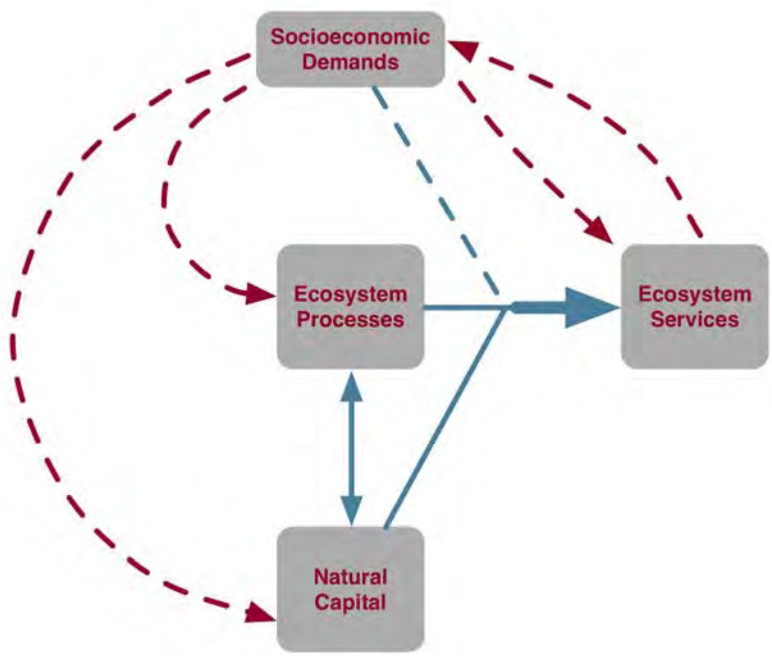
Several efforts have attempted to organize and categorize ecosystem services. A broad, international collaboration called the Millennium Ecosystem Assessment split ecosystem services into four broad categories: provisioning services (such as

[1] Naiman, R., C. Johnston, and J. Kelley. 1988. "Alteration of North American Streams by Beaver." *Bioscience*. 38(11):753-762

the supply of food and water), regulating services (such as the supply of flood protection and pollination), cultural services (such as the supply of spiritual and aesthetic value), and supporting services (such as the supply of soil formation and biogeochemical processes).[2] In general, we consider ecosystem services to be the natural processes and products that provide benefits to society.

Figure 1 demonstrates the conceptual framework within which we consider ecosystem services. We include ecosystem services that are directly and indirectly associated with human well-being. Furthermore, while we understand that the full range of ecosystem services is very broad, this analysis focuses on those that are both relevant and valuable to the specific geographic area. Next, we describe the components in the conceptual frameworks and how they interact.

Figure 1. Conceptual Framework for Understanding Ecosystem Services



Source: ECONorthwest. Solid lines represent direct effects, while dotted lines represent indirect effects.

Natural Capital

The supply of goods and services—of all kinds—available to households, businesses, and communities in a given place and time depends on the supply of capital, which is the term economists use to describe the inputs used to produce the goods and services. Economists often separate capital into five categories:

[2] Millennium Ecosystem Assessment. 2003. *Ecosystems and Human Well-being.*

- **Financial Capital** (e.g., the money we keep in banks and the value of stocks we trade in the market)
- **Built Capital** (e.g., our houses, offices, cars, and other tangible manufactured goods)
- **Natural Capital** (e.g., trees, water, soil, gases, and other things we typically consider to be part of nature)
- **Human Capital** (e.g., the knowledge and skills embodied within people)
- **Social Capital** (e.g., the access to goods and services we obtain through social relationships)

In most cases, different forms of capital are used together to produce a good or service. For example, a skilled craftsperson may manipulate lumber with a set of machinery to produce a table or chair that has greater value to an individual than any of the capital inputs independently. Our understanding of ecosystem services begins with natural capital. This term describes the inventory of nature's basic building blocks, such as vegetation, water, wildlife, soils, and gases. Some types of natural capital have value as stand-alone goods, such as a tree, a gallon of water, or a deer. Most natural capital, though, has value only through its many symbiotic relationships with other units of natural capital that, through the complex workings of an ecosystem provide goods and services of value to society.

Ecosystem Processes

While some forms of natural capital have value as stand-alone goods, their value increases when linked together through ecosystem processes. Ecosystem processes "are the characteristic physical, chemical, and biological activities that influence the flows, storage, and transformation of materials and energy within and through ecosystems."[3] Nutrient cycles, biogeochemical cycles, water cycles, life cycles, etc. all contribute to the maintenance and accumulation of natural capital and help shape what we view as nature. The relationships between natural capital and ecosystem processes allow for the accumulation and appreciation in value of natural capital over time. Natural capital and ecosystem processes are difficult to consider in isolation. Both are necessary to produce and maintain a viable ecosystem.

Ecosystem Services

An ecosystem service exists if humans derive a benefit, from some combination of natural capital and ecosystem process. Ecosystem services only exist insofar as there is human demand for their supply. The set of ecosystem services in an area can expand or contract depending on human preferences over time and across geographic areas. Furthermore, while natural capital, ecosystem processes, and ecosystem services are categorized separately, socioeconomic demand has the potential to impact the supply of and demand for each. Human demand is what

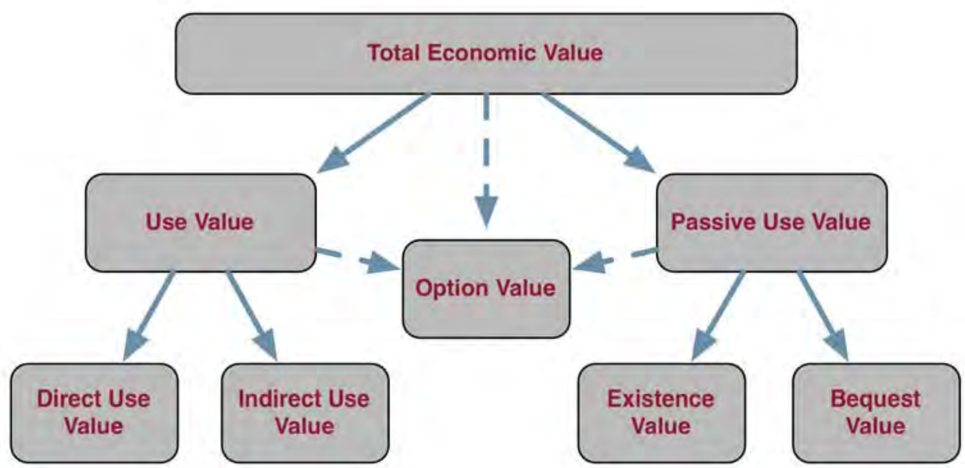
[3] USEPA. 2009. *Valuing the Protection of Ecological Systems and Services*. p. 12

transforms the supply of natural capital and ecosystem processes into ecosystem services.

Types of Value

As previously noted, ecosystem services exist only insofar as there is human demand for their supply. Furthermore, the value of ecosystem services is derived from a number of ways in which humans demand their supply. Figure 2 demonstrates the various types of economic value for ecosystem services. Total economic value is made up of several components. Use value is perhaps the clearest type of value. **Direct use value** describes the value associated with direct use of an ecosystem service such as breathing clean air or drinking clean water. **Indirect use value** describes the ecosystem services that precede that direct service such as the soil fertilization, which allowed for the growth of the vegetation that helped purify the air.

Figure 2. Components of Total Economic Value



Source: ECONorthwest

Passive use values are less obvious but can be greater than use values. Existence value describes an individual's demand for the existence of a particular object. Bequest value describes an individual's demand for the future existence of a particular object. Typically, these values are described in terms of an individual's willingness to pay for an object's current or future existence. For example, if an individual is willing to pay a positive sum of money to prevent bald eagle extinction, then she likely is placing existence value on the species. Similarly, if she would be willing to donate a positive sum of money to a conservation fund aimed at maintaining bald eagle health into the future, she likely is placing bequest value on the species.

Option values can be either use or passive use, and describe the value of keeping the option open to utilize a resource or service in the future. For example, farmers in the Escalante Basin might currently have all the water they need, but there would still be value to increased water storage capacity in case they require more water in the future, or lose existing water sources.

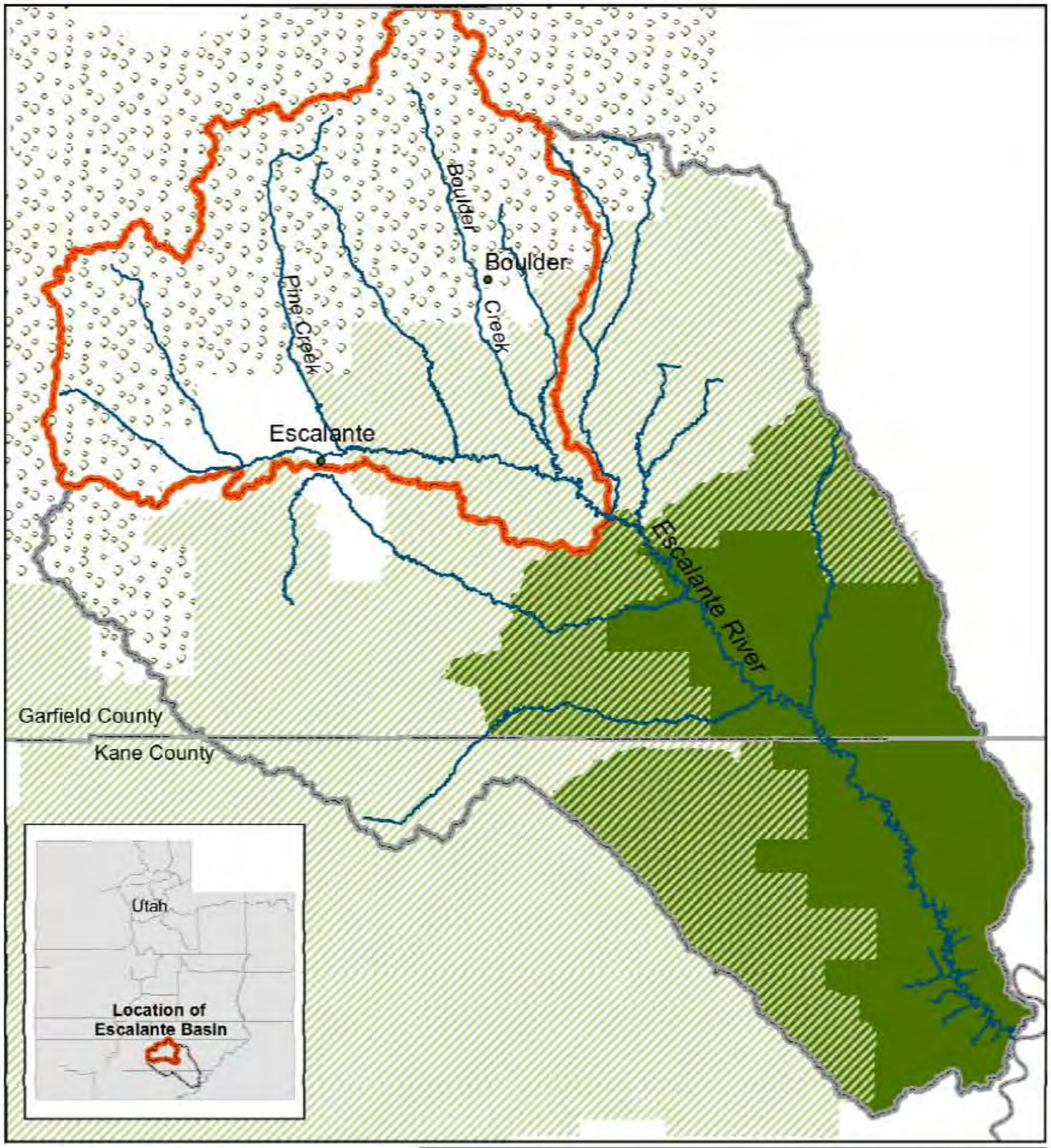
B. The Escalante Basin: Biophysical Characteristics

The Escalante Basin covers about 2,000 square miles and is located in Southern Utah. The northern portion of the basin lies within Garfield County and the southern portion lies within Kane County. For our analysis, we distinguish between the northern part of the basin and the southern part. In the north, perennial tributaries carry snowmelt and precipitation from the Aquarius Plateau, Boulder Mountain, and the Escalante Mountains. These waterways run through forested landscapes as they travel south. In the south, rivers, creeks, and streams continue through the increasingly dry, desert landscapes found on the Kaiparowits Plateau and Fiftymile Mountain. Figure 1 shows a map of the Escalante Basin. It includes the basin's boundary, political boundaries, major rivers and streams, and other areas of interest such as the Grand Staircase-Escalante National Monument and Dixie National Forest.

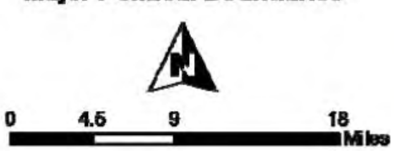
1. Maps and ecosystem type distribution and quantities

The primary ecosystems in the study area are forest, desert, wetland, riparian, and riverine. Figure 3 shows a map that distinguishes each of these areas. The northern part of the basin contains forests, wetlands, riparian and riverine ecosystems. The southern part of the basin is primarily desert but also contains riverine and riparian areas.

Figure 3. Political Map of the Escalante Study Area



Escalante Basin
Major Political Boundaries

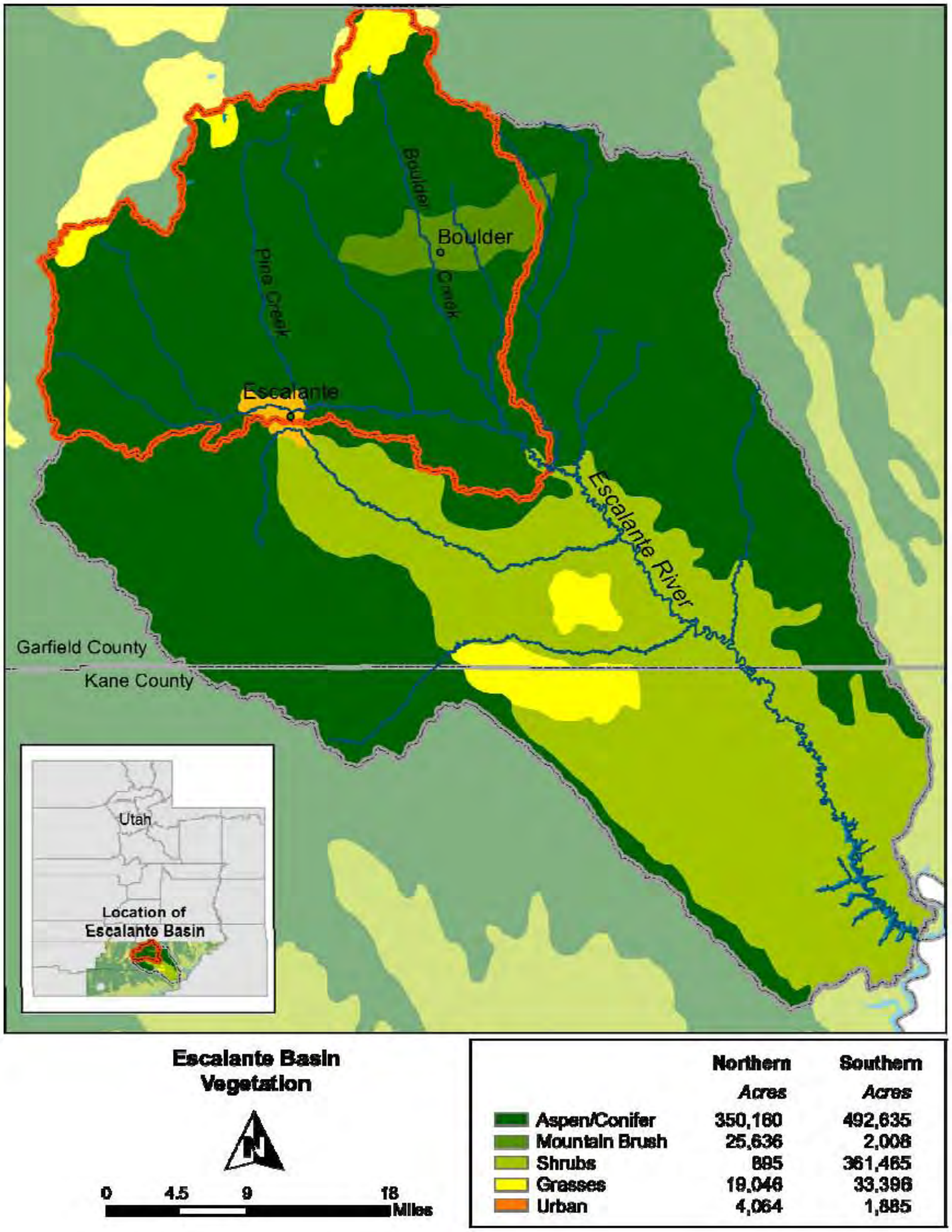


	Northern *Acres*	Southern *Acres*
Dixie National Forest	264,178 Acres	57,968 Acres
Glen Canyon National Recreation Area	99,955 Acres	566,198 Acres
Grand Staircase - Escalante National Monument	-	248,577 Acres

Source: ECONorthwest

Note: Orange boundary indicates northern portion and gray indicates southern portion for our analyses

Figure 4. Vegetation Map of the Escalante Study Area



Source: ECONorthwest

Note: Orange boundary indicates northern portion and gray indicates southern portion for our analyses

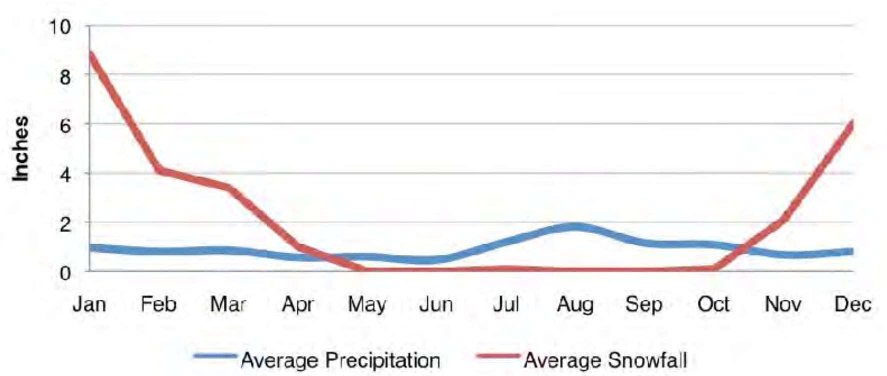
2. Precipitation, snowpack, surface water, and groundwater

Restoration of beavers and their dams to the Escalante Basin would potentially increase water storage capacity, stream baseflows, and groundwater recharge. In this section, we describe the current state of water resources in the basin. We identify local water scarcity to identify areas and levels of demand for water resources, potentially addressed by beaver activity.

Precipitation, Snowfall, and Snowpack

Precipitation and snowfall are variable across the basin. The northern portion of the basin receives the most precipitation (12-16 inches per year) and the southern portion of the basin receives the least precipitation (6-8 inches per year).[4] Figure 5 shows the monthly average precipitation and snowfall in Escalante. The town of Escalante receives about 11 inches of precipitation with 26 inches of snowfall per year. Precipitation peaks in August with just less than 2 inches of rainfall on average. Snowfall peaks in January when it snows about 9 inches on average.

