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ADAPTATION TO
CLIMATE CHANGE TEAM

VALUING ECOSYSTEM GOODS AND SERVICES IN THE COLUMBIA RIVER BASIN

ACKNOWLEDGEMENTS

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INTRODUCTION

This report has three objectives:

1. To identify the connections between food, water, energy, and biodiversity (the nexus) in the Columbia River Basin (CRB).
2. To estimate the economic value of some of the non-market benefits that ecosystems in the CRB provide to the US – as well as some of the costs to British Columbia (BC) incurred by the co-ordinated management of water flows under the Columbia River Treaty (CRT, or “the Treaty”).
3. To consider the effects on these values and connections between changing supplies and demands driven by a changing climate and a growing population.

The values presented in this report apply to the CRB in the US as a whole. While further work will be needed to estimate the values directly associated with the Treaty, our analysis clearly demonstrates the need for acknowledgment of non-market, ecosystem-based values connected to Treaty operations as the sovereign parties consider options for renegotiation, or modification, of the CRT. We acknowledge that many cultural and spiritual ecosystem values transcend economic values. We present this work as a comment on the fact that the contribution of ecosystems is currently valued at zero in the CRT.

We organize the report in three sections, each of which aligns with one of the report's objectives:

Section 1 outlines the past, present, and future contexts of the Treaty. We introduce the geography and political jurisdictions of the CRB, outline the history and original intentions of the Treaty, and describe the modern context under which the Treaty may be renegotiated or modified. We also discuss the nexus of natural resources in the Basin – food, water, energy, and biodiversity – in the context of the Treaty.

In **Section 2**, we detail the methods we used to arrive at our estimates of the economic benefits of ecosystem goods and services (EGS) in the CRB. We introduce the concept of natural capital valuation and describe some of the techniques researchers use to assign monetary values to nature. We describe the three categories of EGS for which we estimate values in the CRB: fish; regulation of air, soil, and water quality; and ecosystem-dependent culture and recreation. We also report the results of our analysis, summarize low and high estimates for the monetary values of each class of EGS, and provide an estimate of the total ecological benefits received by the US resulting from cross-border flows. We also use a case study of the Arrow Lake Reservoir to discuss some of the opportunity costs BC is incurring due to the coordinated management of the river under the Treaty.

In **Section 3**, we explore the effects that a changing climate may have on the values of EGS and the nexus in the future. We summarize projected changes in hydrology and human development in the CRB, and identify the importance of considering these changes in a renegotiated or modified Treaty.

We conclude by making the case for including the value of ecological goods and services in any discussion of an adjusted Canadian Entitlement, including an outline of potential next steps for translating the basin-wide EGS values we have explored into the more limited and specific parameters of the CRT.

EXECUTIVE SUMMARY

Natural capital is the "planet's stock of renewable and non-renewable natural resources (forests, minerals, oil, plant and animal species), environmental resources (atmosphere, water) and land" (Olewiler, 2007). From this stock of natural resources flow ecological goods and services that benefit society in innumerable ways. The rapid increase in global living standards over the past two centuries is inextricably linked to our dependence on and continued exploitation of natural capital. The relationship between the flow of natural capital (i.e., the rate of extraction and consumption) and the subsequent degradation of the environment often invokes trade-offs of economic growth and environmental sustainability.

At a regional level, the long-term sustainability of the Columbia River and its communities depends on ecosystem functions, and therefore provides clear examples of these trade-offs. The river has enhanced the economic livelihoods of communities in the region, including income derived from the environmental assets that support commercial fishing, agriculture, recreational, and other sectors. The continuance of these activities is directly related to the extent and health of river ecosystems. If the river's management continues to be incautiously focused on the production of economic output, it will eventually offer less for production and sustenance in the future. Put simply, the environmental goods and services offered by the Columbia River represent the 'glue' holding everything together.

Despite these significant benefits, the topic of ecosystem goods and services is under-studied in the Columbia River Basin and the magnitude of climate change and other impacts is poorly understood. When decision makers undervalue the benefits we derive from nature, they underestimate the full costs to society of converting natural resources to uses that destroy or degrade natural capital. Recognition of the benefits of ecosystem goods and services (EGS) by policy makers is therefore an important step in formulating effective natural resources policy that is designed to benefit all other aspects of society and nature.

To help develop a better understanding of the benefits of ecosystems, this study estimates some of the current and future values of EGS in the US portion of the Columbia River Basin, a 670,800 square-kilometer area of land drained by the Columbia River that spans parts of Washington, Oregon, Idaho, and Montana. The dollar values reported here represent best estimates of the economic product of ecosystems in the US portion of the CRB using data and techniques available at this time.

Ecosystem goods and services considered in this study include:

a. Anadromous and resident fish.

b. Regulation of air, water, and soil quality; pollination; and disease and pest control.

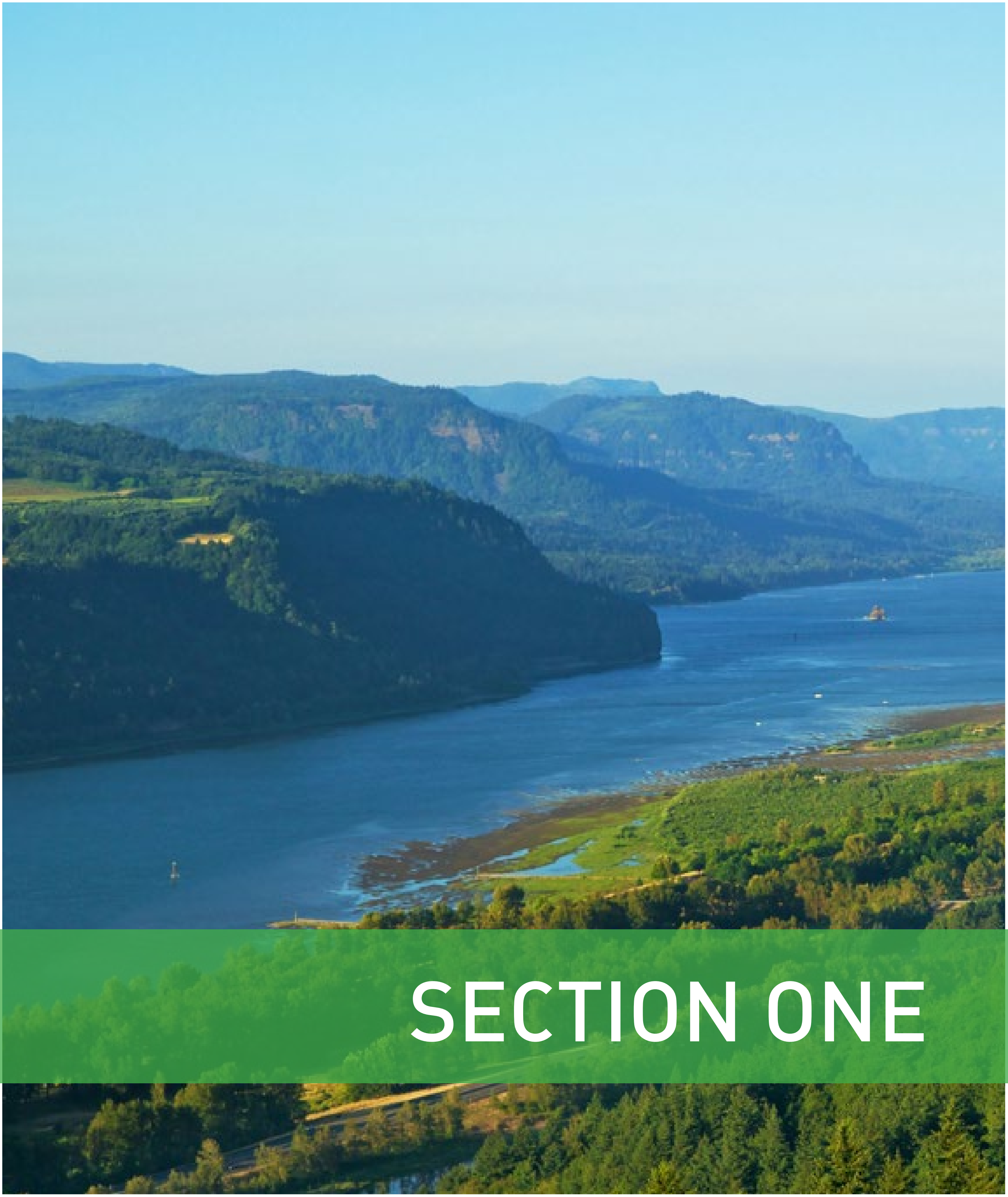
c. Cultural services including recreation and existence values.

- Values for the presence of anadromous fish are estimated based on ex-vessel values and spending by US agencies on rehabilitation and restoration efforts in the US CRB.

- Values for regulatory services are estimated by extrapolating per-acre estimates of economic benefits from primary studies in other regions and transferring values to the present study.
- Values for the economic benefits of ecosystem-dependent recreation and tourism are estimated based on US Census survey data of recreation visitor spending in the region.

The study results are compelling. By supporting fisheries; regulating the quantity and quality of air, water, and soil; attracting recreational visitors; and providing aesthetic, spiritual, or educational value, ecosystems in the CRB produce in total between $19 and $701 billion of benefits to the regional economy every year. The value of fish alone, measured in a number of ways including US agency spending, is between approximately $150 and $600 million annually. Recreation and existence of nature are worth another approximately $1.2 to $2.4 billion annually. The remainder of the value is contributed by regulatory services, which total approximately $18 to $697.5 billion annually (all values in 2013 USD). This large range in values represents an approximate appraisal of the natural capital of the US CRB. Obtained values replace the *former estimate of zero* that has been the default value of ecosystems in the framework of the CRT. Because this study values only a limited range of the known EGS produced in the US CRB, the low end of the range provided can be considered a baseline value.

This study also identifies and considers some of the unvalued and potential EGS in both the Canadian and US portions of the CRB relevant to the CRT, specifically the value of ecosystem services that Canada foregoes under the Treaty. However, more research is recommended to strengthen this evaluation.



SECTION ONE

CHAPTER 1: BACKGROUND

The management of the resources of the Columbia River under the Treaty has significantly changed the distribution of benefits and costs among the economies of the region. In this chapter, we provide context for our analysis by introducing the Columbia River Basin and Treaty, and discussing US and Canadian perspectives on the re-negotiation, or modification, of the Treaty.

1.1 The Columbia River Basin

The Columbia River provides significant natural and managed water resources for the Pacific Northwest (Hamlet & Lettenmaier, 1999). The largest river in the region and the fourth largest in North America (Osborn, 2012), the Columbia is 2,000 kilometers long and drains an area of land roughly the size of France – a total of 670,800 square kilometers (Harrison, 2008a). In BC, the river begins at Columbia Lake in the southern Rocky Mountain Trench and flows north for 518 kilometers before turning south for 700 kilometers and crossing the border into Washington State. South of the US-Canada border, the river continues to bend southwest, and forms the border between Oregon and Washington as it runs towards the Pacific Ocean.

The Columbia River is one of the great rivers of the world in terms of the diversity of its ecosystems and runoff from its watershed. The health of its watershed affects the temperature, stream flow, aquatic species, and other components of the river's biodiversity. Snowpack melt during the spring and early summer produces favourable conditions for freshwater species. The river's habitat is crucial for anadromous fish as they traverse its flows to and from the ocean, as well as resident fish. The river's rich natural processes provide enormous environmental, economic, cultural and social benefits to the regions it passes through. Many industries vital to the Pacific Northwest depend on the river for sport and commercial fisheries, agriculture, transportation, recreation, and hydropower generation.

About five million people live in the US CRB (Volkman, 1997; data from Federal Columbia River System, 2001) spread across four US states: Washington, Oregon, Idaho, and Montana. Estimates of annual population growth for the interior CRB range from 0.3-1.6% by 2040 (National Academy of Sciences, 2004), with the overall US Pacific Northwest region forecast to house between 50-100 million people by 2100 (Lackey, 2009). This growth will be accompanied by increased demands for land, water, and hydroelectric power. For example, in Idaho, Washington, and Oregon, freshwater withdrawals for domestic and public use are projected to increase by 71-85% by 2050 (Independent Scientific Advisory Board, 2007). Continued population growth will increase residential, irrigation, recreational, commercial, and industrial water uses, heightening competition for limited water supplies.

Many rivers within the Columbia River system have already been fully appropriated with aquifers heavily pumped; demands continue to increase, threatening both present and future uses. Collectively, this creates a scenario of competition among the various users of the river, and pitting the needs of the region against the needs of ecosystems. Even without looking to the future, the worry now lies in how the river can meet all these needs while also allowing fish and other species to safely thrive, roam and spawn. Renegotiation of the CRT has the potential to either exacerbate these conflicts, or help resolve them.

The fact that the region's human population seems likely to continue growing suggests that pressure on water and ecosystems will also increase, along with added diversions of water from the Columbia River mainstem and tributaries. The National Academy of Sciences (2004) warns that, "as long as human populations and economic activities continue to increase, so will the challenge of successfully solving the salmon problem" (National Research Council (NRC), 1996). Human activities have already had significant impacts on Columbia River salmon and aquatic habitat (NRC, 2004) and population increases will require continued spending to protect endangered and threatened species and ecosystems.

Compounding these problems are projected impacts from climate change in the US portion of Basin. Taking into account climatic changes, Clarke et al. (2015) warn that 70% of glacier ice in BC could disappear by the end of the 21st century, affecting salmon production throughout the Columbia River (Clarke et al., 2015). A drop in streamflow, coupled with population growth in the US CRB, will heighten competition for limited water supplies, making it necessary to find ways for the CRB to absorb old and new pressures while also maintaining and enhancing ecosystem health for the river system.

Thus, under future scenarios of climate change and population growth, ecosystem remediation in the Basin will become an increasingly significant priority (see Section 3). Indeed, discussion papers prepared by both the Canadian and American entities to the Treaty in preparation for renegotiations refer to the importance of restoring ecosystem functionality. Coordinated and collaborative management of the CRB should be seen as important tools that can be used to adapt to the challenges threatening ecosystem functions.