Figure 5. Average Monthly Precipitation and Snowfall in Escalante, UT (1901-2005)



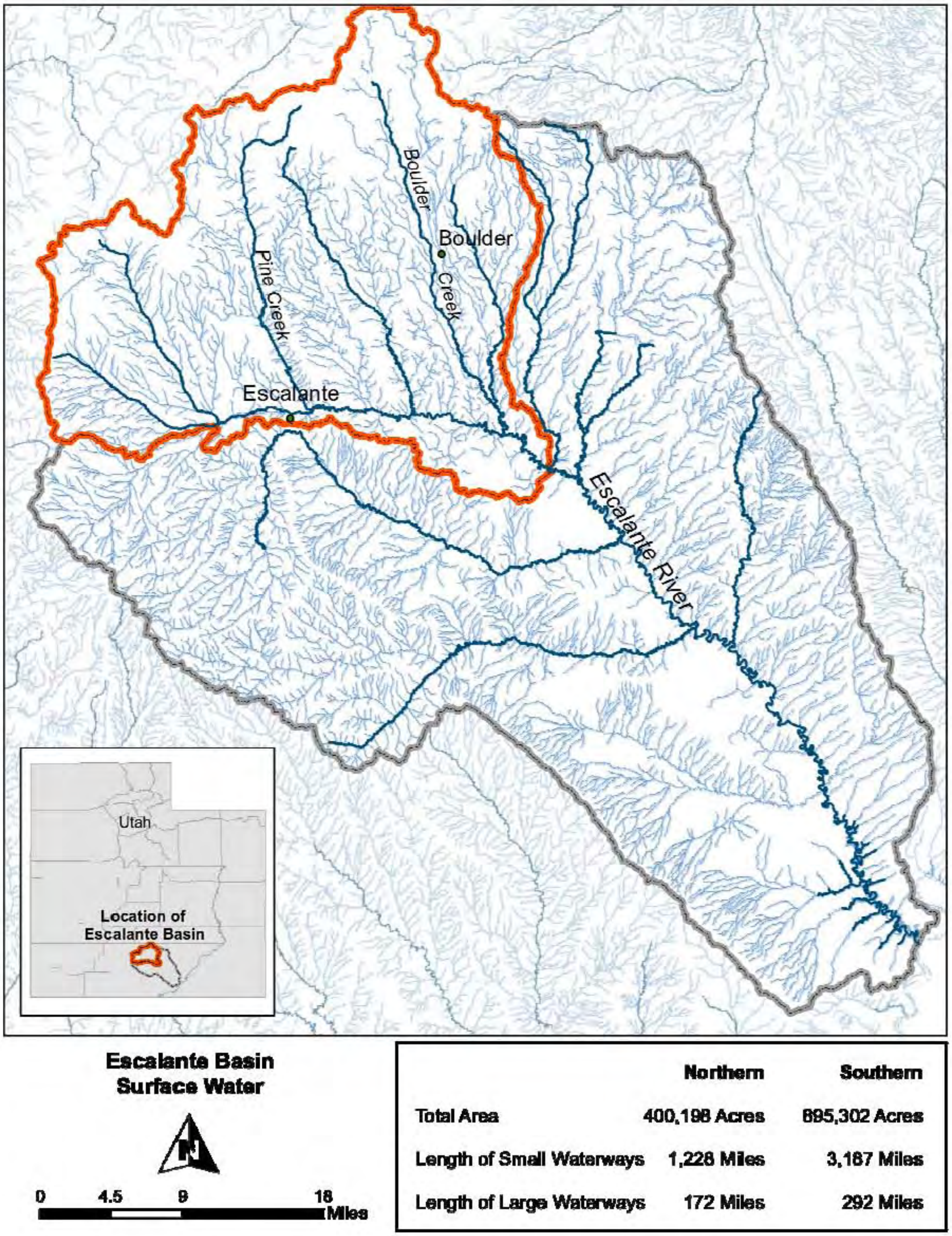
Source: ECONorthwest with data from Western Regional Climate Center. 2010. *Escalante, Utah (422592)*. Retrieved on October 28, 2010 from http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?utesca.

Surface Water

Surface water in the study area consists of water held in reservoirs primarily for agricultural and recreational use and water flowing through rivers, streams, and creeks. Figure 6 shows a map of the rivers, streams, and creeks running through the basin. In general, the waterways in the northern portion of the basin carry more water than those in the south. Furthermore, large waterways (such as the Escalante River, Pine Creek and Boulder Creek) carry more water than the smaller streams and creeks that feed into them. In total, large rivers, streams, and creeks run through 464 miles of the project area. Smaller waterways run for

[4] Millennium Science & Engineering, Inc. No Date. *Escalante River Watershed: Water Quality Management Plan*. Utah Department of Environmental Quality, Division of Water Quality.

Figure 6. Surface Water Map of the Escalante Study Area



	Northern	Southern
Total Area	400,198 Acres	895,302 Acres
Length of Small Waterways	1,228 Miles	3,187 Miles
Length of Large Waterways	172 Miles	292 Miles

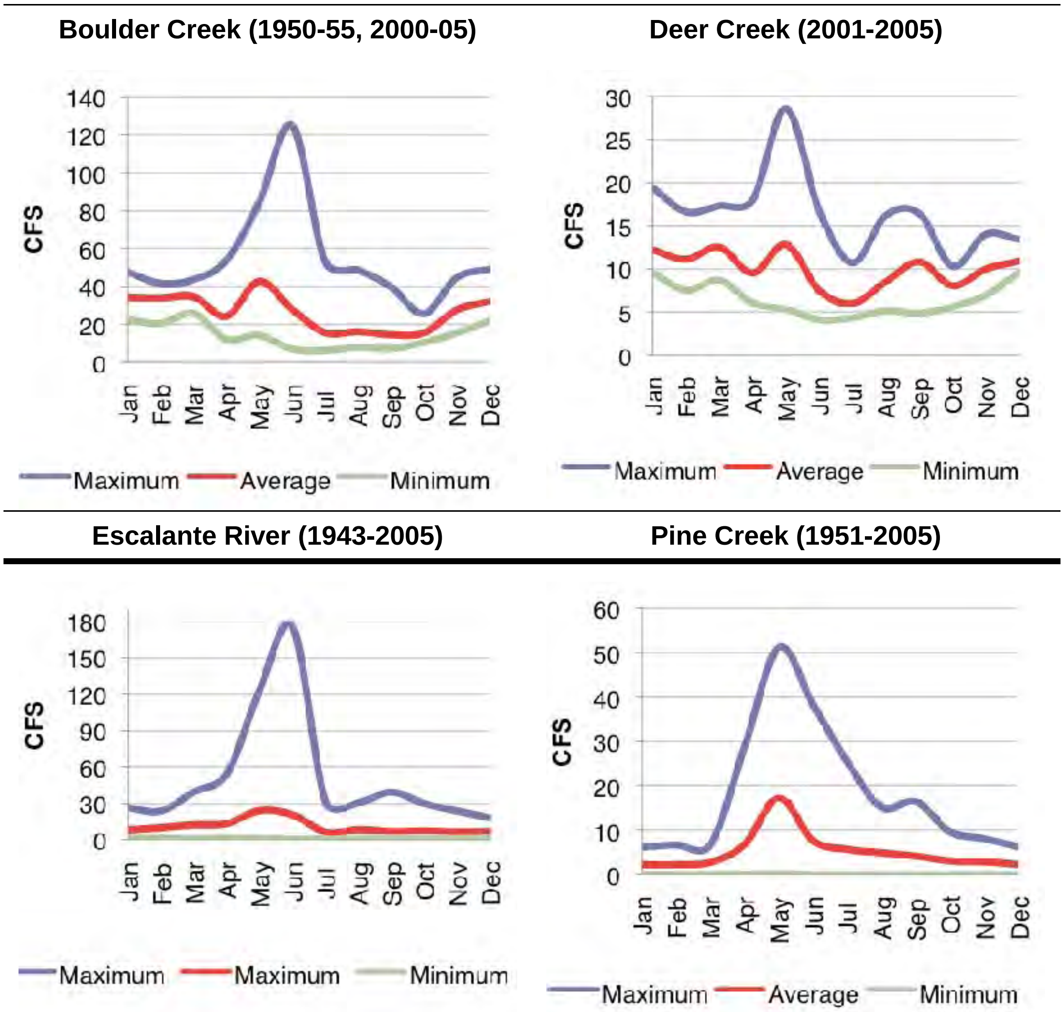
Source: ECONorthwest

Note: Orange boundary indicates northern portion and gray indicates southern portion for our analyses

about 4,400 miles. Some of these rivers become dry during periods of low water flow, while others carry water throughout the year. We distinguish between waterways in the northern portion of the basin and those in the southern portion because those in the south tend to run dry part of the year, while those in the north are more likely to carry water throughout the year.

Stream gauges at Boulder Creek and Deer Creek near the town of Boulder, and at the Escalante River and Pine Creek near the town of Escalante provide stream flow data as far back as 1943. Figure 7 shows minimum, maximum, and average monthly stream flows for each of these waterways over various time periods. The flow in each waterway peaks around May, and then declines with some limited increases during the monsoon season of late summer until winter storms return. Diversions upstream of gauging stations for irrigation and other uses are not included, and would increase these values for certain timeframes.

Figure 7. Minimum, Maximum, and Average Monthly Flows for Large Rivers and Creeks in the Escalante Basin



Source: ECONorthwest with data from U.S. Geological Survey. 2005. *Water Data Report UT-2005*. Retrieved on October 28, 2010 from http://pubs.usgs.gov/wdr/2005/wdr-ut-05/.

We use data from stream gauges along with low flow estimates for several tributaries from the U.S. Geological Survey to estimate minimum, maximum, and average stream flow and volume for the Escalante River.[5] Table 2 and

[5] To calculate the monthly stream flow of the Escalante River at the southern most point of the basin, we summed the stream flows of the major waterways feeding into the Escalante. For some waterways, data were recorded at gauging stations (Escalante River near Escalante, Pine Creek, Deer Creek, and Boulder Creek). Several other large tributaries do not have gauging stations. In 2005, the U.S. Geological Survey released its *Seepage Investigation and Selected Hydrologic Data for the Escalante River Drainage Basin* report where it estimated lower-bound stream flows during the month of October for several large waterways flowing into the Escalante. In one instance, the Escalante River near Escalante, data existed from both sources. We found the relationship between the estimated data and the recorded data and applied that coefficient to the estimated data from the remainder of the waterways. We then summed the adjusted estimates to find the monthly values presented in Table 1 and Figures 6-7.

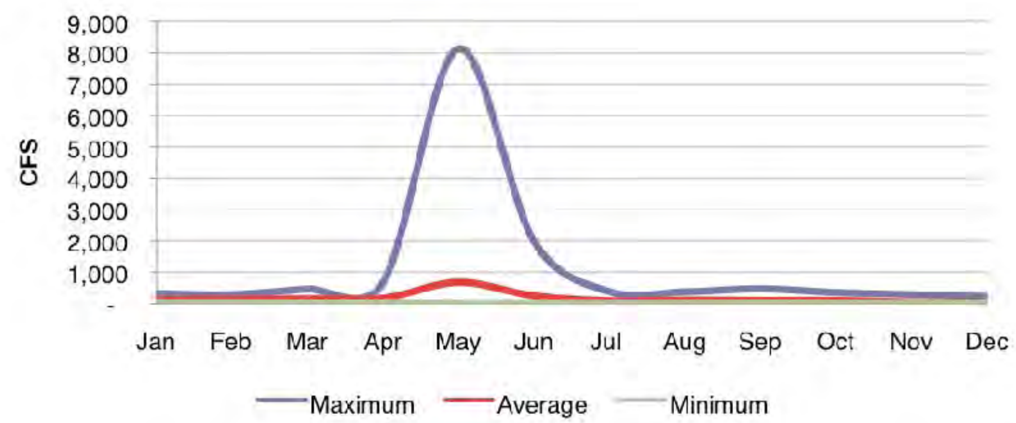
Figures 8 and 9 present the flow and volume data. The annual volume of water running through the basin ranges from about 9,000 acre-feet, during drought years, to more than 800,000 acre-feet during wet years, with an average of about 116,000 acre-feet per year. Stream flow and volume peak in May after which they taper off until the following winter.

Table 2. Estimated Monthly Stream Flow and Volume for the Escalante River

	Stream Flow (CFS)			Volume (acre-feet)		
	Max	**Average**	**Min**	**Max**	**Average**	**Min**
January	318	107	20	19,568	6,572	1,246
February	287	126	21	15,946	7,020	1,148
March	464	153	16	28,540	9,391	993
April	654	166	20	38,938	9,860	1,175
May	8,135	676	10	500,189	41,558	638
June	1,995	243	9	118,706	14,488	553
July	381	84	7	23,418	5,135	458
August	373	108	9	22,924	6,647	525
September	470	92	13	27,947	5,481	770
October	351	93	10	21,607	5,722	624
November	286	36	8	17,013	2,161	469
December	220	38	10	13,545	2,310	644
	Average			**Total**		
Annual	**1,161**	**160**	**13**	**848,342**	**116,346**	**9,241**

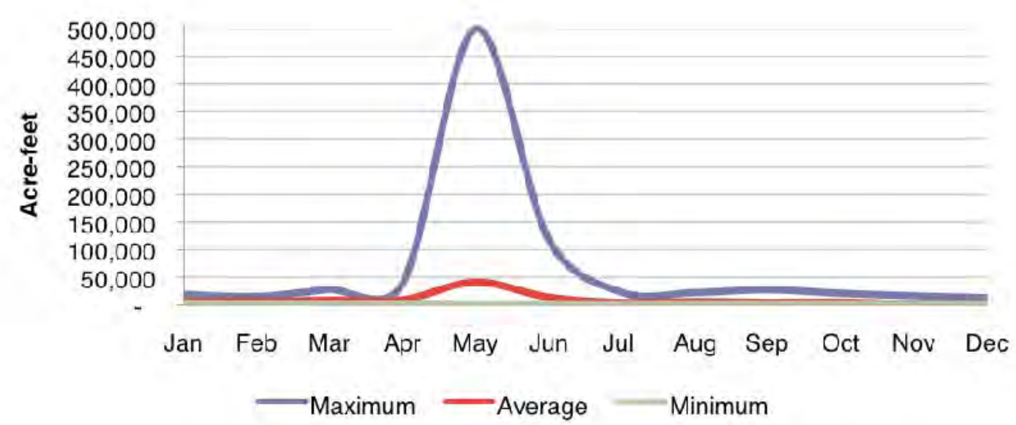
Source: ECONorthwest with data from Wilberg, D. and B. Stolp. 2005. *Seepage Investigation and Selected Hydrologic Data for the Escalante River Drainage Basin, Garfield and Kane Counties, Utah, 1909-2002*. U.S. Geological Survey. Scientific Investigations Report 2004-5233; and Millennium Science & Engineering, Inc. *Undated. Escalante River Watershed: Water Quality Management Plan*. Utah Department of Environmental Quality, Division of Water Quality.

Figure 8. Minimum, Maximum, and Average Monthly Stream Flow in the Escalante River Basin



Source: ECONorthwest with data from Wilberg, D. and B. Stolp. 2005. *Seepage Investigation and Selected Hydrologic Data for the Escalante River Drainage Basin, Garfield and Kane Counties, Utah, 1909-2002*. U.S. Geological Survey. Scientific Investigations Report 2004-5233; and Millennium Science & Engineering, Inc. *No Date*. *Escalante River Watershed: Water Quality Management Plan*. Utah Department of Environmental Quality, Division of Water Quality.

Figure 9. Minimum, Maximum, and Average Monthly Water Volume Flowing through the Escalante River Basin



Source: ECONorthwest with data from Wilberg, D. and B. Stolp. 2005. Seepage Investigation and Selected Hydrologic Data for the Escalante River Drainage Basin, Garfield and Kane Counties, Utah, 1909-2002. U.S. Geological Survey. Scientific Investigations Report 2004-5233; and Millennium Science & Engineering, Inc. No Date. Escalante River Watershed: Water Quality Management Plan. Utah Department of Environmental Quality, Division of Water Quality.

Surface Storage

A number of reservoirs exist in the Escalante River watershed to capture, store and divert surface flows. The Utah Division of Water Resources reports six reservoirs in the drainage, totaling 6300 acre-feet of storage.[6] Water rights exist for other private surface diversions as well.[7] The largest, Wide Hollow Reservoir, is about 2 miles northwest of the town of Escalante and was built in 1954. The reservoir collects water from the Escalante River and its designated uses are water recreation and irrigation.[8] The reservoir has a surface area of about 145 acres and a capacity of about 1,400 acre-feet.[9] The reservoir's original capacity was about 2,400 acre-feet, but has since diminished due to sedimentation. The reservoir is typically emptied by the end of August and begins to fill again in October. The maximum capacity of the reservoir cannot be changed without renegotiating water rights with water right holders downstream. Regulation, however allows for the reservoir to remain full throughout the year. If beaver activity increases streamflow at low flow periods of the year, the total water available from the reservoirs on net annually would increase. Effectively, beaver dams would serve as additional storage capacity upstream.

Groundwater

The USGS maintains one groundwater monitoring well in the Escalante Basin, and levels have been declining over time at this well. The groundwater level was about 53 feet below land surface in 1986 and 74 feet below land surface in 2004.[10] If beaver activity increases infiltration and annual recharge of local aquifers, the total available groundwater would increase. The City of Escalante relies upon groundwater for all domestic and business needs, and groundwater limitations have necessitated constraints on any new connections and withdrawals.

3. Wildlife and Sensitive Species

Restoring beavers and their dams in the basin has the potential to improve the quality and quantity of scarce habitat for rare and other economically-important species. In this section, we consider the potential species that would benefit from improved habitat. Rare species are of particular interest, and economic research

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[6] Utah Division of Water Resources. 2000. Utah State Water Plan: West Colorado River Basin. http://www.water.utah.gov/planning/swp/westcol/.

[7] Utah Division of Water Rights. 2008. Escalante River – Area 97. http://www.waterrights.utah.gov/wrinfo/policy/wrareas/area97.html

[8] Utah Division of Water Quality. Wide Hollow Reservoir. Retrieved on October 28, 2010 from www.waterquality.utah.gov/watersheds/lakes/WIDEHOLL.pdf.

[9] U.S. Army Corps of Engineers, Sacramento District. 2010. Final Environmental Assessment: Wide Hollow Water Supply Storage Facility Project. January.

[10] U.S. Geological Survey. 2005. Water-Data Report UT-2005. Retrieved on October 28, 2010 from http://pubs.usgs.gov/wdr/2005/wdr-ut-05/.

demonstrates the high value society places on their protection, as described later in this report.