The Nexus

Ecosystems are the foundational source of three vital human needs: water, food, and energy. The intersection of these essential aspects of life is known here as the nexus. Healthy ecosystems are critical to the provision of water, food and energy, whether in terms of abundance of fish, flows to turn turbines, or water stored to mitigate scarcity and supply irrigation. Ecosystem function helps to mediate links between the nexus elements by storing, moving, cleaning and buffering flows of water, rendering drought and flood less severe, and food and energy production more reliable. Investing in healthy ecosystems provides resilience against climate changes and population growth such that “a system can absorb recurrent natural and human perturbations and continue to maintain essential function without slowly degrading or even unexpectedly flipping into a less desirable state” (Cosens and Williams, 2012). Dealing with future impacts in the US portion of the Basin therefore requires recognition of the value of biodiversity and the ecosystems that help to restore, enhance, and preserve the nexus.

1.2 The History of the Columbia River Treaty

The future of the region is inextricably tied with the future of the Columbia River Treaty (CRT, or “the Treaty”). Ratified in 1964 between Canada and the US, the Treaty was implemented as a way to co-operatively manage the water-related issues of the Columbia River system. While a number of dams had already been constructed on the US portion of the river, the strategy envisioned by both countries was to store a larger quantity of water and provide a level of flood control that existing dams were unable to meet (Firuz, 2012). Both signatories recognized that storing a higher volume of water to control the river’s flooding could also become an efficient way to generate hydropower. Thus, the Treaty enabled three dams to be built in Canada – the Mica, Duncan and Hugh Keenleyside (originally known as the High Arrow) – and one in the US (Libby). In constructing the three storage dams in Canada, the Treaty required Canada to operate the dam reservoirs for optimum flood control and power in both countries.

In furtherance of the objectives for flood control and power generation, the Treaty established obligations and benefits for each country. The US prepaid Canada $64 million to rent 8.45 million acre-feet (MAF) of storage space in the new Canadian reservoirs for 60 years to support assured flood control (BC Ministry of Energy and Mines, 2013). Each year, the US returns to Canada 50% of the calculated potential downstream power benefits as payment for the US benefits realized by Canadian storage operations in the form of energy and capacity. This amount, which ranges from CAD $150-300 million annually in general BC provincial revenue, is known as the Canadian Entitlement.

Healthy ecosystems are critical to the provision of water, food and energy, whether in terms of abundance of fish, flows to turn turbines, or water stored to mitigate scarcity and supply irrigation.

Since its ratification, the Treaty has been acknowledged internationally as a successful example of equitable benefits sharing (Paisley, 2002). The Treaty has proven to be durable in its ability to offset costs associated with flood damage, while generating billions of dollars in economic development through hydropower generation. Since the Treaty was signed, flood control measures have frequently protected communities from major damage along the Columbia River, avoiding $2 billion in potential damage in one year (BC Ministry of Energy and Mines, 2013). The United States Army Corps of Engineers (USACE) estimates average annual flood damages avoided by the US along the Columbia River to be $100-200 million CAD, although this figure is associated with all the storages along the Columbia River, not just those operated under the CRT (BC Ministry of Energy and Mines, 2013).

In addition to the Treaty's primary purposes of flood control and power generation, it also allowed the US and Canada to develop a number of related agreements that enable the parties to adjust the management of the Columbia River for other purposes, including the restoration and management of fisheries. Two side agreements signed after 1964 – the Non-Power Uses Agreement (NPUA) and the Non-Treaty Storage Agreement (NTSA) – are particularly important for fisheries management. The NPUA is a water augmentation mechanism that supplements flows on the Columbia for fisheries purposes. Under the NPUA, 1 MAF of flow augmentation moves water from January/February to June/July to "more closely replicate portions of the natural hydrograph" (BC, 2013). The NTSA contains a dry year release provision that "guarantees a right to the US to release 0.5 MAF for use in May/June to support salmon migration in the lower Columbia River during the driest 20% of runoff years" (BC Ministry of Energy and Mines, 2013).

BC has emphasized that these side agreements, which produce significant benefits to the US in the form of boosted salmon populations, would not continue if the Treaty were terminated. According to BC, "without the Treaty, these beneficial ecosystem operations would cease to exist and water in the Canadian portion of the basin would be managed solely for Canadian environmental and other interests" (BC Ministry of Energy and Mines, 2013).

The CRT has no expiration date, but, as of September 2014, either country became able to terminate the agreement with ten years' notice. In 2024, Canadian flood control commitments to the US will become limited to a "Called Upon" approach (BC Ministry of Energy and Mines, 2013). After this, the US will have to first make use of all related storage on its side before 'calling upon' Canada to provide flood control (BC Ministry of Energy and Mines, 2013). This means that US reservoirs will have to draft deeper more often, which will likely have impacts on US fisheries, recreation, and irrigation. Regulation of the Columbia River by Canada is the means by which additional inflows and operations are currently coordinated throughout the lower portion of the river. Terminating the Treaty would also therefore lead to significant uncertainty in the US because operations in Canada would no longer be coordinated with US demands. Since utilities have an obligation to meet electrical obligations, this coordination is extremely valuable to US authorities.

1.3 The Future of the Columbia River Treaty

In March 2014, the BC government released its decision on the Treaty, indicating that BC believes the CRT should be continued and that improvements should be sought within the existing framework of the Treaty. The provincial position outlined 14 principles under which BC will propose renegotiation of the terms of the Treaty. Four of these mention ecosystems or salmon (see selected principles in Box 1 – emphases added by ACT)

BOX 7. PRINCIPLES OF A RE-NEGOTIATED COLUMBIA RIVER TREATY FROM BC'S PERSPECTIVE

3. All downstream US benefits, such as flood risk management, hydropower, **ecosystems**, water supply, recreation, navigation and any other relevant benefits, including associated risk reduction arising from coordinated operations compared to alternatives available to each country, should be accounted for and such value created should be shared equitably between the two countries.

7. **Ecosystem** values are currently, and will continue to be, an important consideration in the planning and implementation of the Treaty.

8. The Province will explore **ecosystem**-based improvements recognizing that there are a number of available mechanisms inside and outside the Treaty.

11. **Salmon** migration into the Columbia River in Canada was eliminated by the Grand Coulee Dam in 1938 (26 years prior to Treaty ratification), and as such is not a Treaty issue. BC's perspective is that restoration of fish passage and habitat, if feasible, should be the responsibility of each country regarding their respective infrastructure.

In December 2013, the US Entity recommended to the US State Department that the US re-negotiate the treaty with the dual goals of drastically reducing the size of the Canadian Entitlement, and requiring BC to manage flows so as to support the health of US ecosystems. According to the US Entity, the US seeks a Treaty that will "reflect a more reasonable assessment of the value of co-ordinated power operations…[and] include ecosystem-based management as one of the primary purposes of the Treaty" (BPA & USACE, 2013).

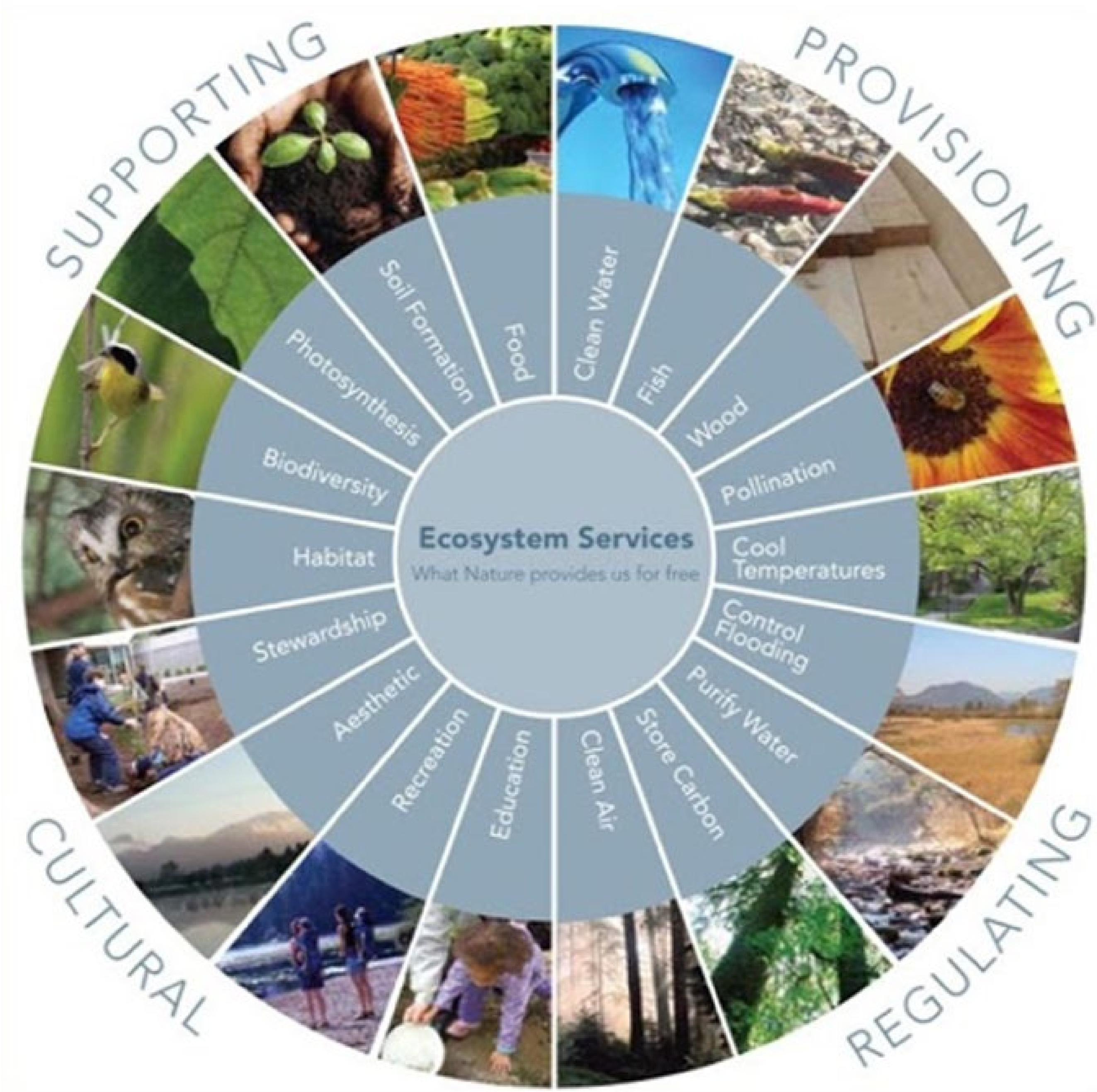
While the US currently generates power from less than half of the Treaty flows, coordinated management of river flows and storage reservoirs has, since 1964, enabled

In coming years, shifts in the timing and amount of water flows caused by a changing climate will strain the equilibrium between supply and demand for water in the CRB, and also drive new opportunities for collaboration.

additional benefits to the US in a range of sectors including provisional, regulatory, and cultural ecosystem services. As we have noted, the US Entity is increasingly diverting water from power generation to other activities such as salmon restoration, and BC currently supports US salmon restoration by augmenting spring flows to simulate the natural flow cycle of the Columbia, as well as augmenting flows during late summer and dry years – all of which are actions that can be critical to fish survival. In the extremely dry winter and summer of 2015, Canada contributed 5.7 million acre feet out of a total of 8.7 million acre feet to support firm energy production in June and July, with much of this release also favouring flows for salmon migration. In addition, Canada released 1.5 million acre feet of augmentation flows specifically for salmon. This arrangement indicates the potential values of Canadian storages from power and fish production as the climate dries over the coming decades (The Columbia Basin Bulletin, July 2015).

In coming years, shifts in the timing and amount of water flows caused by a changing climate will strain the equilibrium between supply and demand for water in the CRB, and also drive new opportunities for collaboration. For instance, BC could support US agriculture by supplying stable, predictable flows to match periods of high US demand.

With re-negotiations pending it is more important than ever to understand the value of the Canadian contribution to US ecosystem services in the CRB.



SECTION TWO

THE VALUE OF ECOSYSTEM GOODS AND SERVICES

CHAPTER 2: METHODS

In this section we answer two questions: First, what benefits do people and nations receive from ecosystems? Second, how can we determine what these benefits are worth? We introduce three benefits the US is currently receiving from the ecosystems of the Columbia River Basin: fish; regulation of air, soil, and water quality; and ecosystem-dependent recreation. We also detail the methods we use to determine the values of these benefits.

2.1 Identifying the Benefits of Nature

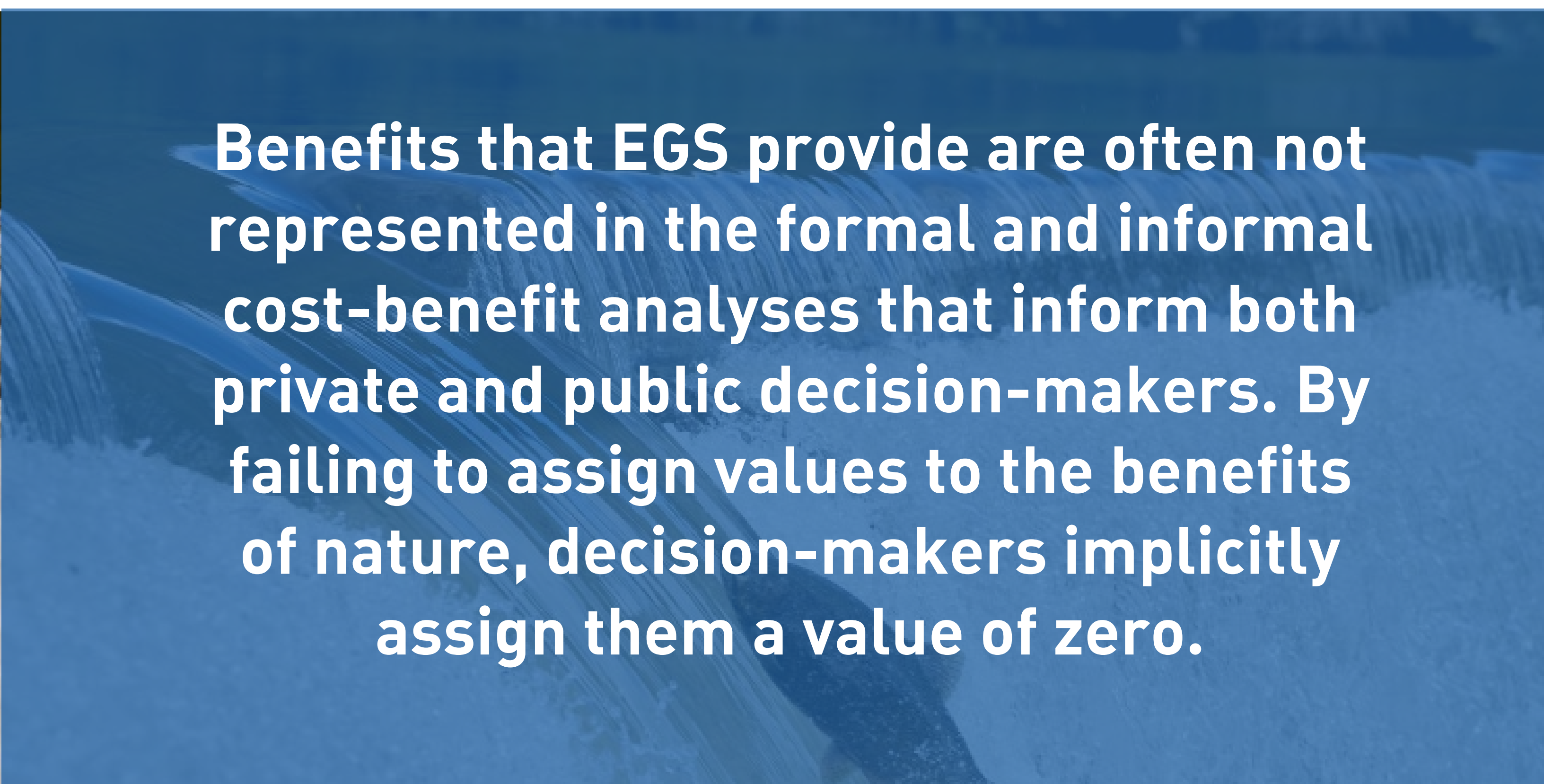
Ecosystem goods and services (EGS) are the products and processes of nature that benefit humans. The *products*, or goods, of nature are more or less tangible: fish caught from a river, berries picked from a field, or timber cut from a forest. The *processes*, or services, of nature can be less tangible: wetlands filter drinking water, marshes reduce greenhouse gas emissions, and forests prevent soil erosion. Ecosystems also benefit humans in even less obvious ways. Lakes and mountains contribute to human health by providing space for people to exercise and recreate. Plants and animals serve as inspiration for culture, art and science. Geological features create senses of belonging or figure in systems of spirituality or religion.

Benefits that EGS provide are often unrepresented in the formal and informal cost-benefit analyses that inform both private and public decision-makers. By failing to assign values to the benefits of nature, decision-makers implicitly assign them *a value of zero*. Under this reasoning, actions that harm ecosystems, and thus their ability to provide goods and services, may appear to have a net benefit to society, when in fact society may incurring a net cost.

For example, developing a wetland in order to build townhouses could appear to provide a net benefit to a community because of the increase in housing, jobs, and future economic activity. Yet wetlands, because of their capacity to hold water, serve to mitigate floods. If, the next year, rivers in the community flood, the losses suffered in terms of property damage and emergency response could far outweigh the gains from the new townhouses. Alternatively, the community could choose to avoid the damages from flooding by building new dikes or regulate new flood proofing standards. The cost of these substitutes could also outweigh the benefit of developing the wetlands. Had the value of the flood control service provided by the wetland ecosystem been considered by the community in its decision-making process, the community might have found that leaving the wetland undeveloped actually produced the most net benefit – especially given that the wetland provides other benefits such as clean air, fish, and carbon sequestration.

Over the last 30 years, ecologists, economists, policy analysts, and others have identified a number of nature's products and processes that provide benefits to humans. In the following analysis we use a modified version of the classification system used by

The Economics of Ecosystems and Biodiversity (TEEB), an international initiative whose aim is to recognize the value of EGS and incorporate those values into public and private policy. Under the TEEB system, EGS are separated into four groups: provisional, regulatory, supporting, and cultural. Provisioning services refer to the material or energy outputs of ecosystems. Regulatory services are the services that ecosystems provide by acting as regulators – i.e. regulating the quality of air or soil or by providing flood or disease control. Supporting services refer to the services ecosystems provide by acting as habitat and sustaining environments for plants and animals, including the maintenance of genetic diversity. Cultural services of ecosystems include encouraging recreation, providing aesthetic beauty, attracting tourism, and playing roles in religious or spiritual belief systems. Table 1 summarizes the categories of EGS and provides brief definitions of each.



Benefits that EGS provide are often not represented in the formal and informal cost-benefit analyses that inform both private and public decision-makers. By failing to assign values to the benefits of nature, decision-makers implicitly assign them a value of zero.

TABLE 1. CLASSES AND DEFINITIONS OF ECOSYSTEM GOODS AND SERVICES

GOOD OR SERVICE	DEFINITION
PROVISIONAL	
Food	Plants, fungi, and animals for human consumption
Fresh water	Water for human consumption
Raw materials	Timber, medicines, etc.
REGULATORY	
Local climate and air quality	Removal of pollutants from atmosphere; regulation of precipitation
Water quality and waste-water treatment	Filtering of human and animal waste; prevention of algae blooms
Prevention of soil erosion; maintenance of soil fertility	Erosion protection provided by plant roots and foliage covers; formation of sand and soil
Biological control	Control of pests and vector-borne diseases
Pollination	Fertilization of plants and crops by insects, bats, birds
Carbon sequestration and storage	Removal of greenhouse gases from atmosphere
Moderation of extreme events	Protection from storms, floods, landslides, etc.; drought recovery
CULTURAL	
Aesthetic, education	Inspiration for art and science; use in education
Recreation, tourism	Space for fishing, camping, etc.
Spiritual and religious	Value of specific features to local and indigenous religions; sense of belonging

Ecosystem Goods and Services in the US Columbia River Basin

The scope of this study is to provide an estimate of the value of non-market benefits the US receives from the healthy functioning of the ecosystems in the CRB in the context of the potential renegotiation of the CRT. Consequently, we restrict our analysis to exploration of the values of a few major benefits provided by ecosystem services in the CRB.

First, we provide estimates for the provisional value of fish (prior to any value-added processing) produced in the CRB. We do not provide estimates for the provisional value of water, as water rights on the US Columbia system are generally allocated through market-based permit systems. Because these values can be determined through the market, they are not included here. Estimates for the value of the timber and other raw materials are also considered market values, and are therefore also beyond the scope of this report. Estimates for the value of the timber and other raw materials are also considered market values, and are therefore also beyond the scope of this report. We also use approximate spending by US agencies on salmon restoration efforts as a proxy for the provisional value of fish.

Second, we provide estimates for the value of the following regulatory services: local climate and air quality; water quality and waste-water treatment; prevention of soil erosion and maintenance of soil fertility; biological control of pests and disease; pollination; and carbon sequestration and storage. We do not provide estimates for the value of the services ecosystems provide in moderating extreme events such as flooding or storms. The value of flood control and landslide prevention, as determined by avoided damages, depends significantly on the proximity to and density of development (e.g., a forest on a hill next to Seattle would provide more benefits with respect to avoided damages from landslides than a forest on a hill next to an undeveloped valley). Determining these values would require determining the costs of replacing development in flood-prone areas and the degree of contribution of healthy ecosystems to flood mitigation, activities that are beyond the scope of this study.

Third, we provide estimates for two cultural values: the value that ecosystems create by facilitating nature-based recreation opportunities such as angling and camping; and the value that ecosystems create by simply existing. We consider the preservation value of ecosystems to represent the spiritual, religious, aesthetic, and educational value ecosystems provide. We do not provide any estimates for the value of supporting services, because these benefits are indirect and especially difficult to quantify.

We also discuss how the exclusion of certain values affects our estimation of the total value of ecosystem goods and services in the US CRB in the **Limitations** section of this report.

2.2 Putting a Price on Nature

Valuation Techniques

Ecosystem goods and services (EGS) are diverse and varyingly amenable to markets and valuation. EGS include tangible and marketable goods such as fish, water, and timber, as well as services that provide indirect benefits such as disturbance regulation and water filtration, the values of which are not recognized or captured within the market. An economic value is a measurement of human well-being, and helps identify the individual and societal trade-offs of scarce and competing resources (Boyle et al., 2003). These economic values can be separated into use values and non-use values associated with EGS. The use values can in turn be further sub-divided into direct and indirect use values.

Direct use values apply to goods whose price is determined by market processes. Examples include timber products derived from forest capital, harvested fish, and agricultural products; the market price paid by individuals reflects the value of a particular item. By comparison, indirect values come from the consumption or use of goods/services that do not have well-defined markets. For instance, the enjoyment we receive from walks in the forest or knowing that a species or ecosystem exists is not reflected in our formal market system.

Researchers in the field of ecosystem valuation have, over the last 30 years, developed a number of techniques for assigning dollar values to the non-market goods and services provided by ecosystems. Many of the values for ecosystems we report here were determined by researchers using one or a combination of the valuation methods detailed in Table 2 below.

TABLE 2. METHODS OF VALUING NON-MARKET ECOSYSTEM GOODS AND SERVICES

METHOD	DESCRIPTION	EXAMPLE
Stated preference	Survey used to elicit information about preferences for a good or service. A contingent valuation is referred to as a stated preference method, because it directly asks individuals (based on a hypothetical scenario) how much they would be willing to pay or accept as compensation for specific environmental services.	What individuals would be willing to pay for the continued existence or substitute of a particular ecosystem good or services, such as water purification and treatment.
Travel cost	Value estimate based on ecosystems or sites used for recreation. The value of the site is reflected in how much people are willing to pay to travel to visit it.	Expenditures made to get to nature sites (e.g. gas, time, parking fee) used to infer the benefits of a recreational site.
Avoided cost	Values based on costs of avoided damages from lost ecosystem services.	Storm protection provided by barrier islands avoids property damages along the coast.
Replacement cost	Substitutability of related goods and services are used as an indicator of economic value for the ecosystem of study.	What people would buy/use as a substitute if a specific ecosystem was not available.
Hedonic pricing	Economic values for ecosystem services that directly affect market prices.	Most often applied to property values impacted by the loss of ecosystem services.
Factor Income	Services provide for the enhancement of incomes.	Water quality improvements increase commercial fisheries catch and therefore fishing incomes.

In a policy context, the valuation of EGS contributes to policy formation and guides decision-making. By accounting for natural capital, economic and environmental objectives become aligned, providing future generations with at least the same benefits from natural resources that existing individuals currently enjoy. Incorporating the values of EGS enables decision-makers to compare alternatives efficiently and effectively: a prerequisite for sustainable policy and sensible conservation decisions. Choices between the conservation of some ecosystems and the continuation and expansion of human activities should be made with foresight that acknowledges potential conflicts and recognition of the value of EGS. Public policies play an essential role in ensuring that these benefits are identified and taken into account in decision-making. Leaders with access to information on the ecosystem goods and services provided by the CRB will therefore be better placed to make efficient, cost-effective and equitable choices, ensuring their benefits thrive and continue into the future.

In the next section, we describe how we apply the above methods of identifying and valuing EGS to the specific task of determining the value of benefits the US derives from ecosystems in the CRB.

2.3 Study-Specific Methods

Our analysis focuses on determining the values of three categories of EGS: fish, regulatory services, and cultural/recreation. We use slightly different methods to determine the value of each service.

Fish

For the provisional value of fish, we perform a primary valuation of the non-market value of fish taken from the US CRB prior to any value-added processing. This method is further discussed in the results section.

Regulatory Services

For the value of regulatory services provided by ecosystems (excluding extreme event moderation), we use an approach known as benefit transfer. Benefit transfer extrapolates estimates of economic benefits from a study that has already evaluated the subject (or one very similar) and transfers those values to the study of interest. Here, we apply the results from studies in other regions as a proxy for measuring EGS in the US CRB.

We conduct the benefit transfer analysis in two steps:

First, we perform a land cover analysis of the region in question to determine the absolute size of different classes of ecosystems. Different classes of ecosystems produce different suites of benefits. For example, wetlands filter more water than forests. Consequently, the value for the service “water filtration” will be higher for a wetland than for a forest.

Second, we develop a database of primary valuation studies performed in other regions that have found dollar values per unit of area for each of the regulatory services in question. The database we develop here is based on databases previously published by the Seattle-based research institute Earth Economics in their valuation of ecosystem goods and services in the Colorado River Basin and Skykomish Watershed. In the interest of accuracy, we include all valuation estimates and then provide a low and high estimate of the total value of regulatory services provided by a particular ecosystem. We summarize the total values for each ecosystem in a table. We also summarize the combined value of regulatory services for all ecosystems.

To undertake an accurate transfer of benefits from primary studies to the CRB context, the following best practices were followed to ensure a consistent, rigorous, and adequate benefit estimation approach:

Currency differences and base year: Currency estimates were adjusted for inflation in the primary study’s domestic currency and converted to Canadian dollars using the exchange rate from the estimation year. All values are expressed in 2013 CAD dollars.

Maintain original unit-value estimate: Because some estimates were made in different units of measure, each estimate is stated in common units.

Context of value estimate: Value estimates were completed in the specific context of the study. In this regard, estimates used in the analysis were applied only if they matched the Columbia River context and characteristics.

Further details of the methods of the particular primary studies whose values we transfer to the US CRB are discussed in the **Results** section.

Cultural Services

For the cultural value of recreation and preservation, we perform a combination of primary valuations and benefit transfer. We provide an estimate of the value of recreational angling and wildlife viewing based on data provided by US Census data. We also provide an estimate of the preservation value of ecosystems in the CRB by transferring a benefit found from a primary valuation study of people's willingness to pay for the preservation of ecosystems in a different region. We discuss the details of this method in the Results section.

CHAPTER 3: RESULTS

Here, we detail the results and methods of our analysis. Through a combination of valuation techniques, we identify the value of three classes of benefits of ecosystem goods and services in the US Columbia River Basin: fish, regulation, and recreation/cultural. We also briefly discuss an alternative way of determining the value of fish in the Columbia River Basin to the US – the amount of spending on salmon restoration efforts by US agencies active in the CRB.