The study area provides a wide range of habitat types accommodating many unique species of wildlife. In the north, Dixie National Forest supports wildlife seeking forested habitats as well as rocky cliffs and plateaus such as cougar, bobcat, blue grouse, golden eagle, cottontail rabbit, wild turkey, antelope, and Utah prairie dog. The rivers and reservoirs in this area contain many species of gamefish, including brook, rainbow, cutthroat, and brown trout.[11] In the south, the Grand Staircase-Escalante National Monument provides drier habitats. One study found that about 100 mammalian species reside in the Monument, including several species of bat; carnivores, such as coyotes, fox, bobcats, badgers, and bears; deer and antelope; and rodents, such as squirrels, chipmunks, and gophers, and rabbits.[12]

Table 3. Federally Listed Threatened, Endangered, and Candidate Species in Garfield and Kane Counties.

Garfield County		Kane County	
Common Name	**Status**	**Common Name**	**Status**
Yellow-billed Cuckoo	Candidate	Yellow-billed Cuckoo	Candidate
Greater Sage-grouse	Candidate	Greater Sage-grouse	Candidate
Ute Ladies'-tresses	Threatened	Coral Pink Sand Dunes Tiger Beetle	Candidate
Utah Prairie-dog	Threatened	Welsh's Milkweed	Threatened
Mexican Spotted Owl	Threatened	Utah Prairie-dog	Threatened
Maguire Daisy	Threatened	Siler Pincushion Cactus	Threatened
Jones Cycladenia	Threatened	Mexican Spotted Owl	Threatened
Humpback Chub	Endangered	Jones Cycladenia	Threatened
Colorado Pikeminnow	Endangered	Southwestern Willow Flycatcher	Endangered
Bonytail	Endangered	Kodachrome Bladderpod	Endangered
Autumn Buttercup	Endangered	Kanab Ambersnail	Endangered

[11] State Parks. 2010. Dixie National Forest. Retrieved on October 22, 2010 from http://www.stateparks.com/dixie.html.

[12] Flinders, J., D. Rogers, J. Webber-Alston, and H. Barber. 2002. "Mammals of the Grand Staircase-Escalante National Monument: A Literature and Museum Survey." *Monographs of the Western North American Naturalist*. 1:1-64.

	Humpback Chub	Endangered
	Bonytail	Endangered
	Southwestern Willow Flycatcher	Endangered

Source: Utah Division of Wildlife Resources. 2010. *County Lists of Utah's Federally Listed Threatened, Endangered, and Candidate Species*. June.

Some species in the study area receive more attention than others because of low population numbers that threaten their future existence. In Garfield County, 12 species have been listed as endangered or threatened or are candidates for potential future listing. In Kane County, 13 species have been listed as endangered or threatened or are candidates for potential future listing. Table 3 lists species and their corresponding status for each county. In addition to the wildlife listed in Table 2, several other species are closely monitored in the Grand Staircase-Escalante National Monument including: desert shrew, Townsend's big-eared bat, western red bat, big free-tailed bat, northern river otter, ringtail and razorback sucker.[13]

C. Escalante Basin Socioeconomic Description

Restoration of beavers and their dams to the Escalante Basin would generate economic benefits for the basin's residents in several ways: by increasing water supplies, improving habitat for many species of fish and wildlife, and strengthening the agriculture and tourism sectors of the local economy. In this section, we provide a profile of the local population, describe the economy, and discuss the potential for restoration of beavers to produce local economic benefits.

1. Local Demographics

Table 4. Demographic Data for Escalante Sub-basin (2000)

	Garfield County	Kane County	City of Boulder	City of Escalante
Total population	4,735	6,046	180	818
Number of households	1,576	2,237	65	304
Median income (1999$)	$35,180	$34,247	$30,000	$32,143
Individuals below poverty level	8.1%	7.9%	13.3%	11.2%

Source: ECONorthwest with data from the U.S. Census Bureau, 2000

[13] Flinders, J., D. Rogers, J. Webber-Alston, and H. Barber. 2002. "Mammals of the Grand Staircase-Escalante National Monument: A Literature and Museum Survey." *Monographs of the Western North American Naturalist*. 1:1-64; and U.S. Army Corps of Engineers. 2010. Final Wetland/Riparian Mitigation and Monitoring Plan for the Wide Hollow Water Supply Storage Facility Project. Sacramento District. January 25.

The Escalante Basin is split between Garfield County and Kane County. Major population centers within the sub-basin are the City of Boulder and the City of Escalante, both in Garfield County. Table 4 summarizes population, household, income, and poverty data for Garfield and Kane Counties and the cities of Boulder and Escalante. About 9 percent of the total population in Garfield and Kane County live in the Cities of Boulder and Escalante. In general, the median household incomes in these cities are lower than those at the county level and, for both cities, the percentage of individuals living below the poverty level exceeds the county averages. The population in this area is predominantly white (about 94 percent) with small numbers of Hispanic and American Indian residents.

2. Water-related Government Activity

The Utah Department of Environmental Quality's Division of Water Quality (DWQ) monitors and enforces water quality criteria in Utah's waterways. For waterways that fail to comply with the state's water-quality criteria, the DWQ must identify strategies for attaining compliance. Upstream of its confluence with Boulder Creek, the Escalante River regularly fails to comply with criteria establish to protect biota dependent on cold water streams. Samples taken in 2003 show that, depending on the monitoring location, water temperature exceeded the maximum temperature threshold (20^{o} Celsius) 64-100 percent of the days that recordings were taken. DWQ cites high variability in stream flow in the Escalante and its tributaries, along with poor riparian canopy cover, as the main reasons for high water temperatures in the upper Escalante.[14]

To accomplish the goal of reducing water temperatures in the upper Escalante and its tributaries, DWQ developed a management plan that states that efforts must be made to improve stream channel stability and minimize stream bank erosion to enhance stream flows, and to enhance the riparian corridor.[15] Table 5 lists several best management practices from the management plan suggested for accomplishing the goal's objectives. Beaver activity under sufficient population levels can contribute to these management goals.

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[14] Utah Department of Environmental Quality, Division of Water Quality. 2004. *Escalante River Watershed Water Quality Management Plan.* Prepared by Millennium Science and Engineering, Inc., and Pocket Water Inc., Salt Lake City.

[15] Utah Department of Environmental Quality, Division of Water Quality. 2004. *Escalante River Watershed Water Quality Management Plan.* Prepared by Millennium Science and Engineering, Inc., and Pocket Water Inc., Salt Lake City.

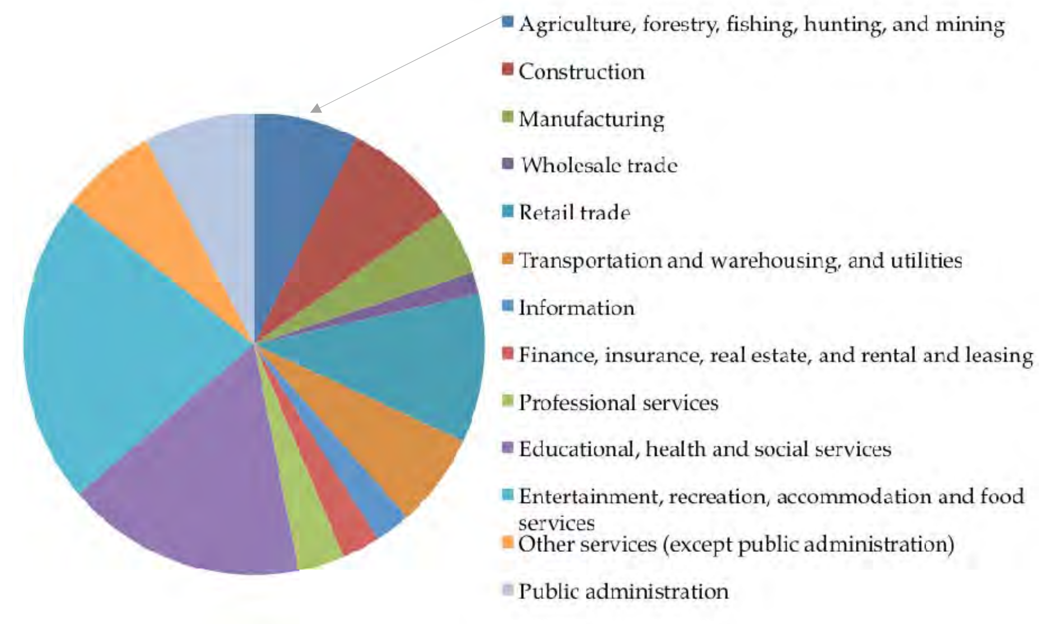
Table 5. Best Management Practices Identified for Lowering Water Temperature in the Upper Escalante and its Tributaries

Best Management Practice
Channel Bank Vegetation
Riparian Herbaceous Cover
Riparian Forest Buffer
Stream Habitat Improvement and Management
Streambank and Shoreline Protection
Channel Stabilization

3. Local Industry and Recreation

Garfield and Kane Counties have similar patterns of industrial activity shown in Figure 10. The largest sector, encompassing entertainment, recreation, accommodation, and food services activities, employs about 21.8 percent of the workers in the region. Education, health, and social services employ about 16.9 percent of the workforce, and retail trade employs about 10.4 percent of the workforce. Agriculture, forestry, fishing, hunting, and mining account for about 7.3 percent of the workforce. These data indicate that recreation, tourism, and related activities associated with the natural amenities of the region are more important to the local economy than historical agriculture-based activities.

Figure 10. General Employment Data for Escalante Sub-basin (2000)



Source: ECONorthwest, with data from the U.S. Census Bureau, 2000

Agriculture

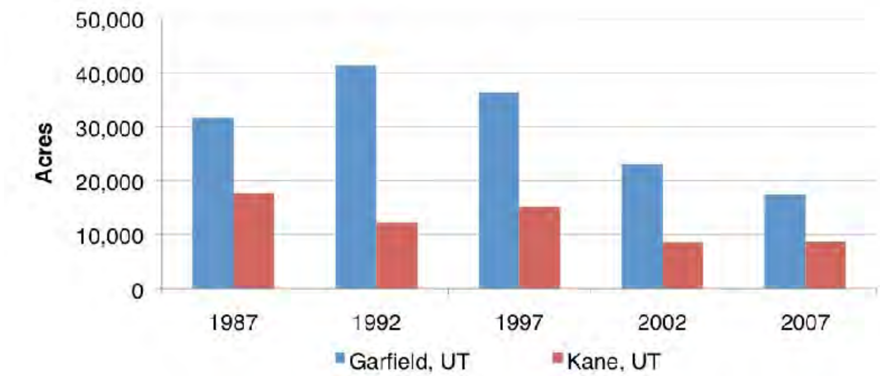
In total, there are about 420 farms encompassing 200,000 acres of farmland in Garfield and Kane Counties (Table 6). The majority of the farmland, about 87 percent, is used for grazing and other non-crop farming activities. Only a small amount, about 13 percent, of total farmland is used for crops. Neither county contains a large amount of irrigated land. In Garfield County, about 27 percent of farmland acres are irrigated; in Kane County, about 4 percent are irrigated. Figure 11 shows the number of farms in each county since 1987. The number of farms in both counties has been relatively stable at around 400 farms in total.

Table 6. Acres of Agricultural Land Use by Category, by County, and for the Escalante Basin (2002 and 2007)

	Garfield County		Kane County	
	2002	2007	2002	2007
Total land in farms	79,879	81,866	155,825	113,417
Total number of farms	225	275	131	145
Total cropland	23,111	17,436	8,585	8,691
Harvested cropland	8,539	11,483	2,144	1,737
Irrigated land	15,429	22,331	3,433	4,315
Irrigated harvested cropland	8,387	10,311	1,883	1,645
Irrigated pastureland and other land	7,042	12,020	1,550	2,670

Source: ECONorthwest, with data from the U.S. Census of Agriculture, 2002, 2007.

Figure 11. Total Cropland by County (1987–2007)



Source: ECONorthwest, with data from the U.S. Census of Agriculture, 1988, 1992, 1997, 2002, 2007

Tourism and Recreation

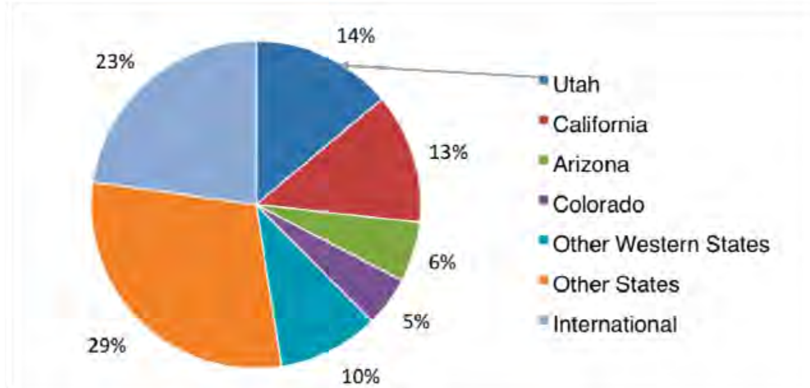
The tourism and recreation industries in the Escalante Basin are primarily tied to Dixie National Forest to the north and the Grand Staircase-Escalante National Monument (the Monument) to the south. The region's unique canyon landscape draws hikers, and the mountains and streams attract fishers and hunters. The accessibility and quality of natural amenities in the region are the principal drivers for demand for tourism, recreation, and associated services in the region.

Grand Staircase-Escalante National Monument

The reputation of the Escalante Basin's natural amenities attracts visitors from well beyond Utah. Due to restrictions on development within the Monument, recreation and tourism are the primary land uses. An estimated 600,000 visitors spend time in the Monument every year, and most of them are participating in some form of recreation.[16] A recent survey of visitors to the Monument collected a wide array of information describing visitor characteristics, preferences, and activities. Figure 12 shows visitor origins to the Monument from a 2006 study. About 48 percent of the Monument's visitors came from Western states, another 29 percent came from other states within the U.S., and about 23 percent came from outside the U.S.

[16] Burr, S., D. Blahna, D. Reiter, E. Leary, and N. Wagoner. 2006. *A Front Country Visitor Study for Grand Staircase-Escalante National Monument*. Institute for Outdoor Recreation and Tourism, Utah State University. IORT Professional Report PR2006-01.

Figure 12. Home Locations of Visitors to Grand Staircase-Escalante National Monument



Source: ECONorthwest, with data from Burr, S., D. Blahna, D. Reiter, E. Leary, and N. Wagoner. 2006. *A Front Country Visitor Study for Grand Staircase-Escalante National Monument*. Institute for Outdoor Recreation and Tourism, Utah State University. IORT Professional Report PR2006-01.

On average, visitors planned on staying in the Monument area for more than three days, with about 90 percent staying at least one day. The most common types of recreation activities in the Monument are hiking, camping, scenic driving, photography, viewing historic sites and wildlife, rock climbing, and fishing. Many of these visitors also spend time in the communities surrounding the Monument. The survey found that about 73 percent of visitors stopped in the City of Escalante, and about 51 percent stopped in Boulder for gas, food, lodging, shopping, or other forms of recreation. Visitors to the Monument spent an estimated $20.6 million in Kane and Garfield Counties, supporting an estimated 430 full-time jobs. The average visitor from Utah spent $74, while the average out of state, domestic visitor spent about $200, and the average international visitor spent $246.[17]

Dixie National Forest

Dixie National Forest covers nearly two million acres in southern Utah. The U.S. Forest Service has estimated that there were about 867,000 visits to Dixie National Forest in 2009 (a visit, in this case, refers to a person entering lands within the Dixie National Forest). The number of people who visited the forest is likely smaller (about 330,000) as some visitors visited on multiple occasions. About 42 percent of visitors to Dixie National Forest come from within 100 miles of the forest, another 41 percent come from 101–500 miles away, and about 17 percent come from over 500 miles away. Most visits to the forest are day visits, although the average amount of time spent per visit is about 18 hours. About 60 percent of visits to Dixie National Forest involve visitors who are spending at

[17] Burr, S., D. Blahna, D. Reiter, E. Leary, and N. Wagoner. 2006. *A Front Country Visitor Study for Grand Staircase-Escalante National Monument*. Institute for Outdoor Recreation and Tourism, Utah State University. IORT Professional Report PR2006-01.

least one night in the forest or within 50 miles of the forest. Those spending the night in the area spend about $200 per visiting group.[18]

The most popular recreation activities in Dixie National Forest include: relaxing (66 percent), viewing natural features (54 percent), hiking (41 percent), viewing wildlife (36 percent), and driving for pleasure (32 percent). Some of the most common primary recreation activities in Dixie National Forest include: downhill skiing (18 percent), fishing (16 percent), and viewing natural features (15.1 percent).[19]

Hunting and Trapping

Table 7. Upland Game Hunting in Garfield and Kane Counties (2008)

Game	Hunter-days afield	Number bagged
Cottontail rabbit	1,380	944
Dove	219	94
Forest grouse	1,101	273
Ring-necked pheasant	40	21
Snowshoe hare	74	0
White-tailed ptarmigan	11	0
Chukar partridge	126	45
Total	**2,951**	**1,377**

Source: Utah Department of Natural Resources. 2008. *Utah Upland Game Annual Report 2008*. Publication No. 09-28.

Three distinct types of hunting occur in the study area: upland game hunting, furbearer trapping, and big game hunting. Tables 7, 8, and 9 show data collected by the Utah Department of Natural Resources regarding each of these hunting categories. The most popular target of upland game hunting in 2008 was cottontail rabbit followed by forest grouse. Hunters spent 1,380 days hunting for cottontail rabbit in Garfield and Kane Counties, bagging 944; they spent 1,101 days hunting for forest grouse bagging 273.

Table 8. Furbearer Trapping in Garfield and Kane Counties (2009)

Game	Trappers afield	Number trapped
Bobcat	214	298
Coyote	61	502
Raccoon	6	8
Beaver	3	3

[18] U.S. Department of Agriculture, Forest Service. 2010. *National Visitor Use Monitoring Results: Region 4, Dixie National Forest*. May.

[19] U.S. Department of Agriculture, Forest Service. 2010. *National Visitor Use Monitoring Results: Region 4, Dixie National Forest*. May.

Red fox	23	48
Gray fox	64	563
Badger	3	6
Muskrat	3	8
Striped/Spotted Skunk	9	14
Total	**386**	**1,450**

Source: Utah Department of Natural Resources. 2009. *Utah Furbearer Annual Report 2008-2009*. Publication No. 10-14.

Table 9. Big Game Hunting in Study Area (2010)

Game	Residents		Non-residents	
	Total Applicants	Total Permits	Total Applicants	Total Permits
Bull Elk	573	37	164	5
Antlerless Elk	656	438	39	35
Pronghorn	1,119	332	332	39
Desert Bighorn Sheep	309	6	0	0
Black Bear	362	25	14	3
Cougar	53	8	14	1
Total	**3,072**	**846**	**563**	**83**

Source: Utah Department of Natural Resources. 2010. *2010 Utah Big Game Guidebook*; Utah Department of Natural Resources. 2010. *Utah Division of Wildlife Resources 2010 Draw 5, Big Game Bonus Point Draw Results*. August; Utah Department of Natural Resources. 2010. *2010-2011 Utah Cougar Guidebook*. Utah Department of Natural Resources. 2010. *2010 Antlerless Guide Book*. Note: Does not include over-the-counter permits.