3.1 Value of Anadromous Fish

Anadromous Fish

Approximately 268 species, subspecies, and fish stocks in the CRB have US federal listings for endangerment: 241 candidates, 11 threatened, and 16 endangered (Thomas & Dombeck, 1996). Salmon are one of these. On their own, salmon play an integral role in the overall productivity and health of a freshwater ecosystem, functioning as indicators of biological integrity through their exposure and response to ambient water and environmental disturbances such as habitat alteration, chemical toxicity, and thermal fluctuations. The decline in salmon stocks results in decreased abundance of other aquatic species and altered nutrient recycling, with detrimental effects on the functioning of river systems. Actions focused on protecting and enhancing salmon stocks are therefore likely to positively affect other components of the river system and benefit a range of resident and anadromous species sharing similar habitat requirements.

Salmon populations of the Columbia River, once numbering between 11-16 million annually (Bottom, 2005), have been steadily declining since the first dam was built, years prior to ratification of the CRT. Salmon populations declined from four to five million in 1980 to less than one million in 2000, of which only 75,000 were wild (Cohen et al, 2000). Critical habitat functions and processes have been limited, and in some cases eliminated, by the blockage of access. Together, Chief Joseph, Grand Coulee, Hells Canyon, and Dworshak dams in the CRB block over 55% of historical tributary and mainstem habitat for anadromous fish (Columbia River Inter-Tribal Fish Commission, 2014). These dams completely block access to upstream fish habitat. Where access has been blocked or constrained, fish populations have become fragmented and resulted in numerous smaller subpopulations, increasing their risk of extinction and vulnerability to the pressures of a changing climate.

Since time immemorial, the Columbia River's salmon sustained the culture and economies of the region's indigenous peoples. Celilo Falls was the oldest tribal fishing area on the Columbia River, east of the Cascade Mountains, on what is today the border between Oregon and Washington. For 15,000 years, Celilo was home to native settlements, trading and fishing villages, until 1957, when the falls and nearby settlements were submerged by the construction of the Dalles Dam. The sharp decline in salmon has led annual tribal catches of salmon to shift from millions to thousands of fish. In one year, tribes now take less than 600 spring Chinook salmon from the river to support religious ceremonies for thousands of tribal members (Columbia River Inter-Tribal Fish Commission, 2014). The loss of salmon for the Columbia's US tribes and BC First Nations has had significant negative impacts on their everyday life, physical and spiritual health, identity and ceremonies. With the decline of salmon in the US, and their outright extirpation and extinction in Canada, except in the Okanagan Basin, ecosystem health basin-wide has declined as evidenced by the Endangered Species Act listings. The loss of salmon has stimulated US efforts to enhance and protect stocks.

Anadromous fish are therefore a significant provisional ecosystem service provided by lakes, rivers, and streams in the CRB. The provision of food provided by fish can be estimated by the ex-vessel values of fish (the price paid per fish on the dock). While we were not able to monetize the provision of food provided by all fish in the CRB, we did quantify that provided by salmon.

TABLE 3. ESTIMATED EX-VESSEL VALUES OF ANADROMOUS FISH IN THE US COLUMBIA RIVER[1]

REFERENCE	LOW VALUE (2013 $CDN/YEAR)	HIGH VALUE (2013 $CDN/YEAR)
National Marine Fisheries Service, 2013; National Oceanic and Atmosphere Administration, 2014; Spirit of the Salmon, 2014	147,600,000	147,600,000

Ex-vessel values represent the price (in $/kg) that fishers receive from selling their catch on the dock.[2] The average ex-vessel price of salmon is estimated at $8.2/kg, the average weight of a salmon at 9kg, and the number of returning salmon in the lower-mid CRB at two million. The value obtained for salmon serves as a rough proxy for benefits received

1 Estimated benefits provided by salmon in the US portion of the CRB are represented by a single value. Without the addition of other estimates, this value represents both low and high values.

2 Ideally, we would use the net price to fishers (i.e. the received price net of their costs to harvest the fish). Cost data is currently unavailable, so received price overestimates benefits. Additionally, excluding cultural values underestimates benefits. The net impact is thus uncertain.

by fishers, the commercial fishing industry, and consumers. These values do not include non-use values associated with salmon such as existence and cultural values, which are likely to be substantial. Without coordinated flows from the Treaty, the benefits provided by salmon could be substantially reduced. If, in the absence of an agreed-upon revised treaty and side-agreements after 2024, BC were to manage flows only for domestic purposes, the loss of coordinated management and timing of flows to salmon and aquatic habitat would likely result in impacts to fish population levels and EGS benefits throughout the Basin.

3.2 Value of Regulatory Services

Ecosystems provide a host of regulatory services that maintain the quality of our air, water, and soil. Most of these values can be determined on a per acre basis and transferred from the region where the primary study was conducted to the region of interest. The following six regulatory ecosystem functions were considered in this report to indicate benefits obtained from the natural control of ecosystem processes: regulation of local climate and air quality; filtration of water; soil formation and prevention of soil erosion; biological control; pollination; and carbon sequestration. In the absence of coordination of flows between Canada and the US, the US stands to potentially lose or reduce the benefits provided by these regulatory services. Regulatory values underpin the three critical nexus elements of water, food and energy, whether in terms of abundance of fish, flows to turn turbines, or water stored to mitigate scarcity and supply irrigation. Regulatory services help to mediate the links between the nexus elements by storing, moving, cleaning and buffering flows of water; reducing the impacts of drought and flood; and ensuring reliable food and energy production in the US portion of the Basin.

Primary studies of regulatory ES most frequently estimate values in units of $/unit area. To determine the area of different ecosystems in the basin, we established the distribution of land cover in the CRB using Geographic Information Systems (GIS) data from the Northwest Habitat Institute (NWHI) and Northwest Power and Conservation Council.[3] The data are from 2000, and divide land in the basin into 30 different classes.

3 Northwest Habitat Institute web site. 2008. (http://www.nwhi.org), Northwest Habitat Institute, Corvallis, OR.

For our purposes, we combined the NWHI categories into six broad classes: developed, farmland, forest, grassland, wetland, and freshwater.

Land Cover Analysis

Our analysis shows that forest is the most prevalent land cover/ecosystem in the US CRB, followed in order by grassland, farmland, wetland, developed land, and freshwater. **Figure 1** illustrates the results of the land cover analysis. The areas in square kilometers for each ecosystem are summarized in **Table 4**.

FIGURE 1. ECOSYSTEM SIZES IN THE COLUMBIA RIVER BASIN

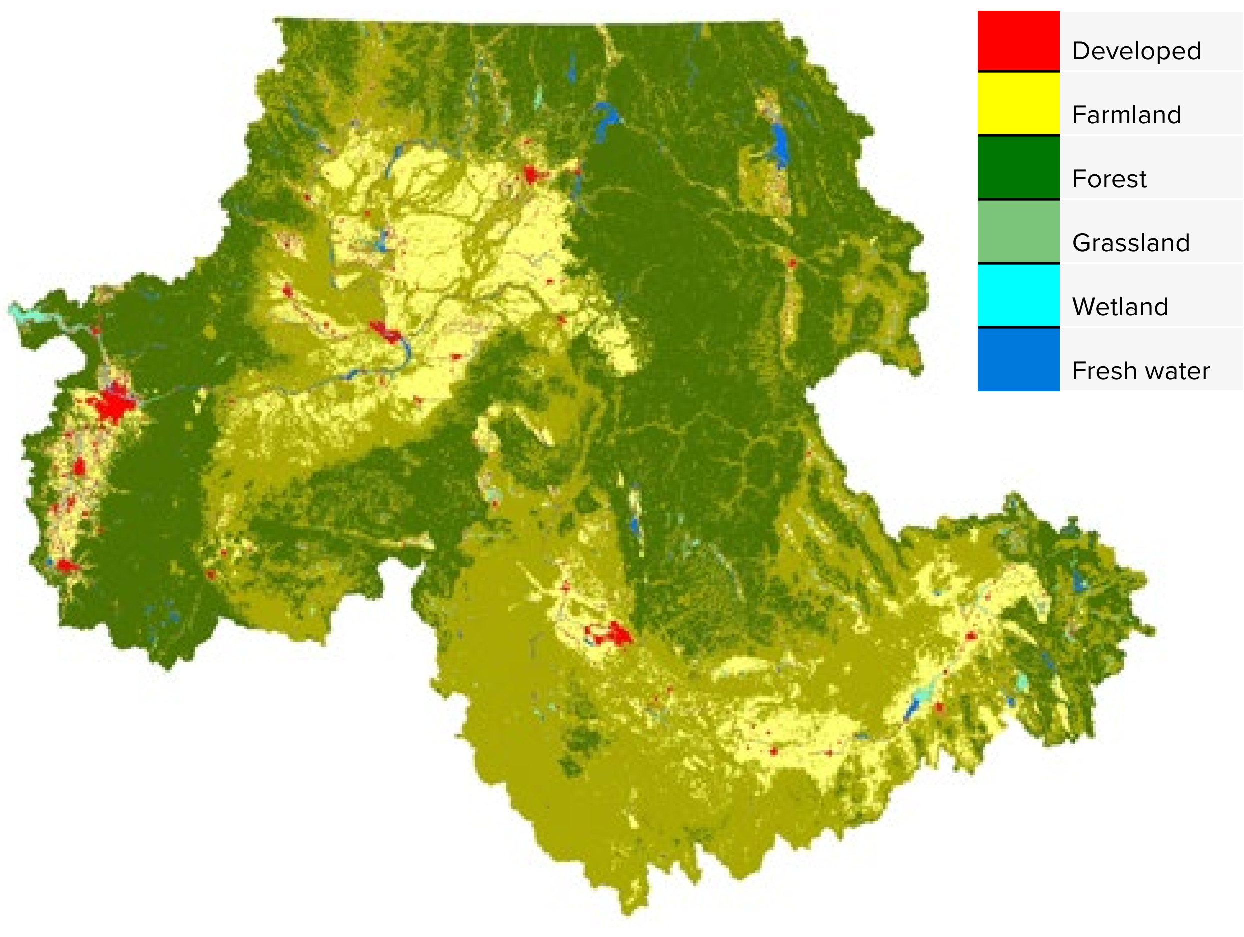


TABLE 4. AREA OF LAND COVERED BY DIFFERENT ECOSYSTEMS IN THE US CRB

ECOSYSTEM/LAND COVER	AREA (SQUARE KILOMETERS)	AREA (ACRES)
Forest	254,875	62,980,886
Grassland	200,047	49,432,613
Farmland	94,776	23,419,623
Wetland	8,680	2,144,871
Fresh water	6,601	1,631,140
Developed	4,574	1,130,258
Total	569,553	140,739,394

In the following sections, we present the value of regulatory services as determined by benefit transfer for each ecosystem. In cases where multiple primary valuation studies report different estimates for the same ecosystem service, we include both the lowest and highest value.

It is important to note that the following tables represent summaries of values reported in primary studies. The database we used to develop these summaries, as well as the full reference for each primary study, is included in the appendices of this report.

Transferred values were converted to CAD 2013 dollars per acre per year, representing the annual flow of value generated by a single ecosystem service on a single land cover each year. Total value of ES for a land cover class (in $/acre/year) was determined by summarizing the available ES values (water quality, pollination, carbon sequestration, etc.).

Values of Regulatory Services Provided by Different Ecosystems

The following tables indicate low and high estimates of the values of the various regulatory ecosystem services. These estimates were originally generated in primary valuation studies that used one or more of the valuation techniques discussed in **Section 2.2** (i.e. contingent valuation, substitute value, etc.). The database we use here is based on databases previously published by the Seattle-based research institute Earth Economics in their valuation of ecosystem goods and services in the Colorado River Basin and Skykomish Watershed.

To illustrate how these values are determined, we examine the origins of the high values for each regulatory ecosystem service provided by forests. Because values for regulatory ES for other ecosystems were determined in similar ways, we do not fully explain the origins of all values here.

Local Climate and Air Quality

Mates and Reyes (2004) use an avoided cost method to arrive at the value of $271.24/acre/year for the benefit provided by forests in the form of regulation of local climate and air quality. According to Mates and Reyes:

> "Trees improve air quality by removing nitrogen dioxide (NO2), sulfur dioxide (SO2), carbon monoxide (CO), ozone (O3), and particulate matter 10 microns or less (PM10) in size... To calculate the value of air pollutants, economists multiply the number of tons of pollutants removed by "externality costs", or costs to society not reflected in marketplace activity, as established by state public service commissions. The value represents costs that society would have paid in areas such as health care, if trees did not remove these pollutants."

Water Quality and Regulation

Zhongwei Liu (2004) uses a replacement cost method to arrive at the value of $287.53/acre/year for the benefit provided by forests in the form of regulation of water quality. Liu determines this cost by multiplying the average quantity of nitrogen and phosphorous that a riparian forest buffer zone removes by the average cost of removing the same quantity of nitrogen and phosphorous through conventional industrial methods. According to Liu:

> "The replacement cost method was used to estimate the value of riparian forest buffer zones based on the cost of nitrogen and phosphorus removal through wastewater treatment plants... Results indicated that the 60-meter, 90-meter and

> 120-meter riparian forest and wetland buffers were able to reduce the mean annual flow by 0.26% - 0.28%, mean annual nitrite plus nitrate by 2.9% - 6.1%, and mean annual total phosphorus by 3.2% - 7.8%."

Erosion Prevention/Maintenance of Soil Fertility

Moore (1986) estimates the value of erosion mitigation provided by forests and other non-agricultural land by analysing the cost of mitigating sediment effects (e.g. the cost of dredging the Port of Portland, municipal water treatment, road drainage system maintenance, etc.) and the relative contribution to sediment run-off of different types of land.

Pollination

According to Wilson (2008):

> "The annual value of pollination services for the Greenbelt is an estimated $360 million, based on the global average of crop production that is dependent on pollination. This proxy value was calculated by multiplying the total value of farm crop production for the Greenbelt ($1.2 billion in 2005) by 30 per cent. Given the significance of natural cover for pollinator biodiversity, nesting habitat, food, and nectar, the total value of pollination services was allocated proportionally to idle agricultural lands, grazing lands (perennial croplands), hedgerows, forest lands, and grasslands with an average annual value per hectare of $1,109 (Table 4). Forest lands represent 56 per cent of this natural cover for pollinators, therefore they provide a value of $202 million per year."