The most popular target for trappers in 2009 was the bobcat, followed by the grey fox. There were 214 trappers targeting bobcat in Garfield and Kane Counties; they trapped 298 bobcats. Another 64 trappers targeted gray fox; they trapped 563. Among big game hunters, pronghorn permits were in the highest demand, followed by antlerless elk. In 2010, 332 of the 1,119 resident hunters applying for pronghorn hunting permits received permits; 438 of the 656 resident hunters applying for antlerless elk hunting permits received permits.

Fishing

Fishing in the study area is more difficult to track than hunting. In the upper reaches of the Escalante River and its northern tributaries, cutthroat, brook, brown and rainbow trout are the primary species of interest to anglers. In the warmer, southern reaches of the Escalante River, most anglers target catfish and suckers.[20]

[20] Utah Travel. 2010. *Southern Utah Fishing Waters*. Retrieved on October 22, 2010 from: http://www. utah.com/fish/southern_utah_fishing_waters.htm.

4. Water and Natural Resource Demand Summary

Many households and businesses, both within the Escalante Basin and beyond, have demands on numerous ecosystem goods and services that healthy beaver populations in the area can provide. Most of these concern the ability of beavers to improve the quantity and quality of water resources in the basin, and, hence, the quantity and quality of habitat for rare and economically-important species.

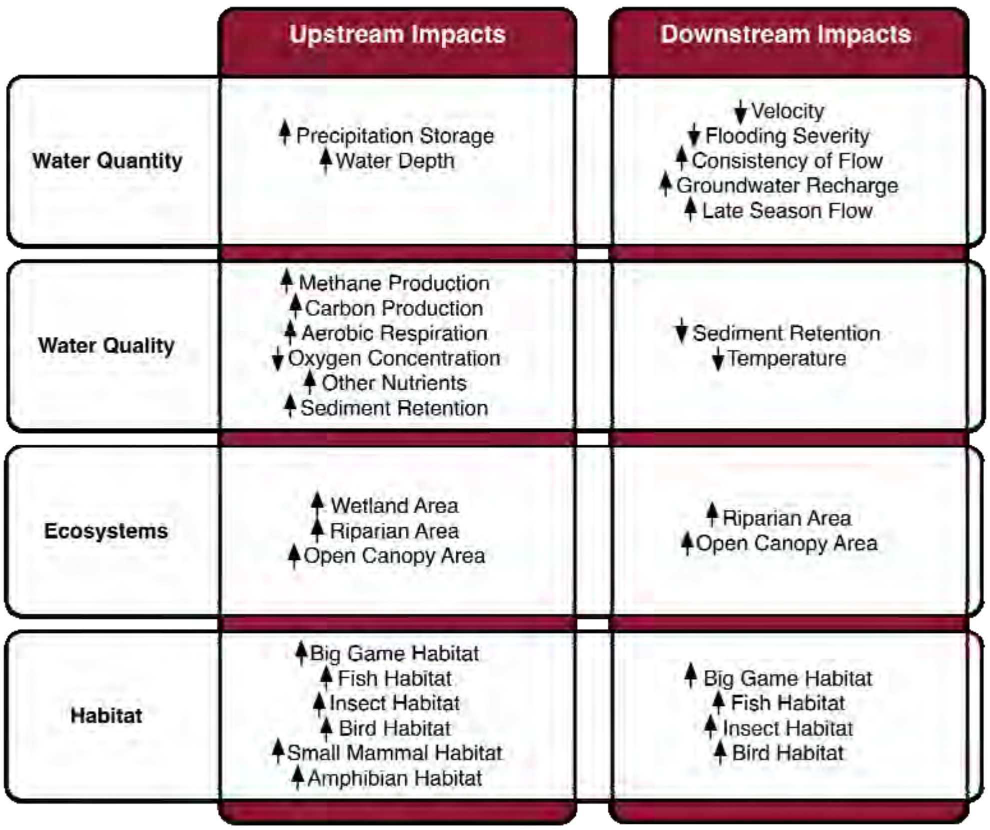
Throughout the region, residents and visitors rely on a functioning watershed and aquifers to provide reliable supplies of water for domestic use. Many different sectors of the region's economy rely on local water availability and quality as well. Farmers in the region require water to irrigate crops and maintain grazing land. Businesses require water to meet the demands of recreationists and tourists. Residents from within the basin as well as many tourists from outside the basin have historically shown demand for recreational opportunities in the area that depend upon or benefit from habitat quality and streamflow quality and quantity.

In the following section, we describe how restoration of beaver activity could contribute to the quantity, quality, timing, and regularity of water resources in the Escalante Basin.

II. Ecosystem Process Effect Analyses

Beavers have the potential to interact with both physical and socioeconomic elements of the study area. In general, beavers interact with the surrounding ecosystem by felling trees, eating tree material, and often building dams with the felled trees and other debris. These activities either directly or indirectly impact the ecosystems and communities surrounding beaver colonies. Here, we describe the potential effects of beaver restoration in three parts: the potential population and distribution of beaver colonies, the structural effects of beaver restoration, and the effects of beaver restoration on ecological processes. Figure 13 provides an overview of the types of effects beaver restoration may have on the ecosystem. The figure distinguishes between upstream and downstream areas and between four categories of effects, those relating to water quality, water quantity, ecosystems, and habitat.

Figure 13. Beavers' Potential Impacts on Streams and Related Ecosystems



Source: ECONorthwest with data from: Gurnell, A. 1998. "The Hydrogeomorphological effects of Beaver Dam-Building Activity." *Progress in Physical Geography*. 22(12):167-189; Naiman, R., J. Melillo, and J. Hobbie. 2986. "Ecosystem Alteration of Boreal Forest Streams by Beaver." *Ecology*. 67(5):1254-1269; Naiman, R., C. Johnston, and J. Kelley. 1988. "Alteration of North American Streams by Beaver." *Bioscience*. 38(11):753-762; Rosell, F., O. Bozser, P. Collen, and H. Parker. 2005. "Ecological Impact of Beavers *Castor fiber and Castor canadensis* and their Ability to Modify Ecosystems." *Mammal Review*. 35(3):248-276.

A. Beaver Restoration: Potential Density and Spatial Distribution

Beavers live in a wide range of aquatic habitats distributed throughout deserts, shrublands, forests, rangelands, agricultural lands, and urban areas of North America. Within each of these habitat types, beavers require a permanent water body and an accessible food source.[21] Beaver populations likely prefer habitat provided in the northern portion of the basin to habitat in the south because of the larger food supply and a more constant flow of water. Recent research in Utah's Strawberry River watershed suggests that there are about 0.4 beaver colonies per river mile in that area, which has more vegetation and water availability than the Escalante.[22] Colony size varies from region to region; estimates range from about 4 to 6 beavers per colony in areas similar to the Escalante Basin.[23]

In our analysis, we divide potential beaver habitat into four categories by quality in terms of potential to support beaver providing valuable services.[24] Table 10 describes these habitat categories and our estimates of the potential concentration of colonies per river mile. These numbers are based on the observed density in the Strawberry watershed in the north, and half this observed density in the south, because the south in general does not have as favorable of conditions. The overall greater area and stream miles in the south though lead to a greater total potential number of colonies. In total, we estimate that the Escalante Basin could support about 1,300 beaver colonies, or about 5,200–7,800 individual beavers could potentially inhabit the Escalante watershed. The majority of the beaver colonies, about 90 percent, likely would live on small creeks and streams, but we do not estimate a specific spatial distribution. Beaver would select their habitat based on a number of factors for which data do not currently exist. Of these factors, water supply, food availability, woody vegetation and human disturbance influence beaver settlement patterns.

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[21] Boyle, S. and S. Owens. 2007. *North American Beaver (Castor Canadensis): A Technical Conservation Assessment.*

[22] Uinta National Forest. 2004. *Strawberry Watershed Restoration Report*. April.

[23] Boyle, S. and S. Owens. 2007. *North American Beaver (*Castor canadensis*): A Technical Conservation Assessment.*

[24] Throughout our analysis, we assume that the large and small waterways in the northern portion of the basin provide prime beaver habitat while the large and small waterways in the southern portion of the basin provide beaver habitat that is about half as good as that provided in the north. This is based on the greater presence of the principle components of dam-building activity, namely flowing surface water and woody vegetation.

Table 10. Beaver Habitat Preference in Escalante Basin and Estimated Colony Densities

	North Portion of the Basin	South Portion of the Basin
Large Waterways	**Preferred beaver habitat** (0.42 colonies per mile) *About 70 colonies*	**Good beaver habitat** (0.21 colonies per mile) *About 60 colonies*
Small Waterways	**Preferred beaver habitat** (0.42 colonies per mile) *About 520 colonies*	**Good beaver habitat** (0.21 colonies per mile) *About 640 colonies*

Source: ECONorthwest with data from Uinta National Forest. 2004. Strawberry Watershed Restoration Report. April.

B. Structural Effects of Beaver Restoration

Most structural effects associated with beaver restoration stem primarily from the construction of beaver dams. Beavers construct dams in waterways to expand their habitat, increase the quantity of nearby and aquatic food sources, and to enhance protection from predators.[25] Once a dam is constructed, water begins to collect and pools and wetlands form upstream. These pools and wetlands expanded over land that was previously covered by riparian and forest habitat. Over time, new riparian habitat forms on the edges of these landscapes. Once the beaver dam fails, the wet areas begin to dry up and meadows thrive until the original composition of the landscape is eventually restored to pre-dam conditions. The particular dam and downstream circumstances can lead to varying site-specific outcomes.

Recent research in Utah's Strawberry Watershed suggests that, if beaver were restored in the Escalante Basin and built dams at similar density to the Strawberry Watershed, beavers could construct 22 dams per river mile. Active dams would constitute about a quarter of total beaver dams at any given time. Given that the waterways in the northern portion of the basin provides better beaver habitat than waterways in the southern portion of the basin, we assume that there would potentially be half as many dams per mile (11 dams) in the south. Table 11 shows our estimated results. Based on these observed densities and river miles in the Escalante basin, we estimate that full beaver restoration and landscape saturation could result in up to 69,000 dams throughout the basin. Only about a quarter of these (about 17,250 dams) would be functional at any given time. Most of the dams, about 90 percent, would be in smaller waterways and just over half (about 55 percent) will be in the southern portion of the basin because there are more than twice as many river miles in the south, even though population densities would likely be less.

[25] Uinta National Forest. 2004. Strawberry Watershed Restoration Report. April.

Our calculations based on beaver dam density are linear functions of these density assumptions. Currently, there are insufficient data to estimate potential beaver dam densities specifically in the Escalante Basin. If research suggests densities other than those assumed, or the reader prefers a different density assumption, resulting estimates can be scaled proportional to the preferred density assumptions.

Table 11. Beaver Habitat Preference in Escalante Basin and Estimated Colony Densities

	North Portion of the Basin	South Portion of the Basin
Large Waterways	**Preferred beaver habitat** (22 dams per mile) *About 3,780 dams*	**Good beaver habitat** (11 dams per mile) *About 3,212 dams*
Small Waterways	**Preferred beaver habitat** (22 dams per mile) *About 27,020 dams*	**Good beaver habitat** (11 dams per mile) *About 35,057 dams*

Source: ECONW with data from Uinta National Forest. 2004. Strawberry Watershed Restoration Report. April.

The size of beaver ponds would vary greatly and depend on stream flow, land topography adjacent to the waterway, and various characteristics of the dam. Research from beaver habitat across the county suggests that the size of beaver ponds may range from 0.2–7.4 acres.[26] Given the Escalante topography, we assume beaver pond size potential would be at the low end of this range. We conduct our analyses for two beaver pond sizes of 0.5 and 1.5 acres, which correspond to total surface areas of 34,500–103,600 acres of ponds in the basin. Furthermore, we assume the average pond would have a surface area to volume ratio of 0.6, from which we estimate that the beaver ponds would hold 0.3–0.9 acre-feet of water at any given time.[27]

Research from Minnesota suggests that, as beavers construct dams, the area of adjacent forestland decreases and the area of ponds, wetlands, and riparian habitat increases.[28] In Table 12, we summarize the potential changes in landscape adjacent to beaver dams, assuming average pond sizes of 0.5 acres and 1.5 acres.

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[26] See, for example: Beedle, D. 1993. *Physical Dimensions and Hydrologic Effects of Beaver Ponds on Kuiu Island in Southeast Alaska*. Thesis submitted to Oregon State University; Cirmo, C. and C. Driscoll. 1993. "Beaver Pond Biogeochemistry: Acid Neutralizing Capacity Generation in a Headwater Wetland." *Wetlands*. 13(4) 277-292; Hodkinson, I. 1975. "Energy Flow and Organic Matter Decomposition in an Abandoned Beaver Pond Ecosystem" *Oecologia*. 21:131-139; Johnston, C. and R. Naiman. 1987. "Boundary Dynamics at the Aquatic-terrestrial Interface: The Influence of Beaver and Geomorphology." *Landscape Ecology*. 1(1):47-57.

[27] ECONW with data from Beedle, D. 1993. *Physical Dimensions and Hydrologic Effects of Beaver Ponds on Kuiu Island in Southeast Alaska*. Thesis submitted to Oregon State University.

[28] Naiman, R., C. Johnston, and J. Kelley. 1988. "Alteration of North American Streams by Beaver." *Bioscience*. 38(11):753-762.

First, ponds would form upstream of the beaver dam. As stream flow changes throughout the year, the landscape surrounding the ponds would become wetlands. Depending on pond size, the area of wetlands associated with each beaver dam could be 0.9–2.6 acres for a total of 60,400–181,100 acres in the basin. Ponds and wetlands formed by beaver dams would alter the existing riparian and forest habitat. As these ponds and wetlands expand, the amount of forested landscape would decrease and the amount of riparian area would increase. In some cases, riparian area could double as a result of beaver activity.[29] Depending on pond size, the net increase in riparian habitat resulting from beaver activity would be 2.5–4.4 acres per pond for a total of 175,100–303,300 acres in the basin.

Table 12. Impact of Beaver Dams on Adjacent Landscapes

	Average Area of Pond	
	0.5 Acres	**1.5 Acres**
Average Volume of Water per Pond (Acre-feet)	0.3	0.9
Average Increase in Area of Wetland per Pond (Acres)	0.9	2.6
Average Increase in Area of Riparian Habitat per Pond (Acres)	2.5	4.4
Total Area of Ponds (Acres)	34,500	103,600
Total Area of Wetlands (Acres)	60,400	181,100
Total Area of Riparian Habitat (Acres)	175,100	303,300

Source: ECONorthwest with data from Naiman, R., C. Johnston, and J. Kelley. 1988. "Alteration of North American Streams by Beaver." *Bioscience*. 38(11):753-762.

The number of years a specific beaver dam remains in use can vary, from a couple of years to centuries.[30] Throughout our analysis, we assume the average beaver dam would retain its function for about 10 years.[31] Once a beaver dam fails, the pond and wetland areas would begin to dry up. Meadows would

[29] Naiman, R., C. Johnston, and J. Kelley. 1988. "Alteration of North American Streams by Beaver." *Bioscience*. 38(11):753-762.

[30] Gurnell, A. 1998. "The Hydrogeomorphological Effects of Beaver Dam-Building Activity." *Progress in Physical Geography*. 22:167-189; Howard, R. and J. Larson. 1985. "A Stream Habitat Classification System for Beaver." *Journal of Wildlife Management*. 49:19-25; Lawrence, W. 1952. "Evidence of the Age of Beaver Ponds." *Journal of Wildlife Management*. 16:69-79; Wright, J. and C. Jones. 2002. "An Ecosystem Engineer, the Beaver, Increases Species Richness at the Landscape Scale." *Oegologia*. 132:96-101.

[31] Wright, J. and C. Jones. 2002. "An Ecosystem Engineer, the Beaver, Increases Species Richness at the Landscape Scale." *Oegologia*. 132:96-101.

sprout throughout the previously saturated land. Depending on the peripheral landscape, these meadows could thrive for decades.[32]

C. Effects on Ecological Processes of Beaver Restoration

The structural effects described above contribute to a number of indirect effects on the natural processes that occur both upstream and downstream of beaver dams. For our analysis, we organize these indirect effects or 'process effects' into four categories: water quantity, water quality, ecosystems, and habitat. There are many distinct effects in each of the four categories. Below, we describe these effects. For some, the literature provides enough detail to quantify the potential effects. Where data are insufficient for a quantitative analysis, we provide a qualitative description of the potential effects.

1. Water Quantity

The dams beavers build directly and indirectly impact the water quantity both upstream and downstream of the dam. Beaver dams impede the flow of water and create pools of very slow-moving water directly upstream. At times of low base flows, beaver dams can hold 30 to 60 percent of available water.[33] In systems with seasonal water shortages, this storage and subsequent slow release can be crucial to maintaining minimum baseflows for downstream habitat, and valuable late season flows for irrigators and other water consumers. Furthermore, decreased water velocity and more consistent water volume result in decreased severity of flooding events and increased groundwater recharge in downstream waterways.[34]

Beaver dams collect water upstream and change downstream stream flows. Most notably, beaver dams decrease peak flows and increase flows later in the year by regulating the timing of water discharge. Figure 14 demonstrates the potential change in waterflow throughout the year. Peak waterflow decreases due to water storage behind beaver dams. Waterflow during the rest of the year increases as the water stored in beaver ponds slowly flows through the dam. Furthermore, while the total volume of surface water flowing through the basin likely would decrease with beaver activity, due to evaporation and groundwater infiltration

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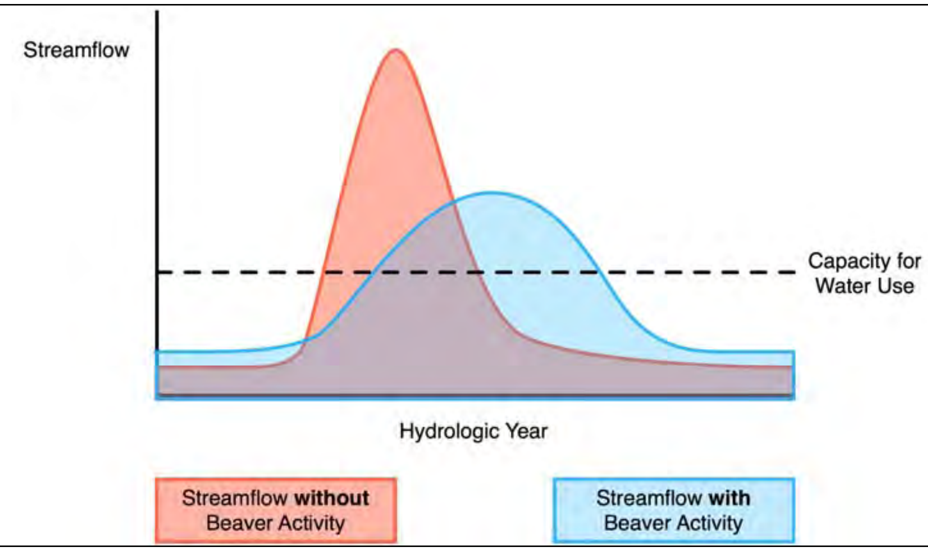
[32] Terwilliger, J. and J. Pastor. 1999. "Wmall Mammals, Ectomycorrhizae, and Conifer Succession in Beaver Meadows." *Oikos*. 85:83-94., Naiman, R., C. Johnston, and J. Kelley. 1988. "Alteration of North American Streams by Beaver." *Bioscience*. 38(11):753-762.