Biological Control

According to Pimentel (1997):

> "Approximately 70,000 pest species attack agricultural crops throughout the world... Natural enemy species ... are effective in protecting [against] pests. For example, bird predation on insects is estimated to provide annual benefits ... to forests of $18/ha."

TABLE 5. VALUE OF REGULATORY ECOSYSTEM SERVICES PROVIDED BY FORESTS

Ecosystem good or service	Low value (2013 CAD/acre/year)	High value (2013 CAD/acre/year)
Local climate and air quality	$61.43	$271.24
Water quality and regulation	$33.67	$287.53
Erosion prevention/ maintenance of soil fertility	$0.82	$0.82
Pollination	$72.79	$426.51
Biological control of pests/ vector-borne diseases	$4.53	$30.14
Total	$173.24	$1,016.24

TABLE 6. VALUE OF REGULATORY ECOSYSTEM SERVICES PROVIDED BY GRASSLANDS

Ecosystem good or service	Low value (2013 CAD/acre/year)	High value (2013 CAD/acre/year)
Local climate and air quality	-	-
Waste-water treatment/water quality	$53.14	$6,759.91
Erosion prevention/ maintenance of soil fertility	$2.38	$3,393.34
Pollination	$1.39	$426.51
Biological control of pests/ vector-borne diseases	$18.55	$314.49
Total	$75.46	$10,894.25

TABLE 7. VALUE OF REGULATORY ECOSYSTEM SERVICES PROVIDED BY FARMLAND

Ecosystem good or service	Low value (2013 CAD/acre/year)	High value (2013 CAD/acre/year)
Local climate and air quality	$100.63	$101.48
Waste-water treatment/water quality	$24.78	$49.11
Erosion prevention/maintenance of soil fertility	$0.34	$205.38
Pollination	$2.78	$1,956.30
Biological control of pests/vector-borne diseases	$14.16	$201.81
Total	$142.69	$2,514.08

TABLE 8. VALUE OF REGULATORY ECOSYSTEM SERVICES PROVIDED BY WETLANDS

Ecosystem good or service	Low value (2013 CAD/acre/year)	High value (2013 CAD/acre/year)
Local climate and air quality	$0.00	$0.00
Waste-water treatment/water quality	$8.21	$15,661.43
Erosion prevention/maintenance of soil fertility	$6.22	$6.22
Pollination	$0.00	$0.00
Biological control of pests/vector-borne diseases	$0.00	$0.00
Total	$14.43	$15,667.65

TABLE 9. VALUE OF REGULATORY ECOSYSTEM SERVICES PROVIDED BY FRESH WATER		
Ecosystem good or service	Low value (2013 CAD/acre/year)	High value (2013 CAD/acre/year)
Local climate and air quality	$0.00	$0.00
Waste-water treatment/water quality	$2.30	$1529.16
Erosion prevention/maintenance of soil fertility	$0.00	$0.00
Pollination	$0.00	$0.00
Biological control of pests/vector-borne diseases	$0.00	$0.00
Carbon sequestration and storage	$0.00	$0.00
Total	$2.30	$1,529.16

TABLE 10. TOTAL VALUE OF ALL REGULATORY SERVICES PROVIDED BY ECOSYSTEMS					
Ecosystem/ land cover	Area (acres)	Low value ($2013 CAD/ acre/year)	High value ($2013 CAD/ acre/year)	Total low value ($2013 CAD/year)	Total high value ($2013 CAD/year)
Forest	62,980,886	$173	$1,016	$10,896,000,000	$63,989,000,000
Grassland	49,432,613	$75	$10,894	$3,707,000,000	$538,518,000,000
Farmland	23,419,623	$143	$2,514	$3,349,000,000	$58,876,000,000
Wetland	2,144,871	$14	$15,668	$30,000,000	$33,605,000,000
Fresh water	1,631,140	$2	$1,529	$3,000,000	$2,494,000,000
			Total	**$17,985,000,000**	**$697,482,000,000**

We estimate that the US receives between $18 and $697.5 billion per year in regulatory benefits from the healthy functioning of ecosystems in the US CRB.

Our estimates are based on a database of primary valuation studies performed in the last few decades and converted to 2013 CAD. Large differences in low and high ranges (for example, a difference of nearly $1,500 in the estimates for water quality services provided per acre of fresh water) can be attributed to different study authors using different valuation methods on ecosystems in entirely different regions. In addition, while we made efforts to minimize double-counting, it is possible that some of the values from the primary valuation studies overlap in their estimates. Consequently, the error associated with our estimates is significant. However, the magnitude of this number, rather than its precise value, is important because it indicates that the US receives significant economic benefits from the ecosystem services across the CRB.

Only a portion of these potential basin-wide benefits can be attributed to the flows regulated under the Columbia River Treaty. This proportion has not yet been calculated. If, however, the parties were to terminate the Treaty, the loss of coordinated management of flows, or the loss of emergency enhancement of flow volume during critical times of drought, could potentially cause a significant reduction in the health of ecosystems in the US, and therefore in the benefits received. These benefits – clean air, clean water, fertile soil – are not optional. If a municipality in the US loses a wetland due to reduced seasonal flows from BC, for example in the case of an extreme drought, that municipality will have to build additional water treatment plants to remove nitrogen and phosphorous from its drinking water. Thus, the US stands to face significant costs in the absence of the coordinated management of the Columbia River enabled by the Treaty.

We recommend further studies to estimate more precisely the proportion of the value of regulatory ecosystem services in the Basin that are dependent on the Treaty in **Next Steps**.

3.4 Cultural Ecosystem Services

Cultural services have non-material and intangible dimensions that benefit individuals through spiritual, aesthetic, existence, tourism and recreational activities. In some ways, these benefits can matter more to individuals than material benefits. For example, while salmon provide food they also represent a valued way of life through fishing, and symbolize deep meaning for the tribes and First Nations who identify with them on a sacred level. Fishing can contribute to communities by shaping who they are and what they value. Salmon are more than important to First Nations and tribes along the Columbia River. Salmon were a "focal point of several stories passed from one generation to the next and as such, comprise an important component of First Nations culture in the region" (Canada Department of Fisheries and Oceans, 2005, 20). In Washington State, a recent stakeholder survey identified recreation, tourism, and cultural values as three of the top five most important values (Iceland et al., 2008). On both sides of the border, salmon are highly valued for recreational and commercial fisheries purposes, with the fish having become extremely popular among anglers. A number of outreach programs have been created to work towards salmon conservation. Omitting these cultural benefits in decision-making could lead to the compromise of community and biodiversity objectives in the US.

Quantifying cultural benefits is extremely difficult; however, they can be approximated by measuring the value of recreation and preservation of freshwater fish and nature in the US Columbia River. In this report, recreation refers to spending by residents related to camping, fishing, wildlife viewing, day trips to parks, etc. Moreover, the value of preservation relates to individual willingness to pay to preserve freshwater fish and nature in the US Columbia River. The following sections provide a comprehensive description and breakdown of these values.

While important, ecosystems' provision of services such as aesthetic beauty and sense of place are far more difficult to determine and to value as separate from recreation and other ecosystem services values. To avoid double counting, these values are not considered here.

Preservation

Society's choices for acquiring market and non-market goods or services are expressed through individuals' willingness to pay (WTP). An increase in an individual's well-being, utility, and welfare can be measured by the maximum amount of dollars that he or she would be willing to forego to obtain a change in environment (Pearce et al, 2006). Moreover, the magnitude of WTP and preservation value depends upon the individual's socioeconomic characteristics, the amount of the valued good available, and the availability of close substitutes for the good or service. The preservation value expressed in this study represents the amount individuals are willing to sacrifice to protect and maintain the existence of freshwater fish in the CRB, even if they do not intend to directly benefit from it.

The WTP to preserve their existence and increase freshwater fish populations in the US CRB is an estimated $1.2 billion. Layton, Brown and Plummer (2001) found WTP per household to be $15 per month. This value was converted into an annual figure ($180 per year) and multiplied by the estimated number of households in the CRB (five million). In Layton et al. (2001), individuals' WTP was represented across 1,917 Washington state households. Randomly selected respondents based their WTP on knowing that Columbia River freshwater fish would continue to decline over the next 20 years at the same rate they declined over the previous 20 years. We derived an estimate of the number of households living along the US portion of the CRB from the United States Census (2010).

Due to the limitations (see **Limitations** section) of this study, and the broad nature of the question posed to participants, the WTP may be overestimated. However, it shows consistency with other preservation studies. For example, in their Monongahela River study, Desvousges et al. (1983) found $196 annual WTP. Correspondingly, Hanemann et al.'s 1991 study of WTP to increase salmon in the San Joaquin River elicited $415 annually. Thus, an increase in salmon populations could enhance preservation values to residents along the Columbia River from knowing the resource is available, regardless of whether they intend to directly benefit from it.

Recreation

The summer is high season for recreational use on the US Columbia River (Nelitz et al., 2007). Drawdowns for power and fish passage adversely affect some activities (e.g., boating) when water access is too low or reduces aesthetics. Typical dam operations ensure lake levels between 1285-1290 feet by July 31 each year (Nelitz et al., 2007). Recreational uses include fishing, picnicking, sightseeing and hunting, as well as camping, water-skiing, boating, canoeing, kayaking, hiking, swimming, jet-skiing, wildlife observation, horseback riding, rock hounding (users who might actually perceive a benefit to more exposed substrate), scuba diving, photography, and bird watching (Ortolano & Cushing, 1999; 2002).

Recreational fishing is enjoyed throughout the Basin, particularly downstream of Bonneville Dam. Important localized fisheries occur upstream from Bonneville Dam for fall Chinook, and for hatchery spring/summer Chinook and steelhead. Catch and-release fisheries for steelhead in some tributaries are also locally important. Furthermore, non-consumptive fishery-based recreation, such as viewing salmon spawning in rivers and streams, and viewing fish at dams, fish ladders, or fish hatcheries, generates an estimated $80 million a year in tourist expenditures (Fluharty, 1995). In some areas, entire communities, resorts, businesses, and individuals in the US portion of the Basin greatly depend on services related to recreational fishing.

The reason for focusing on these benefits is that they relate most directly to the US's use of the Columbia River system. Recreational activities such as wildlife viewing or fishing would not exist without the ecosystem services of the CRB. Ecosystems provide habitat for species essential to the maintenance and appeal of recreation areas. Degraded habitats can negatively affect recreation experiences and number of visits.

Values of recreation and tourism can be estimated by examining spending habits of visitors to state or national parks. This value is defined as the recreational users' minimum willingness to pay (WTP) for travel expenses on trips to catch fish or watch wildlife in the US CRB. In this case, recreational fishers and wildlife watchers have an individual WTP that is equal to or greater than what they actually spend.

Here, surveys of recreational visitor spending conducted by various state or national agencies within the US CRB are used as primary valuation studies to generate estimates of values for cultural ES in the CRB. These surveys often do not differentiate between spending on recreational angling versus spending on recreational camping, etc., and so these values should be viewed with caution to avoid issues of double counting (refer to **Limitations of Ecosystem Valuation Exercises** below). Moreover, the value obtained for recreational fishing is conservative as it does not account for capital costs on equipment used to fish. Expenditures on specific equipment (e.g., fishing boats) were not included due to uncertainty on whether these costs represented a one-time cost or a cost incurred for multiple trips. Nevertheless, if population levels improve sufficiently for aquatic species such as salmon, this will lead to an expansion of recreational angling opportunities and economic impacts in the US CRB. Recreational angling can drive economic benefits through purchases that have direct effects on businesses, income, tourism, and employment in economies of the region.

TABLE 11. ESTIMATED ECONOMIC BENEFITS GENERATED FROM ECOSYSTEM-DEPENDENT RECREATION IN WASHINGTON STATE

Reference	Value (2013 CAD/year)
TCW Economics, 2008	1,062,000,000
Earth Economics, 2014	20,500,000,000
U.S Census Bureau, 2011 (Wildlife Watching)	1,312,038
U.S. Census Bureau, 2011 (Recreational Fishing)	507,024

TABLE 12. ESTIMATED ECONOMIC BENEFITS GENERATED FROM ECOSYSTEM-DEPENDENT RECREATION IN OREGON STATE.

Reference	Value (2013 CAD/year)
White and Gooding, 2012	51,560,000
U.S. Census Bureau, 2011 (Wildlife Watching)	2,052,587
U.S. Census Bureau, 2011 (Recreational Fishing)	311,765

In White and Gooding (2012), the authors state:

> "The average trip spending of visitors ranges from about $40 per party per trip for local residents on day trips to nearly $226 per party per trip for non-local residents on overnight trips away from home. On average, most local area expenses are for gasoline, groceries, and purchases in restaurants/bars. The reported 3.5 million visits annually to Oregon State Parks properties in the Columbia River Gorge Management Unit yield about $50 million in visitor spending in local communities. Non-local residents account for about $33 million of that spending."

TABLE 13. ESTIMATED ECONOMIC BENEFITS GENERATED FROM ECOSYSTEM-DEPENDENT RECREATION IN IDAHO STATE

Reference	Value (2013 CAD per year)
McKean and Taylor, 1998	36,450
U.S. Census Bureau, 2011 (Wildlife Watching)	344,549,376
U.S. Census Bureau, 2011 (Recreational Fishing)	198,539

McKean and Taylor (1998) write:

> “The primary objective of the demand analysis was to estimate willingness-to-pay per trip for recreation in the Snake River Basin in central Idaho. Consumer surplus (the amount by which total consumer willingness-to-pay exceeds the costs of production) was estimated at $87.24 per person per travel cost trip. The average number of recreation trips per year from home to the Snake River Basin in central Idaho was 2.76 (sample of 288 recreationists) resulting in an average annual willingness-to-pay of $241 per year per recreationist. The total annual willingness-to-pay for all recreationists in the Snake River Basin of central Idaho is estimated at $25.1 million.”

TABLE 14. ESTIMATED ECONOMIC BENEFIT GENERATED FROM ECOSYSTEM-DEPENDENT RECREATION IN MONTANA STATE.

Reference	Value (2013 CAD/year)
U.S. Census Bureau, 2011 (Wildlife Watching)	740,554,752
U.S Census Bureau, 2011 (Recreational Fishing)	198,370

TABLE 15. TOTAL ECONOMIC BENEFITS GENERATED FROM ECOSYSTEM-DEPENDENT RECREATION IN ALL CRB STATES.