[33] Kay, C. 1994. The impact of native ungulates and beaver on riparian communities in the intermountain west. Natural Resources and Environmental Issues 1: 23-44.

[34] Gurnell, A. 1998. "The Hydrogeomorphological Effects of Beaver Dam-Building Activity." *Progress in Physical Geography*. 22(12):167-189.

taking place in beaver ponds, the total volume of water that can be captured would likely increase.[35]

Figure 14. Illustrative Example of Annual Waterflow with and without Beaver Activity



Source: ECONorthwest

Note: This figure is for illustrative purposes only; not drawn to scale. Difference in peaks could vary significantly.

Research suggests that beaver dams can hold up 30–60 percent of base flow and discharge it later.[36] Table 13 summarizes our analysis on the potential changes to stream flow in the Escalante Basin. In Table 2 we show the Escalante River, with monthly averages ranging from 36 to 676 cubic feet per second at its mouth, carries an estimated total volume of water running through the basin that ranges from 9,241–848,342 acre-feet per year. If beaver dams can store 30–60 percent of the stream flow and release it later, they may be regulating 2,772–509,005 acre-feet of water per year. With these assumptions, we estimate the average beaver pond can hold about 0.04–7.4 acre-feet of water, total, throughout the year. At any given time, however, the total volume of water in each pond likely would be less because each dam slowly discharges water throughout the year. By holding water captured during the highest flow periods, and releasing it at lower flow periods, beaver dams effectively create new water supply during times of water scarcity.

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[35] The total volume of water with beaver activity (the area of the blue figure) is less than the total volume without beaver activity (the area of the pink figure). The total volume of *usable* surface water, however, likely would increase (the area of the blue figure below the dashed line is larger than the area of the pink figure below the dashed line).

[36] Kay, C. 1994. The impact of native ungulates and beaver on riparian communities in the intermountain west. Natural Resources and Environmental 1: 23-44.

Table 13. Estimated Changes in Stream Flow and Volume in the Escalante Basin due to Beaver Dams

	Assuming Maximum Stream Flow	Assuming Average Stream Flow	Assuming Minimum Stream Flow
Annual Stream Flow (cfs)	4,181–8,361	577–1,153	46–92
Annual Volume (acre-feet)	254,503–509,005	34,904–69,808	2,772–5,545

Source: ECONW with data and assumptions from Wilberg, D. and B. Stolp. 2005. *Seepage Investigation and Selected Hydrologic Data for the Escalante River Drainage Basin, Garfield and Kane Counties, Utah, 1909-2002*. U.S. Geological Survey. Scientific Investigations Report 2004-5233; and Millennium Science & Engineering, Inc. *Undated. Escalante River Watershed: Water Quality Management Plan*. Utah Department of Environmental Quality, Division of Water Quality; Kay, C. 1994. The impact of native ungulates and beaver on riparian communities in the intermountain west. Natural Resources and Environmental Issues 1: 23-44.

In addition to their effect on surface water, beaver dams affect groundwater by increasing recharge and retention.[37] Research from a semi-arid region of central Oregon analyzed the impact of beaver activity on groundwater by recording the water height in various wells near the John Day River. The water height in a well near a beaver dam, for example, rose 0.35 meters while the water level in the nearby beaver pond rose 0.22 meters. The water height in another well far downstream of any beaver activity rose only 0.17 meters during the same period.[38]

The textbook estimate for the rate of water flow through the ground on the Colorado Plateau, which includes the Escalante Basin, is hydraulic conductivity of 10^{-11}–10^{-8} meters per second.[39] If we assume a hydraulic conductivity rate of 10^{-9} meters per second, and beaver pond sizes of 0.5 and 1.5 acres, groundwater recharge throughout the basin could range from 3,000–9,000 acre-feet per year. If this water supplies aquifers used by communities in the basin and we do not assume any other loss, at a national average indoor water consumption per capita of 69 gallons, this would provide sufficient annual indoor water for 232-696 people.

[37] See, for example: Lowry, M. 1993. *Groundwater Elevations and Temperature Adjacent to a Beaver Pond in Central Oregon*. Dissertation submitted to Oregon State University; Pollock, M., M. Heim, and D. Werner. 2003. "Hydrologic and Geomorphic Effects of Beaver Dams and their Influence on Fishes." *American Fisheries Society Symposium*. 1-21.

[38] Lowry, M. 1993. *Groundwater Elevations and Temperature Adjacent to a Beaver Pond in Central Oregon*. M.S. Thesis submitted to Oregon State University.

[39] Fetter. C. 2001. *Applied Hydrogeology: Fourth Edition*. Princeton Hall, Inc.

2. Water Quality

Beaver dams have several impacts on water quality, both upstream and downstream of the dam. A dam's impacts on water quality stem primarily from sediment capture in pools of very slow-moving water upstream of the dam. As water slows, sediment sinks to the bottom of the pool. The sediment is typically a mix of organic an inorganic components. Once the sediment has settled, a number of biogeochemical processes occur, changing the nutrient composition of the pond floor. Many of these nutrients remain on the bottom of the pond and are not released into downstream waterways. The increased sediment retention behind the dam can lower the concentration of certain nutrients in water downstream.

The primary means by which beaver dams affect upstream and downstream water quality is through sediment retention. Sediment accumulates in river systems due to stream-bank erosion. Sediment increases turbidity in waterways, which may inhibit plant growth, clog the gills of fish, and inhibit feeding by fish.[40] There is a statistically significant relationship between the surface area of a beaver pond and the amount of sediment it retains.[41] We continue with our use of beaver pond size categories of 0.5 and 1.5 acres. Applying the relationship between beaver pond surface area and sedimentation volume from the literature, we estimate that the average beaver pond collects about 29,500-85,200 cubic feet of sediment throughout its lifetime.[42] The average beaver pond remains intact for less than 10 years.[43] To estimate how much sediment beaver ponds collect each year in the basin, we assume that the rate of beaver dam construction equals the rate of beaver dam collapse and that the average beaver dam remains functional for 10 years. Assuming a total of about 69,000 beaver dams in the basin, beaver dams would capture 204 million–549 million cubic feet of sediment annually.[44]

The findings from research on the impact of beaver dams on water temperature have been mixed. Some research suggests that water temperature may decrease along with a decrease in suspended sediment because sediment absorbs heat

[40] U.S. Environmental Protection Agency. 2010. *Turbidity: What is Turbidity and Why is it Important.* Water Monitoring and Assessment.

[41] Naiman et al. 1986 as cited in Butler, D. and G. Malanson. 1995. "Sedimentation Rates and Patterns in Beaver Ponds in a Mountain Environment." *Geomorphology*. 13:255-269.

[42] The relationship between surface area and sediment volume is described by the following equation where surface area is in square meters and volume is in cubic meters: Volume = 47.3 + 0.39 x [Surface Area].

[43] Wright, J. and C. Jones. 2002. "An Ecosystem Engineer, the Beaver, Increases Species Richness at the Landscape Scale." *Oegologia*. 132:96-101.

[44] To estimate annual sediment capture, we multiply sediment capture per pond by the number of ponds (69,069) and then divide by 10. We divide by 10 to estimate an annual value.

more readily than water.[45] Furthermore, water temperatures may decrease downstream of beaver dams due to the upwelling of cool deep water to the

Table 14. Estimated Changes in Sediment Retention in the Escalante Basin due to Beaver Dams

	Average Area of Pond	
	0.5 Acres	**1.5 Acres**
Average sediment retained per dam, lifetime (cubic feet)	29,500	85,200
Average sediment retained per dam, annually (cubic feet)	2,950	8,520
Average sediment retained by all dams in basin, annually (cubic feet)	204 million	549 million

surface below the dam.[46] Other studies, however, suggest that beaver dams increase water temperature in the summer and decrease it in the winter.[47] If water temperature decreases, it may contribute to an increase in dissolved oxygen concentrations downstream of beaver dams. Dissolved oxygen concentrations may also increase due to enhanced photosynthetic activity brought about by decreased turbidity from sediment retention and the subsequent increase in plant productivity.

Furthermore, the delayed water flow can decrease the temperature of water downstream. The increased base flow decreases the average temperature, particularly the peak temperatures, downstream of a beaver dam. Sediment retention by beaver dams also can reduce the amount of sediment reaching downstream, human-made reservoirs, which store water primarily for agricultural and recreational use. Sedimentation in reservoirs decreases water capacity and can have impacts throughout the area.

The sediment retained in beaver ponds can contain nitrogen, phosphates, fecal coliform, heavy metals, and other pollutants associated with agricultural runoff,

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[45] U.S. Environmental Protection Agency. 2010. *Turbidity: What is Turbidity and Why is it Important.* Water Monitoring and Assessment.

[46] Pollock, M., T. Beechie, and C. Jordan. 2007. "Geomorphic Changes Upstream of Beaver Dams in Bridge Creek, an Incised Stream Channel in the Interior Columbia River Basin, Eastern Oregon." *Earth Surface Processes and Landforms*. 32:1174-1185.

[47] Shetter, D. and M. Whalls. 1955. "Effect of Impoundment on Water Temperatures of Fuller Creek, Montmorency County, Michigan." *Journal of Wildlife Management*. 19:47-54; Collen, P. and R. Gibson. 2001. "The General Ecology of Beavers as Related to their Influence on Stream Ecosystems and Riparian Habitats, and the Subsequent Effects on Fish." *Reviews in Fish Biology and Fisheries.* 10:439:461; Rosell, F., O. Bozser, P. Collen, and H. Parker. 2005. "Ecological Impact of Beavers and their Ability to Modify Ecosystems." *Mammal Review*. 35:248-276.

sewage, and livestock.[48] By trapping sediment, beaver ponds also trap store, and process the attached pollutants. Nitrogen is transformed into nitrate, which fuels the growth of plants in the beaver pond as well as plants in the meadows that grow on the dried sediment subsequent to a dam's failure or full sedimentation.[49] Beaver ponds can reduce acidity downstream by trapping sulfates.[50] The pond sediment stores other pollutants that are later neutralized by the plants growing in post-dam meadows. Storing pollutants in the pond's floor means cleaner water with better water quality is traveling downstream through the basin.[51] Indirectly, beaver dams may increase water quality by increasing the size of wetlands and riparian habitat in the area. Wetlands increase water quality in much the same way as beaver ponds do by capturing and storing sediment. Riparian vegetation can increase water quality by removing pollutants and pollutant-carrying water and breaking down toxins.[52]

3. Habitat for Fish and Wildlife

Beaver activity can play important roles in maintaining valuable habitat for fish and wildlife and increasing habitat diversity. Wetlands and ponds created by beavers form particularly valuable ecosystems and habitat types because of the range of valuable services they provide, and the significance of the plant and animal species they support. Riparian areas resulting from beaver activity also can provide a valuable link between aquatic and terrestrial habitats. In general, active beaver dams absorb nutrients, which are slowly absorbed by plant both

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[48] Skinner, Q., J. Speck, M. Smith, and J. Adams. 1984. "Stream Water Quality as Influenced by Beaver within Grazing Systems in Wyoming." *Journal of Range Management*. 37::142-146; Collen, P. and R. Gibson. 2001. "The General Ecology of Beavers as Related to their Influence on Stream Ecosystems and Riparian Habitats, and the Subsequent Effects on Fish." *Reviews in Fish Biology and Fisheries.* 10:439:461; Muller-Schwarze, D. and L. Sun. 2003. *The Beaver: Natural History of a Wetlands Engineer*. Cornell University Press, Ithaca.

[49] Naiman, R. and J. Melilo. 1984. "Nitrogen Budget of a Subarctic Stream Altered by Beaver." *Oecologia*. 62:150-155.

[50] Driscoll, C., B. Wyskowski, C Cosentini, and M. Smith. 1987. "Processes Regulating Temporal and Longitudinal Variations in the Chemistry of Low-Order Woodland Stream in the Adirondack Region of New York." *Biogeochemistry*. 3:225-241; Naiman, R. C. Johnston, and J. Kelley. 1988. "Alteration of North American Streams by Beaver." *Bioscience*. 38:753-762; Smith, M., C. Driscoll, B. Wyskowski, C. Brooks, and C. Cosentini. 1991. "Modification of Stream Ecosystem Structure and Function by Beaver in the Adirondack Mountains, New York." *Canadian Journal of Zoology*. 69:55-61.

[51] Collen, P. and R. Gibson. 2001. "The General Ecology of Beavers as Related to their Influence on Stream Ecosystems and Riparian Habitats, and the Subsequent Effects on Fish." *Reviews in Fish Biology and Fisheries.* 10:439:461.

[52] See, for example: Lowrance, R., L. Altier, J. Newbold, R. Schrnabel, et al. 1997. "Water Quality Functions of Riparian Forest Buffers in Chesapeake Bay Watersheds." *Environmental Management*. 21 (5): 687-712; Wegner, S. 1999. *A Review of the Scientific Literature on Riparian Buffer Width, Extent, and Vegetation.* Office of Public Service & Outreach, Institute of Ecology, University of Georgia; Hassett, B., M. Palmer, E. Bernhardt, S. Smith, J. Carr, and D. Hart. 2005. "Restoring Watersheds Project by Project: Trends in Chesapeake Bay Tributary Restoration." *Frontiers in Ecology*. 3(5):259-267.

while the dam is active as well as after it fails. Increased nutrients and changes in habitat edges create an environment that promotes diversification among plant species through habitat succession. Furthermore, a wide range of aquatic invertebrates, amphibians, reptiles, mammals, and birds thrive on the more diverse range of habitat types produced by beaver dams.

Research has shown that, by changing surrounding habitat in this manner, the construction of beaver dams increases species richness among plants both in areas directly impacted by beaver dams as well as adjacent areas. Research on the east coast has found that beaver dams increase the number of herbaceous plant species at the landscape scale (including both beaver-modified areas as well as areas without beaver modifications) by 33 percent.[53] At the pond level, research has shown that very old ponds (over 56 years old) have twice as many rare plants as young ponds.[54]

By slowing water flows and increasing water depth, beaver dams create enhanced habitat for aquatic invertebrates upstream. Invertebrates associated with flowing water that exist in waterways unaffected by beaver activity will continue to exist upstream and downstream of beaver pools. New species of invertebrates associated with ponds will begin to accumulate in beaver ponds and will increase species diversity.[55]

Research suggests that, in general, beaver activity has a positive impact on fish species throughout the western U.S. To the extent that beaver dams increase flows during typically low-flow periods, or transform intermittent waterways to perennial waterways, fish benefit from the increased duration of preferable habitat.[56] Furthermore, beaver ponds can provide habitat for fish during drought and other low-flow events.[57] The increased diversity in aquatic invertebrates provides an enhanced food source for some species of fish while they travel through beaver ponds.[58] Also, at the landscape scale, beaver activity increases

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[53] Wright, J. and C. Jones. 2002. "An Ecosystem Engineer, the Beaver, Increases Species Richness at the Landscape Scale." *Oecologia*. 132: 96-101.

[54] Bonner, J. J. Anderson, J. Rentch, and W. Grafton. 2009. "Vegetative Composition and Community Structure Associated with Beaver Ponds in Canaan Valley, West Virginia." *Wetlands Ecology and Management*. 17:543-554.

[55] Naiman, R., C. Johnston, and J. Kelley. 1988. "Alteration of North American Streams by Beaver." *Bioscience*. 38(11):753-762.

[56] Finley, W. 1937. "The Beaver – Conserver of Soil and Water." *Transactions of the American Wildlife Conference*. 2:295-297.

[57] Jakober, M. T. McMahon, R. Thurow, and C. Clancy. 1998. "Role of Stream Ice on Fall and Winter Movements and Habitat Use by Bull Trout and Cutthroat Trout in Montana Headwater Streams." *Transactions of the American Fisheries Society*. 127:223-235.

[58] See, for example: Gard, R. 1961. "Effects of Beaver on Trout in Sagehen Creek, California." Journal of Wildlife Management. 25:221-242; Hodkinson, I. 1975. "Energy Flow and Organic Matter Decomposition in an Abandoned Beaver Pond Ecosystem" Oecologia. 21:131-139; Rutherford, W.

species richness among fish by providing a more diverse range of habitat.[59] Research from New Mexico, Colorado, and California shows that trout are larger and more prevalent in streams with beaver ponds[60]. In basins with salmon populations, research shows that beaver ponds provide preferred habitat among juveniles.[61] Beaver dams may make it more difficult for fish species that spawn in the fall to reproduce. For species that spawn in the spring, however, beaver dams have not been shown to impact reproduction.[62] In the Pacific Northwest, watersheds that lost beaver ponds experienced reduced salmon smolt production, as slow-water habitat is a primary limiting habitat characteristic.[63]

Beaver introduce large woody debris into streams, providing valuable habitat and refugia for resident and migrating fish. Woody debris introduced by beaver provide habitat in the region of their ponds as well as downstream. Large woody debris can also play important roles for morphological stream channel processes important to maintaining habitat diversity[64].

Several studies across the country have established that many amphibian and reptile species prefer waterways with beaver activity to those without it.[65] Beaver

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1955. "Wildlife and Environmental Relationships of Beavers in Colorado Forests." Journal of Forestry. 53:803-806.

[59] Snodgrass, J. and G. Meffe. 1999. "Habitat Use and Temporal Dynamics of Blackwater Stream Fishes in and Adjacent to Beaver Ponds." *Copeia.* 62-639; Collen, P. and R. Gibson. 2001. "The General Ecology of Beavers as Related to their Influence on Stream Ecosystems and Riparian Habitats, and the Subsequent Effects on Fish." *Reviews in Fish Biology and Fisheries.* 10:439:461.

[60] Gard, R. 1961. "Effects of Beaver on Trout in Sagehen Creek, California." *Journal of Wildlife Management*. 25:221-242; Rutherford, W. 1955. "Wildlife and Environmental Relationships of Beavers in Colorado Forests." *Journal of Forestry*. 53:803-806.

[61] Collen, P. and R. Gibson. 2001. "The General Ecology of Beavers as Related to their Influence on Stream Ecosystems and Riparian Habitats, and the Subsequent Effects on Fish." *Reviews in Fish Biology and Fisheries.* 10:439:461; Leidholt-Bruner, K. D. Hibbs, and W. McComb. 1992. "Beaver Dam Locations and their Effects on Distribution and Abundance of Coho Salmon Fry in Two Coastal Oregon Streams." *Northwest Science*. 66:218-223.

[62] Collen, P. and R. Gibson. 2001. "The General Ecology of Beavers as Related to their Influence on Stream Ecosystems and Riparian Habitats, and the Subsequent Effects on Fish." *Reviews in Fish Biology and Fisheries*. 10:439:461.

[63] Pollock, M., G. Pess, T. Beechie and D. Montgomery. 2004. The importance of beaver ponds to coho salmon production in the Stillaguamish River basin, Washington, USA. *North American Journal of Fisheries Managemen*t 24: 749-60.

[64] Abbe, T. and D. Montgomery. 1996. Large woody debris jams, channel hydraulics and habitat formation in large rivers. Regulated Rivers: Research & Management 12: 201-21.

Hilderbrand, R., A. Lemly, C. Dolloff and K. Harpster. 1997. Effects of large woody debris placement on stream channels and benthic macroinvertebrates. Canadian Journal of Fisheries and Aquatic Sciences 54: 931-39.

[65] Karraker, N. and J. Gibbs. 2009. "Amphibian Production in Forested Landscapes in Relation to Wetland Hydoperiod: A Case Study of Vernal Pools and Beaver Ponds." *Biological Conservation*. 142:2293-2302; Popescu, V. and J. Gibbs. 2009. "Interactions between Climate, Beaver Activity, and

ponds have more individual amphibian and reptilian organisms and higher species diversity than similar waterways without beaver activity.[66] A study of frogs and toads found increased numbers in areas of beaver ponds relative to unobstructed streams.[67] Boreal toads have been found to disproportionately use beaver ponds for breeding in parts of southern Utah.[68]

Similarly, beaver activity has been shown to have a positive impact on bird population and species diversity. Bird species typically associated with riparian habitat as well as neotropical migratory birds were found in more abundance and greater diversity near beaver activity than in unmodified waterways.[69] One study found that the diversity of bird species near a beaver pond was three times greater than near an unmodified waterway.[70] Waterfowl, as well, have been shown to prefer habitat impacted by beaver activity to unmodified waterways.[71] Research from Wyoming found that duck density on streams with beaver ponds was 7.5 ducks/km while density on unmodified waterways was only 0.1 ducks/km.[72]

Beaver activity also can increase the abundance and diversity of mammalian species. Small mammals, such as muskrat, otter, mink, vole, shrew, and mouse,

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Pond Occupancy by the Cold-Adapted Mink Frog in New York State." *Biological Conservation.* 142:2059-2068; Metts, B., J. Lanham, and K. Russell. 2001. "Evaluation of Herpetofaunal Communities on Upland Streams and Beaver-Impounded Streams in the Upper Piedmont of South Carolina." *American Midland Naturalist*. 145:54-65.

[66] Metts, B., J. Lanham, and K. Russell. 2001. "Evaluation of Herpetofaunal Communities on Upland Streams and Beaver-Impounded Streams in the Upper Piedmont of South Carolina." *American Midland Naturalist*. 145:54-65.

[67] Stevens, C., C. Paszkowski and A. Foote. 2007. Beaver (castor canadensis) as a surrogate species for conserving anuran amphibians on boreal streams in Alberta, Canada. *Biological Conservation* 134: 1-13.

[68] Fridell, R. A., K. M. Comella, G. N. Garnett, B. A. Zettle, T. K. Smith, and D. L. Harstad. 2000. Boreal toad (Bufo boreas boreas) distribution surveys in southwestern Utah 1994 - 1998. Publication Number 00-10, Utah Division of Wildlife Resources, Salt Lake City, UT.

[69] Cooke, H. and S. Zack. 2008. "Influence of Beaver Dam Density on Riparian Areas and Riparian Birds in Shrubsteppe of Wyoming." *Western North American Naturalist*. 68:365-373; Bulluck, J. and M. Rowe. 2006. "The Use of Southern Appalachian Wetlands by Breeding Birds, with a Focus on Neotropical Migratory Species." *Wilson Journal of Ornithology*. 118:399-410.

[70] Medin, D. 1990. *Bird Populations in and Adjacent to a Beaver Pond Ecosystem in Idaho.* USDA Forest Service Intermountain Research Station Research.

[71] Longcore, J., D. McAuley, G. Pendelton, C. Bennatti. T. Mingo, and K. Stromborg. 2006. "Macroinvertebrate Abundance, Water Chemistry, and Wetland Characteristics Affect Use of Wetlands by Avian Species in Maine." *Hydrobiologia*. 567:143-167; McKinsrtry, M., P. Caffrey, and S. Anderson. 2001. "The Importance of Beaver to Wetland Habitats and Waterfowl in Wyoming." *Journal of the American Water Resources Association*. 37:1571-1577.

[72] McKinsrtry, M., P. Caffrey, and S. Anderson. 2001. "The Importance of Beaver to Wetland Habitats and Waterfowl in Wyoming." *Journal of the American Water Resources Association*. 37:1571-1577.

have been found in higher abundance in beaver-modified waterways throughout the U.S. than in unmodified waterways.[73] In general, the small mammals that benefit from beaver activity are those typically associated with pond, wetland, and riparian habitats. By increasing the amount of these types of habitat, beaver activity creates conditions that can attract and support these species. Beaver activity also can increase the abundance of large mammals, such as bears, deer, elk, moose, and raccoons.[74] Beaver ponds, wetlands, and meadows attract these large mammalian species by providing an abundant vegetative food source and water.

4. Other Effects

In addition to the effects described above related to water quantity, water quality, and habitat, beaver restoration can have impacts on other ecosystem processes related to storm and flood resilience and recreation. We first describe how beaver restoration could increase storm and flood resilience through water regulation, stormwater treatment, and erosion prevention. We then describe how beaver restoration could increase the quantity and quality of recreational opportunities throughout the Escalante Basin. Most impacts on recreation are related to the structural and process effects previously described in this section.

Several studies have concluded that beaver activity in a river system decreases the intensity of major flood events throughout the system. In general, beaver activity causes water to rise more slowly downstream, thus dampening the peak flow during times of flooding.[75] Simulation models looking at how beaver activity impacts the intensity of flooding events has shown that a single beaver pond could reduce peak flow of a two-year flood event by about 5 percent and that a series of several ponds could reduce peak flow by 14 percent.[76] Similar research on the ability of beaver-related wetlands to reduce flooding intensity suggests that beaver activity could reduce the intensity of a flood wave by more than 90 percent.[77]

Despite their potential ability to reduce the intensity of some floods, beaver activity likely will not completely eliminate the likelihood of future flooding

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[73] Leighton 1933, Rutherford 1955, Neff 1957, Dubuc et al. 1990, McKinstry et al. 1997, Rosell et al. 2005; Medin and Clary 1991, Suzuki and McComb 2004; Medin and Clary 1991

[74] Rosell, F., O. Bozser, P. Collen, and H. Parker. 2005. "Ecological Impact of Beavers and their Ability to Modify Ecosystems." *Mammal Review*. 35:248-276.

[75] Beedle, D. 1991. "Physical Dimensions and Hydrologic Effects of Beaver Ponds on Kuiu Island in Southeast Alaska." Oregon State University; Gurnell, A. 1998. "The Hydrogeomorphological Effects of Beaver Dam-Building Activity." *Progress in Physical Geography*. 22(12):167-189.

[76] Beedle, D. 1991. "Physical Dimensions and Hydrologic Effects of Beaver Ponds on Kuiu Island in Southeast Alaska." Oregon State University

[77] Hillman, G. 1998. "Flood Wave Attenuation by a Wetland Following a Beaver Dam Failure on a Second Order Boreal Stream." *Wetlands*. 18:21-34.

events in the basin. Beaver activity may, however, reduce the overall impact of future flooding events by improving the water quality of the flood waters. Previously, we described how beaver dams would retain suspended sediment within the basin's waterways. In doing so, the dams would capture harmful pollutants and improve water quality downstream. In general, the negative impacts of floods from rivers with poor water quality are larger than those with better water quality. So, to the extent that beaver activity improves downstream water quality, it likely also would decrease the negative impacts associated with future flooding events.

The improvements to water quality, water quantity, and habitat likely would all contribute to substantial improvements in the quality and quantity of recreation opportunities in the Escalante Basin. Research suggests that beaver activity increases the diversity and quantity of wildlife in the surrounding area. Many of the recreational opportunities provided within the basin are based on wildlife. In some cases, beaver activity may increase the quantity of species sought by hunters and anglers. Sensitive species in the basin may also benefit from the improved quantity and quality of habitat from beaver restoration. Species associated with wildlife watching may also proliferate in the new habitats surrounding beaver activity. In addition to generating recreational benefits associated with fish and wildlife, beaver activity may change the timing of water flows and create water-related recreational benefits downstream. If, for example, beaver activity promotes perennial stream flows in a previously dry stream, the number of water-based recreation days in the area likely would increase.

III. Benefits of Ecosystem Services

Beavers, like any species, interact with and often cause some sort of change in the surrounding environment. In the previous section, we describe some of those interactions and how beaver restoration in the Escalante Basin may affect water quantity, water quality, habitat, and other ecosystem structures and processes. In this section, we describe the difference between the environments in two scenarios: a 'with beavers scenario' in which beavers are repopulated throughout the Escalante Basin and a 'without beavers scenario' in which beaver populations are historically low, as they are now. First, we describe our conceptual framework for evaluating the differences between scenarios and the techniques used to place values on the scenarios. Second, we describe the values associated with differences in specific services provided by the environment such as the regulation of water flow and the provision of habitat. Third, we describe the values associated with changes in ecosystem-wide services, such as wetlands and riparian forests that may result from beaver activity. Table 15 lists the ecosystem services associated with beaver activity identified in the literature and described in the previous section, the services we quantify, and the services we monetize in this section.

Table 15. Summary of Effects and Services Identified, Quantified, and Monetized

Beaver Ecosystem Effects Quantified	Beaver Ecosystem Services Identified in the Literature and Described Qualitatively	Beaver Ecosystem Services Monetized
Structural Effects • Number of Colonies • Number of Dams • Pond Size • Wetland Creation • Riparian Creation **Process Effects** • Water Storage • Sediment Capture • Water Temperature • Habitat Creation	**Water Quantity** • Regulation of Quantity • Regulation of Timing **Water Quality** • Sediment Retention • Pollutant Storage • Temperature Reduction • Filtration **Habitat** • Invertebrate Habitat • Fish Habitat • Reptile Habitat • Amphibian Habitat • Bird Habitat • Mammal Habitat **Other Services** • Flood Mitigation • Recreation	**Water Quantity** • Water Storage **Water Quality** • Sediment Retention • Pollutant Storage • Temperature Reduction **Habitat** • Riparian Habitat • Wetland Habitat • Aquatic Habitat **Other Services** • Recreation

A. Values of Specific Ecosystem Services

In this section, we identify the demand for the various services associated with beaver activity. Toward this end, we rely on the earlier discussions of the potential effects of beaver activity on the structure and processes of ecosystems in the Escalante Basin. Where sufficient data exist, we quantify the economic values of specific goods and services associated with the potential effects of beaver restoration on these structures and processes. Where they do not, we provide a qualitative description of the goods and services and of their potential economic importance.

1. Water Quantity

Reduced Sedimentation in Reservoirs

Sedimentation in Wide Hollow Reservoir provides benefits that would be representative of other reservoirs in the basin. When constructed, the reservoir had a capacity of about 2,400 acre-feet. Since then, the capacity has decreased by about 1,000 acre-feet due to the accumulation of about 43.5 million cubic feet of sediment.[78] Annually, the reservoir loses 0.9 percent of its original capacity to sedimentation, a rate nearly 5 times higher than the average sedimentation rate for the rest of Utah's reservoirs.[79] There is currently a proposal to increase the size of the Wide Hollow Dam to recover the reservoirs original storage capacity. The estimated cost of the project is about $13 million.[80]

The Utah Department of Natural Resources estimates that in 2008, agricultural production relying on the Wide Hollow Reservoir experienced $270,000 less net farm income than had the reservoir been able to reach its original capacity of 2,400 acre-feet. Factoring in the economic multiplier associated with agricultural production, they estimate nearly $720,000 in income was lost throughout the area due to the reservoir's sediment build up.[81] If sediment continues to build up in the reservoir and the reservoir's capacity continues to dwindle, the annual economic losses likely will continue to increase. Beaver activity upstream of the reservoir could reduce these future losses by preventing further decreases in the reservoir's capacity.

We estimate that there are about 400 miles of creeks, streams, and rivers upstream of the point at which the Wide Hollow Dam diverts water to the reservoir. Following assumptions previously described, we estimate that, if fully restored, the waterways upstream of the reservoir could have nearly 9,000 beaver dams. Furthermore, these beaver dams could retain about 1–3 million cubic feet

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[78] U.S. Army Corps of Engineers, Sacramento District. 2010. Final Environmental Assessment: Wide Hollow Water Supply Storage Facility Project. January.

[79] Utah Department of Natural Resource. 2010. *Managing Sediment in Utah's Reservoirs*. March.

[80] Utah Department of Natural Resources. 2010. *Managing Sediment in Utah's Reservoirs*. March.

[81] Utah Department of Natural Resources. 2010. *Managing Sediment in Utah's Reservoirs*. March.

of sediment per year depending on the size of beaver ponds. While beaver dams likely would not prevent all sedimentation in the reservoir, our estimates suggest that it could substantially reduce the historical sedimentation rate. By preventing sedimentation in the reservoir, beaver dams likely would reduce the future costs associated with reservoir maintenance and would reduce the amount of revenue lost by agricultural and other related industries due to diminished reservoir capacity.

Reduced Suspended Sediment Basin-Wide

Sediment capture by beaver ponds in the Escalante Basin provides benefits beyond Wide Hollow Reservoir, as suspended sediment increases turbidity, inhibits plant growth, clogs fish gills, inhibits fish feeding, increases water temperature, and increases concentrations of harmful pollutants. We discuss values associated with changes in specific elements of water quality in the following section. Here we estimate the value of sediment retention in beaver dams by estimating the avoided cost of dredging that sediment downstream.

In previous sections we estimate that, basin-wide, beaver activity has the potential to retain 204 million – 549 million cubic feet of sediment. To estimate the value of this service, we assume that if that sediment wasn't captured by beaver dams, it would be dredged out of the waterway further downstream. Research suggests that dredging costs about $2 per cubic yard of sediment removed.[82] Assuming all of the sediment retained by beaver activity in the basin would be dredged if allowed to flow through the basin, dredging costs of $15–40 million per year could be avoided.

Timing of Water Flow

We estimate that beaver dams could change the flow patterns of 2,700–509,000 acre-feet of water per year, depending on overall precipitation patterns, by storing water in pools and slowly releasing it later in the year. In some cases, this regulation of water flow has transformed waterways with intermittent water flows into perennial streams. Demand for more consistent water flows takes many forms. More consistent water flow likely would allow reservoirs to store more water, on an annual basis, than the existing water flow scenario in which flows peak in late May and dwindle throughout the rest of the year. With more water stored in reservoirs, the agricultural sector in the area would have a more robust and more secure water source for irrigation, which likely would increase revenues in the sector as well as other industries in the region reliant on the success of agriculture.

Figure 15 shows the average end-of-month storage volume of Wide Hollow. The reservoir's volume slowly increases during autumn and winter. After March, however, its volume rapidly decreases as water is used for irrigation throughout the northern portion of the basin. Since being built in 1954, the reservoir's

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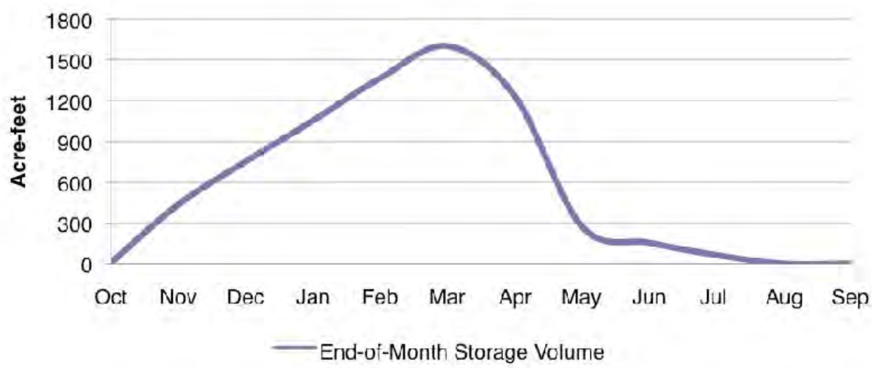
[82] Utah Department of Natural Resources. 2010. *Managing Sediment in Utah's Reservoirs*. March.

capacity has decreased from about 2,400 acre-feet to 1,400 acre-feet due primarily to sediment buildup. A proposal to increase the size of the dam and restore the Reservoir's original capacity is currently under review. The project would cost about $13 million to complete.[83] If the historical sedimentation rate in the reservoir continues into the future, the project would essentially increase the capacity of the reservoir by 500 acre-feet over the next 50 years. Furthermore, if we assume that the project would increase the total volume of water stored annually by 500 acre-feet over the next 50 years, the price of water would be about $520 per acre-foot.[84] If we consider the future water supply discounted at 3 percent, the current price paid for each annual acre-foot of capacity increases to $980. We use the value of $520 for valuation below as a conservative estimate.

Figure 15. Wide Hollow Reservoir's Average End-of-Month Storage Volume



Source: U.S. Army Corps of Engineers, Sacramento District. 2010. Final Environmental Assessment: Wide Hollow Water Supply Storage Facility Project. January.

We estimate that each beaver dam could hold about 0.3–.9 acre-feet of water at any given time. Furthermore, we estimate that there could be up to 9,000 beaver dams upstream of the Wide Hollow Reservoir. Combined, these dams could store 2,700–8,100 acre-feet of water at any given time. Beaver dams fill and release water repeatedly during the year, but we assume one fill and release on net per year. Applying the conservative water value derived from the cost of the dam project ($520 per acre-foot), the beaver dams upstream of the Reservoir could augment the reservoir by storing water with a value of $1.4 million - $4.2 million each year. Table 16 lists some of the water quantities that may be stored in beaver pools throughout the basin. To the extent that no future human built surface storage would be allowed, the avoided cost of storage approaches typical costs for "new" water supply in terms of desalination or recycling, which would double these benefit estimates.

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[83] U.S. Army Corps of Engineers, Sacramento District. 2010. Final Environmental Assessment: Wide Hollow Water Supply Storage Facility Project. January.

[84] To estimate the value of the water stored due to the dam project, we divide the cost of the dam project ($13 million) by the total increase in the volume of water stored (25,000 acre-feet).

Table 16. Estimated Volume of Beaver Ponds and Value of Alternative Water Sources

Volume of Water Stored by Beaver Activity	
Volume of the Average Beaver Pond	0.3–0.9 acre-feet
Total Volume of Beaver Ponds Upstream of Wide Hollow Reservoir	2,700–8,100 acre-feet
Total Volume of All Beaver Ponds in Basin	20,000–60,000 acre-feet
Value of Alternative Water Sources	
Value of Water Provided by the Wide Hollow Dam Project	$520 per acre-foot
Desalination	$2,000–$3,000 per acre-foot
Water Reuse	$300–$1,300 per acre-foot

Source: ECONorthwest with data from U.S. Army Corps of Engineers, Sacramento District. 2010. Final Environmental Assessment: Wide Hollow Water Supply Storage Facility Project. January; Brown, T. 2004. The marginal economic value of streamflow from national forests. Disc. Pap. DP-04-1, RMRS-4851. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station.

Table 16 also shows the potential water volume stored and released during times of non-peak flow or infiltrated into the groundwater. This water would be available for domestic and commercial use, as well as instream flows. More consistent water flows would also benefit wildlife in the basin by providing more consistent and secure food sources and habitat. Specific impacts on habitat and other impacts on wildlife are discussed later in this section. The enhanced wildlife likely would have additional impacts on the quality and quantity of recreation opportunities, aesthetic resources, and quality of life. These effects are also discussed later in this section.