State	Low value (2013 CAD/year)	High value (2013 CAD/year)
Washington	507,024	20,500,000
Oregon	311,765	51,560,000
Idaho	36,450	344,549,376
Montana	198,539	740,554,752
Total	1,053,778	1,157,164,128

TABLE 16. TOTAL CULTURAL ECOSYSTEM GOODS AND SERVICES IN THE COLUMBIA RIVER BASIN

Cultural ecosystem good or service	Low value (2013 CAD/year)	Low value (2013 CAD/year)
Recreation	1,053,778	1,157,164,128
Preservation (aesthetic, religious, etc.)	1,200,000,000	1,200,000,000
Total	1.2 billion	2.4 billion

3.5 Total Value of Ecosystem Goods and Services in the Columbia River Basin

TABLE 17. TOTAL VALUE OF SELECTED EGS IN THE US COLUMBIA RIVER BASIN		
Ecosystem good or service	Low value (2013 CAD 000 000s/year)	High value (2013 CAD 000 000s/year)
Anadromous fish (provisional)	$150	$600
Regulatory services (regulatory)	$349,551	$1,447,612
Cultural	$1,201	$2,357
Total	~ 19, 000	~ 701, 000

3.6 Spending by Two US Agencies on Ecosystems

As mentioned above, fish and wildlife contribute to communities along the Columbia River through recreation opportunities, tourism, and cultural services, delivering spiritual and aesthetic benefits. The value of funds allocated by US fish and wildlife and state agencies in the US portion of the Basin to fisheries recovery, conservation, and public education and information programs is used to illustrate the cultural, provisional, and recreation benefits provided by fisheries in the US Columbia River.

TABLE 18. ESTIMATED VALUES GENERATED FROM FISH AND WILDLIFE SPENDING IN THE CRB FROM SELECTED FEDERAL AGENCIES	
Reference	High value (2013 CAD/year)
Bonneville Power Administration	500,000,000
U.S. Army Corps of Engineers, 2013	98,000,000

Bonneville Power Administration

Bonneville Power Administration (BPA) is required by the Northwest Power Act to mitigate dam impacts on fish and wildlife. As a federal agency, BPA also has obligations under the Endangered Species Act and under long-held treaties with Columbia Basin tribes to restore fish and wildlife populations. From 1978, when expenditures began, through 2011, BPA has spent $12.4 billion on fish and wildlife in the CRB (not including $2.09 billion in capital investments such as the construction costs of facilities such as fish hatcheries and fish-passage facilities at dams, or $1.71 billion in credits from the federal government) (NWPCC, 2011).

Spending between 1978-2011 includes the following:

- $3.92 billion for power purchases to meet electricity demand requirements in response to river and dam operations required to assist fish passage and improve fish survival that reduce hydropower generation;
- $2.73 billion in foregone hydropower sales revenue from required river operations to assist fish passage and improve fish survival;
- $3.16 billion for the Northwest Power Conservation Council's fish and wildlife program budget, including work on fish production, habitat enhancement, etc.;
- $1.99 billion in fixed expenses for interest, amortization, and depreciation on capital investments; and,
- $1.18 billion to fund fish and wildlife projects undertaken by the US Army Corps of Engineers or the Bureau of Reclamation (these expenditures include, for example, operations and maintenance costs of certain fish-production facilities, fish passage facilities at dams, and research activities) and reimburse the US Treasury for the hydropower share of major dam modifications by the Corps of Engineers, such as installing spillway weirs, bypass systems, fish-deflection screens in front of turbine entrances, and spillway modifications to reduce dissolved gas (NWPCC, 2011).

BPA's spending obligations rose dramatically in 2008 with the completion of the National Oceanic and Atmospheric Administration (NOAA) Fisheries' Federal Columbia River System biological opinion planning process. This directive aims to improve the state of Endangered Species Act listed salmon and steelhead survivals by investing heavily in their habitat, improved hatcheries, and hydro system passage technologies (George, 2014).

Each year, BPA spends over half a billion to bring roughly two million fish back to the Columbia River (George, 2014). On average, BPA invests $250 per fish in industries performing work on BPA's behalf in support of the Columbia salmon. In some regions, such as Idaho, money spent per fish is much higher, reaching $8,000 per fish (George, 2014). BPA projects its spending to rise to $550 million for fiscal years 2016-2017, a dramatic increase from the $330 million spent during 2007-2009 (George, 2014). In 2008, BPA and other federal agencies signed new "Fish Accords" with treaty tribes and states that resulted in pledges of more than $1 billion in additional spending on fish and wildlife projects over the period ending in 2018 (George, 2014).

US Army Corps of Engineers

In 2013, the United States Army Corps of Engineers (USACE) dedicated $98 million to Columbia River fish mitigation in Washington, Oregon, and Idaho. Money spent is used to fund projects that restore Columbia River velocities and depths to levels similar to those prior to river alterations, and provide access to historic spawning reaches. The USACE has identified the eight hydroelectric projects on the Columbia as major contributors to the mortality of downstream migrating fish (USACE, 2013).

Collectively, these values reveal authorities' minimum willingness to pay to protect and preserve fish species in the river. Many species in the river are linked closely to the social and cultural heritage of residents in the Pacific Northwest. Yet, while expenditures for fisheries education and conservation in the river could underestimate the value held by society for fish, they could also be overestimates because, through their expenditures, authorities inform individuals (who may not have known otherwise) how important fisheries are. Notwithstanding these concerns, overall, expenditures made by BPA and the USACE have been interpreted as actions illustrative of society's value to these services in the US CRB (National Academy of Sciences, 2004).

CHAPTER 4: COSTS TO BRITISH COLUMBIA

In this chapter, we explore some of the opportunity costs BC incurs by not being able to manage its resources entirely for domestic purposes. Other than the value of the Canadian Entitlement, BC currently receives no direct financial benefits from the Columbia River Treaty. When the Treaty was signed and the dams built, “110,000 hectares (270,000 acres) of Canadian ecosystems were inundated; residents, First Nations, communities and infrastructure were displaced; farms and forestry activities were impacted” (CRTR, 2014a).

For example, in 2008, the community of Golden drafted an appeal to the Premier for damages incurred by the creation of reservoirs. In this appeal, Golden expressed a summary of estimated losses in key sectors: $7.5 million in potential annual revenues from damage to the local timber supply; $50 million in lost waterfront recreation development; $45 million lost to depletion of wildlife resources; and $13 million in loss of waterfowl resources (Davidson & Paisley, 2009). Golden states that the cumulative impacts of these effects have been affecting their region for over 40 years. Other communities located around the Basin have drafted letters to BC Hydro expressing similar concerns, outlining losses to forestry, regional transportation, recreation and tourism, and community economic development (Davidson & Paisley, 2009).

Mid-Arrow Project

The Arrow Lakes reservoir, created by the Columbia River Treaty through the impoundment of the Upper and Lower Arrow Lakes, was viewed as the most important Canadian reservoir for flood control during original Treaty negotiations. The large amount of storage it provides at low economic cost has significant implications for the negotiation of downstream benefits (CRTR, 2015). Because of the short time required for flow releases from Arrow to reach the lower Columbia, the US depends on the management of Arrow for flood control. Headwater reservoirs (e.g., Mica, or Hungry Horse) have longer travel times (CRTR, 2015).

Biodiversity in the region has been severely negatively impacted by the creation of the Arrow Lakes Reservoir. While all BC Treaty reservoirs had similar types of impacts, construction of the Keenleyside Dam and the Arrow Lakes reservoir inundated the largest areas of both water and land in BC: a total of 126,637 acres (CRTR, 2014b) including 51,269.9 acres of aquatic and terrestrial ecosystems. BC lost 3,431.6 acres of wetlands, 3,563.5 acres of riparian and forest areas,[1] and 3,844.3 acres of upland ecosystems (CRTR, 2014b). Substantial habitat losses in Arrow Lakes impacted amphibians, water birds, waders, songbirds, bats and aerial insectivores (Utzig & Schmidt, 2011). Assessments describe a wide range of impacts to aquatic species, although the significance of particular impacts

1 Approximately 40% of the flooded forest ecosystems were late seral forests. Mid seral stands accounted for 40% of the flooded forested ecosystems, and the remaining 20% were early seral (Utzig & Schmidt, 2011).

on individual species varies depending on their life history (Utzig & Schmidt, 2011). Major impacts reported to fish species include loss of riverine habitat, nutrient losses, changes in flow regimes, alteration in water quality/turbidity, habitat/population fragmentation, and entrainment (Utzig & Schmidt, 2011).

In addition to impacts to biodiversity, over 2,300 people were displaced, and over a dozen small communities, their infrastructure, public spaces and way of life were lost in the Arrow Lakes valley (CRTR, 2014b).

The rise and fall of the reservoir's water levels and unnatural draw down continues to affect the surrounding ecosystems, cultural and recreation interests, and economies in the region.[2] Despite the low carbon power benefits received by BC, under current Treaty operations, communities within the Canadian portion of the CRB suffer from a lack of control over their own resources and the benefits therein.

In preparation for CRT negotiations prior to 2024, the province is now examining the management of the Arrow Lakes reservoir to find ways to mitigate the impacts cited above. Arrow has the most potential of any of the Canadian reservoirs to change its operations post-2024. Although it is a large storage facility (7.1 MAF), it is a relatively low head dam, generating only 185 megawatts of energy (CRTR, 2015). Depending on changes to the CRT in 2024 or after, Arrow could operate as a near run-of river facility, with most of the flow regulation being provided by the upstream Mica facility. In this case, only a small draft at Arrow would be required for local Canadian flood control (CRTR, 2015).

BC Hydro has also invested in a re-vegetation program at the Arrow Lakes reservoir. The province is exploring opportunities to enhance vegetation in the Arrow Lakes reservoir by maintaining more stable reservoir levels for longer periods, in acknowledgment of the importance of the riparian and wetland vegetation surrounding the reservoir in terms of enhancing productivity, providing wildlife habitat, protecting cultural heritage sites, and improving aesthetic benefits within the drawdown zones. A narrow mid-level range is suggested as a way to meet many ecosystem needs and some flood control.

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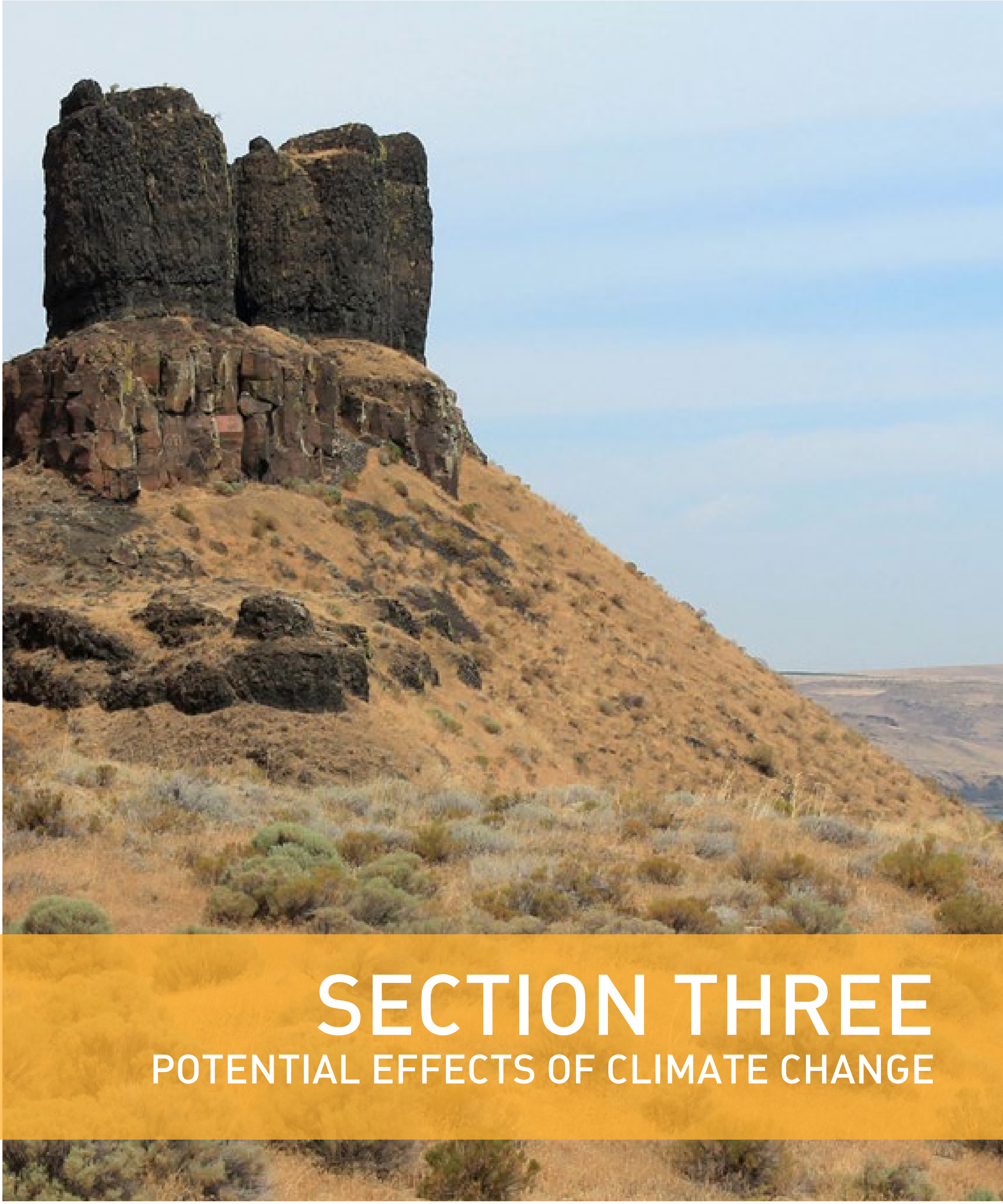
2 Fluctuating reservoir levels have led to property and infrastructure erosion surrounding Arrow Lakes. An increase in boating accidents (e.g., Arrow Park) has been cited due to low reservoir levels. In other cases, high reservoir levels have led roads to sink and erode. Moreover, river level fluctuations and high water periods erode sands, requiring beach replacement every two years (for further information refer to LG Committee, 2014).