Aquifer Recharge

While beaver-dam activity might decrease the total quantity of surface water flowing downstream, it is likely to increase the total regional groundwater capacity. Groundwater research in the basin reveals connectivity of the upper watershed with lower reaches of the basin via groundwater.[85] Beaver dams increase groundwater levels during both periods of high and low flows, leading to increased downstream baseflows.[86] It is therefore likely that beaver dams would increase groundwater availability. The communities of Escalante and Boulder rely on groundwater for their water supply, suggesting this would have

85 Wilberg, D., B. Stolp and R. Geological Survey, Va. 2005. Seepage investigation and selected hydrologic data for the Escalante River Drainage Basin, Garfield and Kane counties, Utah, 1909-2002: United States Geological Survey.

86 Westbrook, C., D. Cooper and B. Baker. 2006. Beaver dams and overbank floods influence groundwater-surface water interactions of a rocky mountain riparian area. Water Resources Research 42: W06404.

a noticeable benefit if not immediately, in the future.[87] Appropriate avoided costs for valuing this water would be based on the best available opportunities for providing new water supplies otherwise. All surface water and groundwater rights are fully appropriated in the Escalante Basin, including downstream flows to the Colorado River.[88]

Considering the full allocation of water rights for the basin, it is appropriate to think that new opportunities would rely upon water reuse or complex downstream contracts involving funding for desalination, both of which would be expensive (see Table 16) and of lower quality. We use the demonstrated cost of water captured by Wide Hollow Reservoir as a conservative cost estimate, even though water rights are not available to allow such additional direct surface capture. In our discussions with water law experts for Utah, all believe that storage by beaver ponds would not be considered an infringement on existing rights, although human improvements to beaver dams are not allowed.[89]

2. Water Quality

Sediment Capture and Pollutant Removal

The suspended sediment typically retained in beaver pools is full of nitrogen, phosphates, fecal coli form, heavy metals, and other pollutants commonly associated with agricultural runoff, sewage, and livestock.[90] By trapping this sediment in pond floors, beaver dams effectively remove suspended sediment from the basin's waterways. Removal of potentially harmful pollutants from the basin's waterways, in general, increases water quality throughout the basin. There are many state and federal regulations identifying maximum concentrations of various pollutants in waterways. While the Escalante River does not currently exceed maximum thresholds for pollutants, removing additional pollutants would nonetheless improve the basin's water quality, and protect it as future conditions, including climate change and increased public usage, potentially increase pollutant loads.

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[87] City-Data.com. 2010. http://www.city-data.com/city/Escalante-Utah.html, http://www.city-data.com/city/Boulder-Utah.html

[88] Utah Division of Water Rights. 1947-1970. Beaver River/Escalante Valley Adjudication (Iron County Civil No. 630504415). http://www.waterrights.utah.gov/adjdinfo/pdbook.asp; and Utah Division of Water Rights. 2008. Escalante River – Area 97. http://www.waterrights.utah.gov/wrinfo/policy/wrareas/area97.html

[89] See Vogrin, B. 2010. Backyard pond drained to appease water cops. *The Gazette*. Colorado Springs, CO. April 21.

[90] Skinner, Q., J. Speck, M. Smith, and J. Adams. 1984. "Stream Water Quality as Influenced by Beaver within Grazing Systems in Wyoming." *Journal of Range Management*. 37::142-146; Collen, P. and R. Gibson. 2001. "The General Ecology of Beavers as Related to their Influence on Stream Ecosystems and Riparian Habitats, and the Subsequent Effects on Fish." *Reviews in Fish Biology and Fisheries.* 10:439:461; Muller-Schwarze, D. and L. Sun. 2003. *The Beaver: Natural History of a Wetlands Engineer*. Cornell University Press, Ithaca.

Ecosystem services that provide improvements in water quality can have several different sources of economic value based upon the types of demand for clean water. Figure 16 shows some of those relationships. A river that is safe to swim in, for example, derives use value from households as well as passive use value based on feelings of altruism for future generations. A river that provides fish safe to eat, on the other hand, derives use value from households as well as markets along with the passive use values attributable to altruism for future generations.

Figure 16. Water Quality Categories and Economic Value Types

Water Quality Services	Economic Value for Water Quality Improvements				
	Use Related Services			Passive-Use Related Services	
	Market Production	Household Production	Public Sector Production	Existence and Intrinsic Values	Altruism and Bequest Motives
Primary Contact Recreation (Swimmable)		X			X
Secondary Contact Recreation (Boatable, Fishable)		X			X
Agricultural Water Supply	X				X
Industrial Water Supply	X				X
Public Water Supply			X		X
Aesthetics	X	X			X
Fish Consumption	X	X			X
Aquatic Life				X	X

Source: Van Houtven, G. J. Powers, and S. Pattanayak. 2007. "Valuing Water Quality Improvements in the United States Using Meta-Analysis: Is the Glass Half-Full or Half-Empty for National Policy Analysis?" *Resource and Energy Economics*. 29:206-228.

One way to estimate the value of improved water quality is to estimate the public's willingness to pay for it. Typically, waterways are split into four categories depending on their water quality: non-boatable, boatable, fishable, and swimmable. A 1993 study found that households would be willing to pay about $160 per year to maintain boatable water quality. Furthermore these households would be willing to pay an additional $120 per year to improve the water quality to fishable conditions, and another $135 per year to improve the fishable waters to swimmable status.[91] In addition, households place a value on

[91] Carson, R. and R. Mitchell. 1993. "The Value of Clean Water: The Public's Willingness to Pay for Boatable, Fishable, and Swimmable Quality Water." *Water Resources Research*. 29(7): 2445-2454.

water quality in rivers that is about twice the value they place on water quality in lakes. This study estimated that households would be willing to pay about $28, annually, to improve the water quality in a nearby river by 1 percent.[92] Other studies have found comparable values associated with household willingness to pay for improvements in water quality.[93] Individuals traveling to the area for recreation would also benefit from improvements in water quality. Research from the East coast found that a new policy that promised to improve water quality and increase fish catch increased consumer surplus (value beyond prices paid) associated with water-based recreation by about $30 from $73 to $103 per trip.[94]

The values associated with improvements in water quality described above likely underestimate the value of transforming a stream with intermittent water flow to a stream with perennial flow. Similarly, the values likely overestimate the value of small improvements in water quality. Research suggests, however, that household are willing to pay positive sums of money for marginal improvements in water quality even if those improvements do not significantly change the potential uses of the waterway. In the Escalante Basin, the water quality in most waterways likely would not improve dramatically with beaver restoration. Even slight improvements, however, likely have economic value. Based on household willingness-to-pay $28 per year for a 1 percent increase in water quality, improvements in the basin impacting households in Garfield and Kane Counties would be worth $100,000 per year per percent improvement.[95]

Water Temperature

Water temperature is one aspect of water quality that is particularly valuable in the Escalante Basin, particularly for cold water game fish and other aquatic life. The Utah Department of Water Quality management plan for the Escalante Basin focuses on water temperature.[96] As previously described, efforts are being made at the state level to reduce the water temperature in the upper Escalante River to meet state guidelines. To reduce water temperature, the state is organizing and funding projects aimed at improving stream channel stability and minimizing

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[92] Magat, W. J. Huber, W. Viscusi, and J. Bell. 2000. "An Iterative Choice Approach to Valuing Clean Lakes, Rivers, and Streams." *Journal of Risk and Uncertainty.* 21(1):7-43.

[93] Van Houtven, G. J. Powers, and S. Pattanayak. 2007. "Valuing Water Quality Improvements in the United States Using Meta-Analysis: Is the Glass Half-Full or Half-Empty for National Policy Analysis?" Resource and Energy Economics. 29:206-228.

[94] Whitehead, J. 2000. "Measuring Recreation Benefits of Quality Improvements with Revealed and Stated Behavior Data." *Resource and Energy Economics*. 24(4):339-354.

[95] There are about 3,800 household in Garfield and Kane Counties. If each household is willing to pay $28 for each percent improvement in water quality, they would, as a whole, be willing to pay $107,000 per year.

[96] Utah Department of Environmental Quality, Division of Water Quality. 2004. *Escalante River Watershed Water Quality Management Plan.* Prepared by Millennium Science and Engineering, Inc., and Pocket Water Inc., Salt Lake City.

stream band erosion to enhance stream flows, and enhancing riparian corridor. The management plan recommends revising the beneficial use category to 3B - warm water fishery, which would reduce the necessary amount of temperature reduction.

In 2000, the U.S. Forest Service estimated restoration costs associated with streambank stabilization and riparian management in Gifford-Pinchot National Forest in Washington. They estimated total costs for river restoration would be about $74,000–$411,000 per river mile.[97] These costs include planning and design, materials, mobilization, equipment, labor, riparian planting and maintenance, and instream structure maintenance.

Table 5 provides the Best Management Practices identified to improve water temperature as part of the Management Plan for the Escalante Basin. These restoration goals are all services that could be provided by dam-building beaver activity. We estimate that there are about 1,400 miles of creeks, streams, and rivers flowing into and through the northern portion of the Escalante Basin contributing to infractions of water temperature regulations. While restoration likely is not necessary along each mile of waterway in this area, some areas likely will require restoration to meet water temperature goals. If, for example, 10 percent of the waterways, about 140 miles, require restoration, costs could be as high as $10 million – $58 million. If beaver restoration has the capacity to reduce water temperature below the maximum threshold, it could save the state tens of millions of dollars in restoration costs that it would otherwise have to fund.

4. Recreation Benefits

Beaver restoration likely would have several impacts on recreational benefits derived within the Escalante Basin. Improved water quantity and water quality characteristics likely would improve the quantity and quality of habitat for several recreationally important species throughout the basin. Demand for hunting permits in the area exceeds the number of permits granted (See section I.C.3 of this report). In 2010, for example, only about 25 percent of the 3,635 hunting permits for big game were granted. If the structural and process effects of beaver restoration increase the prevalence of species associated with hunting demand, the state may increase the number of permits it grants to hunters in the region. Similarly, many people enjoy the fishing opportunities offered in the Escalante Basin. There are insufficient data available to quantify the number of potential fishers in the area, but the high prevalence of fishing guides in the area and associated marketing is an indicator. Research suggests that any increase in the quantity or quality of fishing opportunities in a river system is valuable to existing and potential future fishermen, and anecdotal reports by anglers and

[97] Bair, B. 2004. *Stream Restoration Cost Estimates*. US Department of Agricultural, Forest Service. Gifford-Pinchot National Forest.

guides in the basin corroborate this.[98] Table 17 describes some values associated with hunting and fishing in Utah both by residents and non-residents.

Table 17. Average Recreation Expenditures in Utah

		Utah Residents	Nonresidents
Fishing	Average Fishing Days per Angler	12	5
	Trip-related Expenditures per Angler	$464	$745
	Equipment and Other Expenditures per Angler	$648	$178
	Total Expenditures per Angler per Day	$93	$185
Hunting	Average Hunting Days per Hunter	11	4
	Trip-related Expenditures per Hunter	$454	$515
	Equipment and Other Expenditures per Hunter	$1,441	$477
	Total Expenditures per Hunter per Day	$173	$248
Wildlife Watching	Average Wildlife Watching Days per Participant	12	5
	Trip-related Expenditures per Participant	$251	$922
	Equipment and Other Expenditures per Participant	$407	$564
	Total Expenditures per Participant per Day	$55	$297

Source: U.S. Fish and Wildlife Service. 2008. Utah National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, Utah. May.

The benefits of recreation are worth at least as much as the expenditures to undertake them. Table 18 lists estimated consumer surplus values derived from recreation activities popular in the basin. [99] To the extent that beaver restoration increases the quantity and/or quality of opportunities to engage in these forms of recreation, the total value and net benefits derived from recreation in the basin likely will increase. While technically costs, some of the expenditures associated with recreation represent demand for goods and services provided locally, and generate jobs and income.

[98] See, for example: Davis, R. 1963. "Recreation Planning as an Economic Problem." Natural Resources Journal. 3:239-249; Hushak, L., J. Winslow, and N. Dutta. 1988. "Economic Value of Great Lakes Sportfishing: The Case of Private-Boat Fishing in Ohio's Lake Erie." Transactions of the American Fisheries Society. 17:363-373; Stoll, J. 1983. "Recreational Activities and Nonmarket Valuation: The Conceptualization Issue." Southern Journal of Agricultural Economics. 119-125.

[99] The amount of money recreationists pay to enjoy the region's recreational goods and services is usually less than what they are willing to pay. The difference between what they would be willing to pay and what they actually pay to participate in a recreation activity represents consumer surplus, a net benefit.

5. Aesthetic Benefits

Individuals who live adjacent to, nearby, or within view of the waterways within the basin enjoy benefits, such as scenic views and access to recreational opportunities. To a certain extent, the value of these household amenities is incorporated into the market price of a property. In some cases, however, the market price may not fully account for the value people derive from them. Where beaver restoration improves the quality or quantity of amenities adjacent to, nearby, or within view of the basin's residents, it could increase property value. If, for example, a resident of Escalante or Boulder owns a home adjacent to a stream with intermittent flows, and beaver restoration leads to permanent water flow through the stream, the homeowner likely will benefit in two ways. First, the value of the resident's home and property likely will increase resulting from the increase in amenities nearby. Second, the resident will absorb the amenity value not reflected in the increase in property value.

Table 18. Consumer Surplus of Various Recreation Activities ($/Day)

	Intermountain Area	U.S. Average
Camping	$43	$38
Picnicking	$43	$38
Swimming	$24	$18
Sightseeing	$43	$38
Off-road driving	$21	$16
motor boating	$43	$38
float boating	$61	$55
Hiking	$43	$38
Biking	$25	$19
Downhill Skiing	$43	$38
Cross Country Skiing	$36	$30
Snowmobiling	$17	$11
Big Game Hunting	$63	$57
Small Game Hunting	$43	$38
Water Fowl Hunting	$56	$50
Fishing	$52	$47
Wildlife Viewing	$43	$38
Horseback Riding	$43	$38
Rock Climbing	$122	$116
General Recreation	$43	$38
Other Recreation	$43	$38

Source: Rosenberger, R., and J. Loomis. 2001. *Benefit Transfer of Outdoor Recreation Use Values: A Technical Document Supporting the Forest Service Strategic Plan (2000 Revision)*. General Technical Report: RMRS-GTR-72. U.S. Department of Agriculture, Forest Service.

6. Existence Values

The national and international prominence of the Grand Staircase-Escalante Monument, heightened by the designation and political activity but driven by the unique and stunning landscape, generates wide-reaching demand for protection of the structure and ecological function of the region. People care about the continued undisturbed existence of rare and scenic areas such the Escalante Basin. People also hold option values for these areas in the hope of potentially visiting them at some point. The presence of threatened and endangered species in the area heightens this concern.

Sensitive Species

Beaver activity in the basin likely will increase the quantity and quality of pond, wetland, and riparian habitat. These habitat improvements likely will assist in the recovery of a number of sensitive species found throughout the basin. Economic research has shown that people place a considerable value on the continued survival of endangered and threatened species. Table 19 describes some of the values associated with a wide range of threatened, endangered, and rare species. The values are in terms of household willingness to pay to protect each species. In most instances, the species in Table 19 do not match up directly to sensitive species found in the Escalante Basin although parallels exist, such as Colorado River cutthroat trout similar to values reported elsewhere for salmon and steelhead. The data, however, serve to provide support for the notion of value attributable to sensitive species including those in the Escalante Basin.

There are several sensitive plant species in the basin, however there is little literature describing the economic value of these species. Research suggests that the household willingness to pay to protect sensitive plant species is lower than their willingness to pay for mammals and birds, but likely higher than their willingness to pay for insects or reptiles.[100] Furthermore, there are many recorded instances of private and public funding spent on efforts aimed at protecting sensitive plant species, this spending provides evidence a general demand from the public to protect sensitive plant species.[101] In addition, special management actions to protect sensitive species often create additional costs for governments, firms, and households.[102]

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100 Martin-Lopez, B., C. Montes, and J. Benayas. 2007. "The Non-Economic Motives Behind the Willingness to Pay for Biodiversity Conservation." *Biological Conservation*. 139(1-2): 67-82.

101 Hounslow, E. *What is a Charismatic Plant?* Dissertation.

102 Wilcove, D. and L. Chen. 1998. "Management Costs for Endangered Species." *Conservation Biology*. 12(6): 1405-1407.

Table 19. Household Willingness to Pay for Sensitive Species

Species	Annual Willingness to Pay	Lump Sum Willingness to Pay
Arctic Grayling	–	$24
Bald eagle	$41	$316
Bighorn sheep	$18	–
Dolphin	$38	–
Falcon	–	$34
Gray whale	$37	–
Humpback whale	–	$255
Monk seal	–	$177
Owl	$69	–
Salmon/Steelhead	$86	–
Sea lion	$76	–
Sea otter	$43	–
Sea turtle	$20	–
Seal	$37	–
Silvery Minnow	$40	–
Squawfish	$13	–
Striped Shiner	$9	–
Turkey	$14	–
Anadromous fish (WA)	$256	–
Whooping crane	$60	–
Wolf	–	$65
Woodpecker	$17	–

Source: Richardson, L., and J. Loomis. 2009. "The Total Economic Value of Threatened, Endangered and Rare Species: An Updated Meta-Analysis." *Ecological Economics*. 68(5): 1535-1548.

B. Values of Ecosystem-wide Ecosystem Services

So far, we have described specific services potentially provided by beaver restoration in the Escalante Basin. Here, we present examples of how these values can accumulate within a specific ecosystem, and how that ecosystem can then be valued. Valuation by land type is difficult and relies on several strong assumptions. For example, it often assumes homogeneity of ecosystem services provided throughout the area in consideration. Oftentimes, however, the ecosystem services provided by a land type vary, sometimes dramatically, due to specific characteristics within the area in consideration and the affected population. Thus, the estimates of value for different land types necessarily embody considerable uncertainty.

1. Riparian Habitat

Riparian forests (the vegetated areas adjacent to rivers and streams) provide several different types of ecosystem services. One way to estimate the values of these ecosystem services is to evaluate the willingness of individuals, municipalities, or other agencies to pay for restoring riparian habitat. Portland, OR avoided purchasing a $200 million filtration treatment system for its water supply by protecting 102 square miles of its watershed. This avoided cost constitutes an economic benefit of $3,000 per acre for water filtration services.[103] Similarly, Clean Water Services, a water-resource management utility in northwestern Oregon avoided investing in a chiller for a water treatment plant on the Tualatin River by planting riparian vegetation to shade and cool the river, for a savings of $50 million.[104]

Previously, we described costs associated with restoring streams and creeks to assist in efforts aimed at reducing water temperatures in the Escalante River. Those costs were about $74,000–$411,000 per river mile.[105] We estimate that of those costs, activities dealing specifically with riparian restoration are about $45,000–$230,000 per river mile, suggesting that these areas are worth at least that much if others are willing to spend those funds restoring them. Yet another estimate of the value of riparian habitat, based on the net primary productivity of various landscapes in the U.S. National Wildlife Refuge System, suggests that the ecosystem service values of forests, generally, may be about $850 per acre per year. [106] These estimates come from meta-analyses of many individual site-specific studies. Riparian areas are unique in that they interact with aquatic systems and thus provide more services than general forests. For our analysis, we assume that riparian areas are only slightly more valuable than general forests, and make a conservative estimate of $1,000 per acre per year for the value of services provided by riparian areas.

The literature suggests that each beaver pond could generate 2.5–6.8 acres of new riparian habitat. Basin-wide, these estimates suggest that beaver activities could generate about 175,100–469,900 acres of new riparian habitat. Table 20 shows how some of the values associated with the services riparian areas provide, described above, could relate to the basin. Depending on the method of valuation, we estimate that the economic value new riparian habitat generated

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[103] ECONorthwest, with data from the Portland Water Bureau, http://www.portlandonline.com/water/index.cfm?c=29784; and Krieger, D. 2001. *Economic Value of Forest Ecosystem Services: A Review.* The Wilderness Society.

[104] Niemi, E., K. Lee and T. Raterman. *Net Economic Benefits of Using Ecosystem Restoration to Meet Stream Temperature Requirements.* ECONorthwest.

[105] Bair, B. 2004. *Stream Restoration Cost Estimates.* US Department of Agricultural, Forest Service. Gifford-Pinchot National Forest.

[106] Ingraham, M. and S. Foster. 2008. "The Value of Ecosystem Services Provided by the U.S. National Wildlife Refuge System in the Contiguous U.S." *Ecological Economics*. 67:608-618.

by beaver activity could be $219 million – $1.4 billion, as a one-time payment, or $175 million – $470 million per year.

Table 20. Water Quality Values, Per Unit and Basin-Wide

Method of Valuation	Unit Value	Basin-wide Value
Water Filtration Services	$3,000 per acre	$525 mil. – $1.4 bil.
Avoided Riparian Restoration Costs	$45,000–$230,000 per river mile	$219 mil. – $1.2 bil.
Base Value of Net Primary Productivity	$1,000 per acre per year	$175 mil. – $470 mil.

Source: ECONorthwest with data from the Portland Water Bureau, http://www.portlandonline.com/water /index.cfm?c= 29784; Krieger, D. 2001. *Economic Value of Forest Ecosystem Services: A Review.* The Wilderness Society; Bair, B. 2004. *Stream Restoration Cost Estimates*. US Department of Agricultural, Forest Service. Gifford-Pinchot National Forest; Ingraham, M. and S. Foster. 2008. "The Value of Ecosystem Services Provided by the U.S. National Wildlife Refuge System in the Contiguous U.S." *Ecological Economics*. 67:608-618.

Notes: To estimate avoided riparian restoration costs, we assume that riparian forests created by beaver activity would be the same as restoring about 10% of the riparian habitat in the basin.

2. Wetland Habitat

Wetlands are a well-studied habitat type that provides well-documented values for some of the types of ecosystem services provided by beaver restoration. Table 21 provides several estimated values for the ecosystem services provided by wetlands. The first set of rows estimates the values associated with several different wetlands that researchers assumed provide only a single type of service. In many cases, a wetland may provide multiple services, however. The range of values associated with single-service wetlands is about $18–$9,200 per acre per year. Another estimate, based on the net primary productivity of various landscapes in the U.S. National Wildlife Refuge System suggests that the ecosystem service values of wetlands, generally, may be about $2,400–$12,400 per acre per year. [107] These estimates come from meta-analyses of many individual site-specific studies. From a consideration of expenditures, a review by the Environmental Law Institute of U.S. Army Corps of Engineers average expenditures per-acre for wetland restoration projects in the district including the Escalante Basin found a range of $110,000 to $183,000. [108] For our analysis, we assume the value of wetlands generated from beaver activity is in the middle of the range suggested by the literature, about $8,000 per acre per year.

The literature suggests that each beaver pond could generate 0.9–6.4 acres of wetland habitat. The Escalante topography likely does not lend itself to such per-

[107] Ingraham, M. and S. Foster. 2008. "The Value of Ecosystem Services Provided by the U.S. National Wildlife Refuge System in the Contiguous U.S." *Ecological Economics*. 67:608-618.

[108] Environmental Law Institute. 2007. "Mitigation of Impacts to Fish and Wildlife Habitat: Estimating Costs and Identifying Opportunities." October.

pond acreage, so we reduce the top end estimate by half to 3.2. Basin-wide, these estimates suggest that beaver activities could generate about 60,400–217,250 acres of wetland habitat. The widest range of values associated with wetlands, $18–$12,400 per acre per year, suggests that the value of wetlands created by beaver activities in the basin could be about $1.1 million–$2.7 billion per year. Using the middle value of $8,000 per acre per year, we estimate the value of wetlands created by beaver activity in the basin to be about $483 million–$1.7 billion per year. It is important to note, however, that these values are not entirely traded in markets. In other words, while some of the value associated with wetlands is derived from money changing hands, some of it (potentially most of it) is derived through consumer surplus and other non-market interactions.

Table 21. Value of Ecosystem Services Associated with Wetland Habitat ($/Acre/Year)

Single-Service Wetlands		
Single-Service Wetland Type	**Mean Value**	**Range of Values**
Flood Attenuation	$645	$146–$2,865
Water Quality	$684	$207–$2,260
Water Quantity	$208	$10–$4,216
Recreational Fishing	$585	$156–$2,201
Commercial Fishing	$1,276	$177–$9,214
Bird Hunting	$115	$41–$323
Bird Watching	$1,988	$866–$4,562
Amenity	$5	$2–$23
Habitat	$502	$156–$1,609
Storm Protection	$389	$18–$8,433
General Wetlands from U.S. National Wildlife Refuge System		
Base Value of Net Primary Productivity		$2,400–$12,400

Source: Woodward, R., and Y. Wui. 2001. "The Economic Value of Wetland Services: A Meta-Analysis". Ecological Economics.. 37: 257-270; and Ingraham, M. and S. Foster. 2008. "The Value of Ecosystem Services Provided by the U.S. National Wildlife Refuge System in the Contiguous U.S." Ecological Economics. 67:608-618.

3. Aquatic Habitat

The literature on ecosystem service values associated with aquatic habitat (in this case, ponds forming upstream of beaver dams) is sparse. In many instances, the ecosystem services provided by beaver ponds would be similar to those provided by the surrounding wetlands. Beaver ponds may not, however, provide all of the benefits provided by wetlands, and vice versa. The main ecosystem service benefits provided by ponds include water storage, sediment capture, water purification, and habitat. In some cases, where data are sufficient, we quantify and monetize these benefits in other sections of our analysis. Here we examine aquatic habitat more generally, and estimate the value of ecosystem services provided by ponds by applying per-acre values suggested by relevant literature.

A meta-analysis examining willingness to pay estimates for various freshwater ecosystems suggests that freshwater ponds are about half as valuable as river-fed wetlands.[109] If aquatic habitat created by beaver activity has half the value of wetland habitat, we estimate that ponds upstream of beaver dams may be worth about $1,200–$6,200 per acre per year. For our analysis, we assume the value of aquatic habitat (ponds) generated from beaver activity is in the middle of the range, about $4,000 per acre per year. Throughout our analysis, we have assumed averages for the surface area of beaver ponds in the basin of 0.5 and 1.5 acres. Using the middle value of ecosystem service provided by ponds, $4,000, we estimate the value of each pond may be $2,000–$6,000 per year. Basin-wide, we estimate beaver activity could generate about 34,500–103,500 acres of pond habitat, and that these ponds could produce ecosystem services worth up to $138 million - $414 million per year.

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[109] Brouwer, R., I. Langford, I. Bateman, R. Turner. 1999. "A Meta-analysis of Wetland Contingent Valuation Studies." *Regional Environmental Change*. 1(1):47-57.

C. Climate Change and Beaver Benefits

The global climate is currently changing, and these changes are expected to continue and increase in magnitude.[110] These shifts are altering biophysical processes in predictable and unpredictable, precedented and unprecedented manners.[111] Changes will occur across temperature ranges and extremes, storm and flood patterns, and wildfire occurrence. These biophysical changes have cascading effects on ecosystems. Because of climate change, natural conditions no longer follow predictable and historical patterns of occurrence. This loss of stationarity in natural systems makes probabilistically anticipating natural phenomena difficult[112].

Climate change in the western United States leads to warmer conditions, earlier springs, and drier summers, all increasing water scarcity and fire risk.[113] Similarly, while new specific ranges and magnitudes for storm and streamflow events are not yet known, the fact that they are greater is generally accepted and already observed in some areas.[114] Drier conditions will alter the water cycle as evapotranspiration increases.[115] The Escalante Basin falls within the region of the United States with the highest model confidence that temperatures will increase (Figure 17).

The expected impacts of climate change on the Escalante Basin can to some extent be mitigated by beaver activity. Beaver dams can buffer flood peaks by capturing stormwater, provide increased baseflows during dry periods, and increase overall soil moisture and water availability to reduce wildfire risk.

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[110] Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tigora, and H. L. Miller, Eds., 2007: Climate Change 2007: The Physical Science Basis. Cambridge University Press, 996 pp.

[111] Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE, eds. 2007. Climate Change 2007: Impacts Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge Univ. Press.

[112] Milly, P.C.D., J. Betancourt, M. Falkenmark, R.M. Hirsch, Z.W. Kundzewicz, D.P. Lettenmaier and R.J. Stouffer. 2008. Climate change: Stationarity is dead: Whither water management? Science 319: 573-74.

[113] Westerling, A.L., H.G. Hidalgo, D.R. Cayan and T.W. Swetnam. 2006. Warming and earlier spring increase western U.S. Forest wildfire activity. Science 313: 940-43.

[114] Parry et al. 2007.

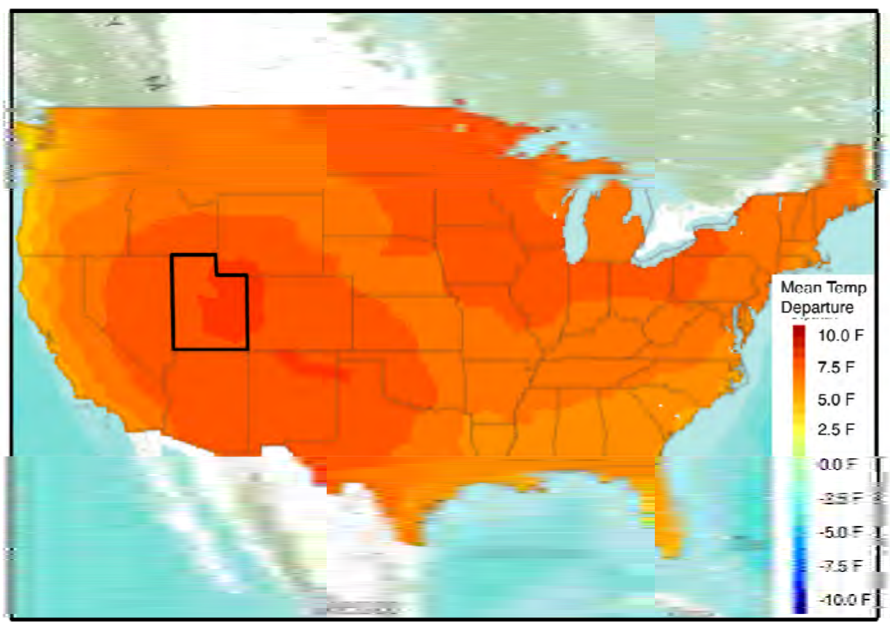
[115] Jung, M., M. Reichstein, P. Ciais, S.I. Seneviratne, J. Sheffield, M.L. Goulden, G. Bonan, A. Cescatti, J. Chen, R. De Jeu, A.J. Dolman, W. Eugster, D. Gerten, D. Gianelle, N. Gobron, J. Heinke, J. Kimball, B.E. Law, L. Montagnani, Q. Mu, B. Mueller, K. Oleson, D. Papale, A.D. Richardson, O. Roupsard, S. Running, E. Tomelleri, N. Viovy, U. Weber, C. Williams, E. Wood, S. Zaehle and K. Zhang. 2010. Recent decline in the global land evapotranspiration trend due to limited moisture supply. Nature advance online publication.

Water-dependent habitat types, particularly wetlands, would be under the most threat from climate impacts, the types of habitat provided by beavers.

Recent literature suggests that changes in hydrologic variability and intermittency likely impact ecosystem size and food chains in rivers.[116] A reduction in future precipitation likely would intensify existing variability and intermittency in the study area's hydrology thus decreasing ecosystem size and food chain length (FCL).[117] Beaver activity to regulate water availability in a drying environment would help mitigate negative impacts of climate change on FCL and species biodiversity in the basin.

We do not quantify the particular values attributable to beavers as adaptation to climate change, but it generally increases the value of the services described above. Dam-building beaver also likely reduce the risk and uncertainty of climate change for residents of and visitors to the Escalante Basin.

Figure 17. Change in Annual Temperature by 2080



Source: The Nature Conservancy, University of Washington, University of Southern Mississippi. 2010. *ClimateWizard*. Retrieved on November 8, 2010 from http://www.climatewizard.org/. High emissions scenario (IPCC A2), and 60 percent of models project a greater increase. Models showing greater increase expand the size of the darkest area.

[116] Sabo, J., J. Finlay, T. Kennedy, and D. Post. 2010. "The Role of Discharge Variation in Scaling of Drainage Area and Food Chain Length in Rivers." *Sciencexpress*. Published online October 14, 2010.

[117] Food chain length (FCL) describes the vertical structure of food webs. An area with a high FCL contains species at multiple levels of the food chain; such as primary, secondary, and tertiary predators whereas an area with a low FCL contains species at only a few levels of the food chain.

D. Summary of Potential Beaver-Provided Ecosystem Service Values in the Escalante Basin and Next Steps

Restoring beaver populations in the Escalante Basin has the potential to generate benefits to residents and visitors across a wide range of ecosystem services. If beaver populations reached their regional potential, the annual value of benefits could reach well into the tens, even hundreds of millions, as we summarize in Tables 22 and 23. These benefits are based on potential levels of beaver activity in the Escalante Basin and consequently for some categories, such as sediment retention, actual levels of benefit are likely to be less. Consequently, for these final summary tables we use the low-end of beaver dam size estimates based on the topography of the Escalante Basin. In some cases within the basin individual dams and resulting effects and benefits could vary by an order of magnitude less or more. Data are insufficient to quantitatively estimate the impacts of beavers on the quality and quantity of several valuable benefits such as recreation opportunities and aesthetics, some of which we list in Table 24.

Recreational benefits, namely hunting, fishing, hiking, wildlife viewing, along with quantified benefits from agriculture and domestic water supply, have the potential to contribute to the regional economy in terms of demand for services that generate jobs, such as guides, hotel keepers, and store and restaurant staff. As the economy of the Escalante Basin increasingly relies upon natural amenities to attract tourism and recreation, ecosystem services such as those provided by beaver activity will become increasingly valuable, as demand increases, and the structure of the local economy adapts to service these interests.

The actual physical effects of beaver vary significantly based on topography, streamflow, and vegetation, among other factors. The total landscape potential for dam-building beaver is sensitive to the density of beaver in the landscape and pond size. Further efforts to better estimate the density, pond size, and locations would improve the estimates of beaver benefits. Extending results from this analysis to other areas should also carefully consider these parameters, as well as the specific scarcities of ecosystem goods and services that could be addressed and thereby generate value.

Table 22. Summary of Quantified Services in the Northern Portion of the Escalante Basin

Ecosystem Service	Demand	Supply	Price	Valuation Method	Total Value
Sediment Retention	Agricultural Users Municipal Users Recreationists Water Agencies	33.6 million cubic yards per year 2,400 cubic yard per river mile per year 1,100 cubic yard per dam per year	$2 per cubic yard	Dredging Costs	$67.2 million per year $4,800 per river mile per year $2,200 per dam per year
Delayed Water Flow upstream of Wide Hollow Reservoir	Agricultural Users Recreationists Water Agencies	9,200 acre–feet per year 6.6 acre–feet per river mile per year 0.3 acre–feet per dam per year	$520 per acre–foot	Avoided Cost	$4.8 million per year $3,400 per river mile per year $156 per dam per year
Riparian Habitat	Recreationists General Population Water Agencies	77,000 acres 2.5 acres per dam	$1,000 per acre per year	Meta–Analysis	$77 million per year $2,500 per dam per year
Wetland Habitat	Recreationists General Population Water Agencies	27,700 acres 0.9 acres per dam	$8,000 per acre per year	Meta–Analysis	$221.6 million per year $7,200 per dam per year
Aquatic Habitat	Recreationists General Population Water Agencies	15,400acres 0.5 acres per dam	$4,000 per acre per year	Meta–Analysis	$61.6 million per year $2,000 per dam per year

Table 23. Summary of Quantified Services in the Southern Portion of the Escalante Basin

Ecosystem Service	Demand	Supply	Price	Valuation Method	Total Value
Sediment Retention	Agricultural Users Municipal Users Recreationists Water Agencies	1.1 billion cubic yards per year	$2 per cubic yard	Dredging Costs	$2.2 billion per year
		12,000 cubic yard per river mile per year			$24,000 per river mile per year
		1,100 cubic yard per dam per year			$2,200 per dam per year
Delayed Water Flow upstream of Wide Hollow Reservoir	Agricultural Users Recreationists Water Agencies	11,500 acre–feet per year	$520 per acre–foot	Avoided Cost	$6.0 million per year
		3.3 acre–feet per river mile per year			$1,700 per river mile per year
		0.3 acre–feet per dam per year			$156 per dam per year
Riparian Habitat	General Population Recreationists Water Agencies	95,700 acres	$1,000 per acre per year	Meta–Analysis	$95.6 million per year
		2.5 acres per dam			$2,500 per dam per year
Wetland Habitat	General Population Recreationists Water Agencies	34,400 acres	$8,000 per acre per year	Meta–Analysis	$275.5 million per year
		0.9 acres per dam			$7,200 per dam per year
Aquatic Habitat	General Population Recreationists Water Agencies	19,100 acres	$4,000 per acre per year	Meta–Analysis	$76.5 million per year
		0.5 acres per dam			$2,000 per dam per year

Table 24. Summary of Service Values Not Totaled

Ecosystem Service	Demand	Supply	Representative Value
Pollutant Removal through Sediment Capture	Agricultural Users Municipal Users Recreationists Water Agencies	Sediment and pollutant volume captured by ponds	$100,000 per year per percent improvement
Water Temperature	Recreationists Water Agencies	Difference in baseflow temperature	$74,000–$411,000 per river mile
Recreation	Recreationists Residents	Increased quality and quantity of recreation opportunities	$75–$375 per recreation day
Aesthetic Benefits	Recreationists Residents	Improved aesthetic characteristics	–
Existence Value	General Population	Habitat, wildlife, and aesthetic characteristics	–
Sensitive Species Habitat	General Population	Viewing, bequest, existence values	$9–$256 per household per year
Flood Resilience	Agricultural Users Residents Water Agencies	Avoided structural damages, flood protection investment	–