Stabilizing the Arrow Lakes reservoir requires a lower water level of between 1415-1425 feet in elevation. Stabilizing the water would also allow for the reclamation and restoration of riparian and riverine ecosystems, beaches, wetlands, agriculture and forestry lands. This in turn would enhance tourism, recreation, employment opportunities, contribute to natural nutrient levels in the water for fish, and address problems of dust-storms, infrastructure damage, property loss, water turbidity, and declining bird, bat, and pollinating insect populations.

While the mid-Arrow strategy would enhance and regenerate ecosystem goods and services around the Arrow Lakes, it raises concerns for the parties to the Treaty because changes to Arrow will affect both upstream (Revelstoke, Mica) and downstream US interests. Specifically, because Canada may be required to continue to provide flood control measures under the "Called Upon" agreement of the Treaty, Canada must be prepared to use its reservoir storage space to assist the US with downstream flooding (after the US has taken all necessary measures first). The US sees Arrow as being key to its flood control needs and providing flexibility in their own system and flow operations. In order to ensure that BC is able to manage its resources and values for domestic purposes, while also meeting "Called Upon" flood control obligations, the concerns of the residents of the Canadian portion of the CRB will be raised and discussed during the Arrow Lakes reservoir review under the Columbia Water Use Plan, scheduled for completion by 2022.[3]

3 The Columbia River Water Use Plan defines how BC Hydro will operate its water control facilities on the Columbia River from Kinbasket Reservoir downstream to the Canada/US border. Water control facilities include the Mica, Revelstoke, and Hugh Keenleyside dams (BC Hydro, 2007).



SECTION THREE

POTENTIAL EFFECTS OF CLIMATE CHANGE

CHAPTER 5: CLIMATE CHANGE

Operational planning under the Columbia River Treaty depends on seasonal and year-to-year adjustments that can be forecast within the scope of historical hydrological variability, providing sufficient flexibility for adaptive management to account for seasonal and year-to-year uncertainty. Unfortunately, climate change is increasing the range of variation beyond what can be predicted based on historic behaviour (Hamlet, 2003); this shift is referred to as the loss of hydrologic stationarity.

Water management in the Treaty relies heavily on predictable natural storage in the form of snowpack. Climate change threatens to alter the river's hydrology and the ability to predict the performance of the river system partly due to its impact on the seasonal distribution of runoff due to warmer temperatures that will diminish snowpack volume and shift winter precipitation from snow to rainfall in parts of the region (Cohen et al, 2000). Annual precipitation has already increased by 26% in the Basin, composed of an increase of 32% in rainfall and a 6% decrease in snowfall (PCIC, 2006). As these changes advance, they will lead to earlier peak and reduced summer flows for the Columbia River on both sides of the border. These shifts combined with the loss of stationarity in the US portion of the Basin, combined with longer, hotter, drier summers, will increasingly threaten its ability to meet water resource needs in the US.

Between 1985-2000, the average loss of volume for all glaciers in the CRB was 16%, with some losing as much as 60% (PCIC, 2006). Climate projections predict a rise in mean temperature within the Basin by 1.1-1.3°C by the 2020s, 2.4-3.0°C by the 2050s, and 3.3-5.0°C by the 2080s (PCIC, 2006). In a worst-case scenario, by the year 2050, stream flow is projected to drop by 50% in the lower portion of the Basin (Hamlet and Lettenmaier, 1999). Moreover, in a recently released study, Clarke et al. (2015) warn that 70% of glaciers in BC could disappear by the end of the 21st century, creating serious problems for ecosystems, power supplies, and water flows along the Columbia River. Specifically, the report states that the Rocky Mountains could lose up to 90% of its glaciers. The loss of glaciers and their cooling influence will also hasten the loss of snowpack. The authors state that the greatest impact will be on freshwater ecosystems, affecting salmon production in the Columbia River (Clarke et al., 2015), especially as salmon cannot tolerate high water temperatures, which cause what is known as a thermal block to migration. The potential for a thermal block will increase as the glaciers melt.

Climate change will therefore pose significant challenges for water quantity, quality, and timing of availability, placing regional and ecosystem needs at risk throughout the CRB. For example, a shift in the hydrograph will affect when and how water is stored, and therefore the amount of water available for power production in the US. Moreover, the value generated by hydropower depends largely on the reliability of water flow and the extent to which hydropower generation matches power demand. Warmer summers may lead to an increased demand for air conditioning and irrigation that coincide with lower flows. Changes to the hydrologic system in the Basin will require adjustments in reservoir management operations. To adapt to these changes, US residents could explore a range of options for increasing non-hydropower renewable energy. In addition, the diversification provided by maintaining a North American grid could be evaluated as one of the benefits of continued US–Canada cooperation under the Treaty (Cosens et al., n.d.).

High temperatures and prolonged low flow periods also pose risks to fish stocks and could potentially lead to higher mortality rates (BC Ministry of Energy and Mines, 2013), and could make it increasingly difficult to meet the in-stream flow requirements set forth for fishery protection; as a result of efforts in the US Pacific Northwest, the per-kilowatt-hour costs of power supply have increased over time because of fish and wildlife adaptation expenditures (Northwest Power Conservation Council, 2014).

The seasonal decline of water availability in the Basin as a result of a changing climate will also have significant impacts on agriculture. Irrigation from surface and groundwater is the dominant off-stream use of water in the Basin: roughly six million acres are irrigated in the mid-lower portions of the river (Cohen et al., 2000). Idaho has the largest irrigated area, with 3.3 million acres (45% of the total Basin), Washington with 1.8 million acres (25%), Oregon with 1.3 million acres (18%) and Montana with 433 thousand acres (6%) (US Department of Energy, 1995; Davidson & Paisley, 2009). Washington's $49 billion food and agriculture industry represents 13% of the state's economy (Washington State Department of Agriculture, 2014). In 2009, agriculture amounted to more than 15% of all economic activity in Oregon, producing an added $22 billion dollars for Oregon's GDP (Sorte et al., 2011). Irrigated crop values range from $150 per acre for hay to $6,000 per acre for apple orchards and vineyards (Volkman, 1997).

As water availability changes, priority structuring of water rights will dominate the allocation of water in the US: senior water rights holders will continue to have access to water, while junior farmers will be obligated to do without, or attempt to purchase water rights from senior holders. Although climate change could result in new agricultural opportunities and provide longer growing seasons, warmer temperatures will also increase the demand for irrigation and value of water. Empirical evidence suggests that, when water becomes tightly restricted within the CRB, marginal values of crops can reach $46 per acre-foot, whereas when water is readily available, crops value at a few dollars per acre-foot (National Research Council, 2004). Recent evidence indicates that marginal values could reach as high as $200 per acre-foot. Thus, under scenarios of water scarcity, the value of water also increases in the CRB.

Assuming an equivalent land base for irrigated agriculture in the future, a 2030 forecast of demand for irrigation water across the entire CRB (four US States and BC) was found to be 13.6 MAF under average flow conditions (Washington State Department of Ecology, 2011). This translates into a roughly 2.5% rise from historic levels (Washington State Department of Ecology, 2011). If less water were available to be diverted toward irrigation needs, agriculture in Washington and Oregon could experience annual costs ranging from $465 million to $2.4 billion, depending on the amount of water lost (Goodstein & Matson, 2007). For example, in 2001, low snowpack in the Klamath Basin led authorities to shut off irrigation channels affecting 12,000 farms (34% of irrigated land in the basin) to maintain water levels for endangered species (Erickson & Gowdy, 2007). As a result, gross farm incomes fell between $48-$64 million in a region that generated average revenues of $97 million during the previous three years (Erickson & Gowdy, 2007).

Ultimately, a failure to address low flows could therefore result in both fish and farmers bearing the brunt of climate change, if no effort is made to adapt (Hamlet, 2003). Many other sectors will suffer as well, including river transportation and navigation, which will also be impacted by low summer flows. Assisting other water users will result in reservoir drawdowns that pose challenges and costs to navigation, by either halting traffic or requiring users to find alternate modes of transportation. The marginal value of water for navigational purposes on the Columbia River has been estimated at $5.60/acre-foot (WSTB and BEST, 2004); therefore, there will also be quantifiable economic impacts to navigation due to climate changes in the Basin.

Climate change may also impact urban water supplies within the Basin. For example, the 2°C warming projected to occur by the 2040s will increase demand for water in Portland, Oregon by 5.7 million m3/year, with an additional demand of 20.8 million m3/year due to population growth, while decreasing supply by 4.9 million m3/year (Mote et al., 2003). This creates potential for a supply and demand gap that is likely to exacerbate competition between water users.

Climate change effects on the global hydrological cycle require most areas to prepare for unpredictable magnitudes and durations for major flood and drought events. The estimated cost of replacing water to offset potential reductions in Columbia flows in the

Although climate change could result in new agricultural opportunities and provide longer growing seasons, warmer temperatures will also increase the demand for irrigation and value of water.

summer months is between $1.43-$2.29 billion annually under the severest drought conditions (Goodstein & Matson, 2007). As noted earlier, the opposite issue - that of severe flooding – is currently controlled by Canada's Treaty operations, which save the US millions, and sometimes billions, of dollars in avoided flood damages annually. As more water falls as rain in winter, and climate change drives increasingly intense precipitation events, the risk of major flooding and the value of flow control increases.

These and other climate change projections demonstrate that it is urgent that we prepare for climate change impacts in the CRB by planning adaptive management approaches. Reservoir operations can assist climate change adaptation by capturing water as it runs off in extreme weather events and releasing stored water during periods of water scarcity caused by extreme heat or drought. Reservoir capacity will become increasingly important as glaciers recede, and slow down or cease their provision of meltwater in the spring and summer months, just when energy demand goes up due to heat and the need for air conditioning.

The coordination of the international parties laid out in the Columbia River Treaty represents a crucial opportunity for effective management of these issues. The great Columbia River and its Basin should be viewed as a deeply valuable example of the challenges governance now faces to establish mechanisms within which we can convene to address these future challenges.

CHAPTER 6: CONCLUSIONS

Our findings represent an initial look at ecosystem goods and services (EGS), and identify the following benefits provided by ecosystems in the US Columbia River Basin (CRB).

1. Provisioning Goods Provided by Salmon

Salmon for harvest represent significant monetary value irrevocably tied to economies in the region and benefits to fishers, the commercial fishing industry, US Tribes and consumers. BC has a significant role to play in allocating flows and cooler waters to the US through Treaty mechanisms to guarantee these benefits. Without these coordinated flows, the US may face significant economic losses due to projected climate change impacts leading to salmon stock decline. BC should consider the value of salmon in the US CRB and derive compensation for operations in BC that enhance and preserve this ecosystem service.

2. Agency Spending

US agencies are spending increasing amounts on fish and wildlife restoration and rehabilitation. This spending is fuelled by the listing of salmon under the US Endangered Species Act and the importance of sport and commercial fisheries to the regional economy and regional identity, as well as the desire to avoid lawsuits from Indigenous groups over fishing rights, should the salmon go extinct. For example, in 1951, 1975, and 1991, the Colville and Spokane Tribes took legal actions against the US government for the loss of traditional fishing. In 1994, partial agreement was reached, with the Colville Tribes receiving a lump sum of $53 million and $15 million annually thereafter (Ortolano & Cushing, 1999). The importance of high flows during critical periods indicates that BC has a significant role to play in restoring the salmon fishery in the US Pacific Northwest, and that BC should therefore be compensated for managing its dams in accordance with US desire to restore and maintain salmon.

3. The Value of Regulatory Ecosystem Goods and Services

Regulatory ecosystem services are critical to CRB residents' health and quality of life. Timed BC flows contribute to the health of wetlands, forests, and grasslands, and therefore to the health benefits provided by these ecosystems. For example, managing BC flows to restore wetlands in the US provides a benefit to the US at the expense of BC. BC should likely be compensated for managing flows in such a way that contributes to the overall health of ecosystems in the CRB.

4. The Value of Ecosystem-Dependent Recreation

The primary studies summarized in this report indicate that ecosystem-dependent recreation is a major source of economic activity in the CRB. As recreation spending is tied to the health of the ecosystems on which it depends, and as sport fisheries are particularly dependent on increased flows from BC during summer months, the contribution of BC-managed flows to US economic activity from recreation should be considered.

5. The Amount Individuals Are Willing to Pay to Protect, Enhance, and Preserve Ecosystems

Individual wellbeing, utility, and welfare are linked to the preservation and existence of freshwater fish and nature in the US CRB. The preservation value expressed in this study represents the annual amount US Basin residents are willing to pay to protect and maintain the existence of freshwater fish and nature in the Basin, even if they do not intend to directly benefit from it. This value serves as an indicator of how much money households in the US portion of the Basin might be willing to forego to preserve and restore freshwater fish and ecosystem health. BC should consider conducting an empirical contingency valuation survey (see Methods) with residents in the Basin to discuss whether money from willingness to pay could be used to compensate Canada for water flows and, in doing so, find equitable Treaty impacts.

SIGNIFICANCE FOR BC AND THE COLUMBIA RIVER TREATY

By supporting fisheries; regulating the quantity and quality of air, water, and soil; attracting recreational visitors; and providing aesthetic, religious, or educational value, ecosystems in the CRB produce in total between **$19-$701 billion** of benefits to the regional economy every year. The value of fish alone, measured in a number of ways including US agency spending, is between approximately $150 and 600 million annually. Recreation and existence of nature are worth another approximately $1.2 to 2.4 billion annually The remainder of the value is contributed by regulatory services, which total approximately $18 to 697.5 billion annually (all values in 2013 USD). This large range in values represents an approximate appraisal of the natural capital of the US CRB. Obtained values replace the *former estimate of zero* that has been the default value of ecosystems in the framework of the CRT. Because this study values only a limited range of the known EGS produced in the US CRB, the low end of the range provided can be considered a baseline value.

This large range in values represents an approximate appraisal of the natural capital in the US CRB that replaces the former estimate of zero that has been the default value of ecosystems. Because we only valued a limited range of the known ecosystem services produced in the US CRB in this study, the low end of the range provided can be considered a baseline value.

Overall, this report indicates that the value of nature should be incorporated into the economic analysis of the Columbia River Treaty. The analysis demonstrates that the potential values of ecosystem goods and services in the US Columbia River Basin are significant, and that the exclusion of these values when calculating compensation for Canada could result in significant gaps in assessment of both the values inherent in Canadian system operations, and in the value of our efforts to adapt to a changing climate.

NEXT STEPS & FURTHER RECOMMENDATIONS

This report provides estimates of ecosystem goods and services for the entire US portion of the Columbia Basin. It does not attempt to estimate potential values associated with regulated water releases to the US under the Columbia River Treaty. This will require further work. Nor, as we have stated in the Introduction, does it suggest that these values transcend cultural and spiritual values that cannot be characterized in economic terms. However, it is reasonable to infer that there are real values associated with EGS flowing to Canada as a result of the Treaty. At present, none of this value is included in the financial formulae associated with flood control and hydroelectric power benefits under the current Treaty.

As the climate and hydrology of the Columbia River and its tributaries changes over coming decades, water security for a variety of uses will become increasingly important to the US interests. Accordingly values associated with water use in its rich array of services will also increase.

ACT proposes to undertake further research in the following two areas in order to refine the estimate of non-market values associated with ecosystem goods and services as these might specifically relate to a renegotiated Columbia River Treaty:

1. Focus Analysis on Treaty-Related EGS

There is a need to focus on ways water regulated by BC can support a range of US purposes; for instance, the amount of water that BC may need to send to the US to maintain viability for salmon under the Treaty, and how much these flows would be worth to BC to enhance BC ecosystem-based recreation and/or regulatory services (e.g., wetland carbon sequestration). Technical reports, cost-benefit analysis, and/or case studies could help to explore this question. For example, it would be useful to expand the economic analysis of scenarios of coordinated management and non-coordinated operations, in order to understand the impacts and benefits to users and ecosystems throughout the river, and the potential value of flows to both nations within a changing climate.

2. Research Payment for Ecological Services

Policies and tools are emerging in a number of jurisdictions, whereby beneficiaries of EGS actually pay for these ecological services (PES) in transboundary water management. It would be fruitful to examine best practices in PES and to determine how feasible something like PES would be in a re-negotiated CRT. PES is a market-based mechanism used to encourage conservation of natural resources and is a tool that could be used to address ecosystem health in the Basin. PES reverses environmental degradation by paying landowners for the ecosystem services that their lands provide. The potential for high legal costs related to environmental legislation and Native American fishing rights could incentivize the US to negotiate an alternative payment scheme (from the Canadian Entitlement) for ecosystem services. This could include direct payments (such as payment for ecosystem services) from the US to Canada for environmental services in the form of managed flows designed to assist fisheries conservation.

By providing water quantity and quality and flood protection to the US, Canada restricts its own ability to manage flows for domestic requirements and water resource needs. If these negative impacts are not valued, the overall benefits from coordinated management are reduced and the outcome is less desirable. Instead, these impacts could be valued through a payment scheme for ecosystem services.

Changes such as reduced snowpack, increased winter precipitation, and extreme events – floods and high temperatures, as well as longer, hotter, drier summers – will affect market and non-market values of water in municipal services, agriculture, navigation, fisheries, and flood control.

In addition to these specific projects there are a number of ongoing analyses that should be monitored, as these will contribute to the research proposals above

1. Track Hydrologic Modelling

Currently, more accurate hydrologic modelling is being undertaken in both Canada and the US to predict how climate, hydrology and water temperatures will change over the coming decades. Changes such as reduced snowpack, increased winter precipitation, and extreme events – floods and high temperatures, as well as longer, hotter, drier summers – will affect market and non-market values of water in municipal services, agriculture, navigation, fisheries, and flood control.

These modelling initiatives are being tracked by the Treaty Entities and will provide important new information on changes in hydrology and temperature in the Columbia River and the climate continues to change.

2. Review Fisheries Initiatives

There should be an assessment of how flow and temperature changes might affect fish survival in the Columbia and its tributaries. This assessment should be coupled with an understanding of the preparations for revising the Columbia Water Use Plan (WUP), scheduled to begin at the end of this decade following the completion of the data and monitoring requirements of BC's existing plan. The advent of changes in the flood control regime, and the possibility of a mid-level control for Arrow Lakes that arises from this change, opens up a range of possibilities for including EGS values in both the WUP and the Arrow Lakes analysis.

There is value in assessing the results of fish migrations from the US into the Okanagan tributaries of the Columbia system. The BC Okanagan First Nation's sockeye reintroduction program has allowed salmon in the Columbia River system to return back into the Okanagan Lake. Adult sockeye salmon bound for spawning grounds in the Okanagan River must migrate past ten hydroelectric or flood control dams (nine on the Columbia River mainstem, plus one on the Okanagan River). A 12-year (now in year six) collaborative adaptive management approach by the Okanagan Nation Alliance (ONA), Fisheries and Oceans Canada, Ministry of Environment, Colville Confederated Tribes, and the Bonneville Power Administration is currently in the process of reintroducing sockeye into Okanagan Lake. The dry, hot summer of 2015 with its warm river temperatures will be an important factor in this learning process. We believe there is much to be gained in terms of understanding EGS from looking into this initiative, and working to understand and characterize the indicators of a healthy ecosystem that can support resiliency and migration of fish from the US into BC.

3. Link Market and Non-Market Valuation Studies

It is important to understand the links between this analysis of non-market values with a parallel study undertaken for the BC Ministry of Energy and Mines on market values associated with changing patterns of supplies and demands for water. For example, while there is a lack of literature discussing impacts to navigation in the US portion of the CRB, we feel that climate change could have major significance for these operations. Commercial navigation on the Columbia River is a key contributor to economic sustainability in the US Pacific Northwest (BC Ministry of Energy and Mines, 2013), and the Columbia is an important commercial waterway for transportation of goods to domestic and international markets with over 790 navigable kilometers. Under various climatic and water flow scenarios, there could be quantifiable economic impacts to navigation occurring in the US CRB.

Climate change impacts might also cause losses for recreational and commercial fisheries due to changing flows and species responses. For instance, commercial losses might result from restrictions imposed to protect restored fish co-migrating with harvestable stocks. G. S. Gislason & Associates Ltd. estimated the magnitude of commercial and recreational fisheries on BC's Fraser River to evaluate the impacts of listing sockeye salmon as endangered under the Species at Risk Act (SARA) (Nelitz et al., 2007). Under the current management system, the commercial value of the fishery was estimated at $6.6 million, or $19 per fish, while the recreational fishery was estimated at $6.3 million or $110 per fish. The difference between the current management system and a worst-case scenario where sockeye salmon were listed as endangered was a 94% reduction in the value of both the commercial and recreational fisheries (Nelitz et al., 2007). Thus, this provides a rough measure of the potential magnitude of impacts from changes in water flow (Nelitz et al., 2007).

Few studies have considered the value of recreational benefits (another area of study that might prove fruitful in quantifying potential impacts); however, the recreational value of water in the Columbia Basin has been estimated at $7.7-$130 per acre-foot (WSTB and BEST, 2004).

These points suggest that there would be a great deal to be gained from further studies exploring and quantifying the variety of economic impacts of climate change in the CRB.

LIMITATIONS

Ecosystem valuation exercises have a number of limitations. These do not detract from the major finding that ecosystems in the Columbia River Basin contribute significant benefit to the US, but should be acknowledged when reading this report and applying its findings.

Challenges with Benefit Transfer Methodology:

1. **Applicability of regulatory values from different regions to CRB**: Every ecosystem is unique; therefore primary studies of, for example, the value of filtration of nitrogen by wetlands in the Mackenzie River may vary from the value of the same service by wetlands in the CRB.

2. **Values from primary studies vary in their methods and accuracy**. Contingency valuations (see 'Stated Preference Method' in Table 2) most often rely upon willingness-to-pay (WTP) measures that identify the maximum amount an individual is willing to give up to procure a good or avoid an undesirable change. One disadvantage is that the WTP values are taken from one point in time, and thus cannot reveal how residents' WTP shift with economic and social change. Additionally, WTP is based on varying and subjective circumstances. An individual's level of wellbeing can influence their WTP, and therefore this value could be an underestimate or overestimate. The way that a question is framed or design of the survey can also interfere with WTP measures. For example, studies using WTP are also limited by people's perceptions and knowledge of ecosystem services.

3. **Values used in this study assumed ecosystems are functioning at maximum capacity.** Unhealthy ecosystems, for example, may be sequestering less carbon than usual, and so the values here may be an overestimate.

4. The use of benefit transfer methodology represents an initial look at ecosystems in the US portion of the CRB, but it **excludes benefits that could not be measured or estimated.** For instance, these estimates do not include the connection between salmon and tribal culture. The US CRB is comprised of 15 tribal nations who all share a dynamic relationship with salmon. These values are extremely difficult to quantify and measure, and we were unable to undertake the sort of detailed study required for a meaningful estimate within the scope of this project. It is also likely, as we have previously noted, that there would be reluctance amongst tribes and First Nations to place a dollar value on a matter of such intensely spiritual nature.

5. The use of geographic information systems **(GIS) data is inherently limiting.** Land cover categories are broad and group together distinct ecosystems (i.e. shrub/

scrub and grassland). Primary studies may have been done in a certain sub-type of an ecosystem and then applied to a broad category. Our analysis was based on data from the Northwest Habitat Institute's US Columbia River Basin Current Wild-life-Habitat Types Project, which was conducted in 2000, and land cover may have changed in the intervening decade and a half.

6. Because **primary valuation studies may use different systems** to categorize and distinguish benefits derived from ecosystem services, there is a large risk that some of the values in this report may be overestimates due to double-counting.

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APPENDIX A:
VALUE TRANSFER STUDIES BY LAND COVER

FOREST

		LOW	HIGH
ECOSYSTEM SERVICE	AUTHOR(S)	$/ACRE/ YEAR	$/ACRE/ YEAR
Local climate and air quality	Mates. W., Reyes, J.	$61.43	$271.24
	Wilson, S. J.	$165.98	$165.98
Water quality	Zhongwei, L.	$286.34	$286.34
		$287.53	$287.53
	Olewiler, N.	$33.67	$33.67
	Wilson, S. J.	$208.90	$208.90
Water regulation	Adger, W.N. et al	$0.08	$0.08
Soil erosion control	Moore, W.B	$0.82	$0.82
Biological control	Wilson, S. J.	$11.45	$11.45
	Krieger, D. J.	$10.35	$10.35
	Pimentel, D.	$4.53	$4.53
		$30.14	$30.14
Pollination	Costanza, R. et al	$72.79	$326.95
	Wilson, S. J.	$426.51	$426.51
		$236.68	$236.68

GRASSLANDS

		LOW	HIGH
ECOSYSTEM SERVICE	AUTHOR(S)	$/ACRE/ YEAR	$/ACRE/ YEAR
Water quality	Rein, F. A.	$21,934.08	$21,934.08
	Zhongwei, L.	$6,759.91	$6,759.91
		$11,722.46	$11,722.46
Water regulation	Jones, O.R. et al	$1.62	$1.62
Soil erosion control	Gascoigne, W.R. et al	$7.27	$7.27
	Canadian Urban Institute	$6.22	$6.22
	Wilson, S.J.	$2.38	$2.38
	Rein, F. A.	$3,393.34	$3,393.34
		$39.31	$39.31
		$1,541.00	$1,541.00
		$226.43	$226.43
Nutrient cycling	Canadian Urban Institute	$23.86	$23.86
	Wilson, S.J.	$10.01	$10.01
Soil formation	Canadian Urban Institute	$6.22	$6.22
	Pimentel, D. et al	$7.73	$7.73
	Wilson, S. J.	$2.58	$2.58
Biological control	Pimentel, D. et al	$18.55	$18.55

	Wilson, S. J.	$17.52	$17.52
	Rein, F. A.	$24.66	$24.66
		$314.49	$314.49
Pollination	Wilson, S. J.	$426.51	$426.51
	Costanza, R. et al	$1.39	$7.00
	Wilson, S. J.	$426.51	$426.51

FARMLAND

		LOW	HIGH
ECOSYSTEM SERVICE	AUTHOR(S)	$/ACRE/ YEAR	$/ACRE/ YEAR
Local climate and air quality	Canadian Urban Institute.	$100.63	$100.63
	Sandhu, H.S., Wratten, S.D., Cullen, R., Case, B.	$0.00	$101.48
Water regulation	Sandhu, H.S., Wratten, S.D., Cullen, R., Case, B.	$49.11	$49.11
		$24.78	$24.78
Soil erosion control	Moore, W.B	$4.68	$4.68
	Pimentel, D. et al	$131.75	$131.75
		$119.66	$119.66
	Wilson, S. J.	$2.38	$2.38
Nutrient cycling	Wilson, S. J.	$10.01	$10.01

Soil formation	Pimentel, D.	$7.05	$7.05
	Sandhu, H.S., Wratten, S.D., Cullen, R., Case, B.	$0.00	$44.46
		$14.50	$168.65
		$12.56	$205.38
		$0.34	$5.32
		$0.97	$4.35
	Wilson, S. J.	$2.58	$2.58
Biological control	Cleveland, C.J. et al	$14.16	$201.81
	Pimentel, D.	$82.42	$82.42
		$56.74	$56.74
	Pimentel, D. et al	$30.91	$30.91
	Sandhu, H.S., Wratten, S.D., Cullen, R., Case, B.	$0.00	$48.33
Pollination	Costanza, R. et al	$2.78	$13.99
	Pimentel, D.	$103.09	$103.09
	Ricketts, T.H. et al	$196.21	$196.21
	Sandhu, H.S., Wratten, S.D., Cullen, R., Case, B.	$0.00	$211.66
		$0.00	$219.88
	Winfree et al	$47.14	$1,956.30

WETLAND

		LOW	HIGH
ECOSYSTEM SERVICE	AUTHOR(S)	$/ACRE/ YEAR	$/ACRE/ YEAR
Water quality	Brander, L.M. et al	$16.02	$4,003.85
	de Groot, D.	$15,661.43	$15,661.43
	Gosselink et al	$2,519.32	$7,452.98
	Gren, I.M. and Soderqvist, T.	$423.25	$423.25
		$268.71	$268.71
	Grossman, M.	$10.56	$12.41
	Lant, C.A., and Roberts, R.S.	$206.10	$206.10
	Meyerhoff, J., and Dehnhardt, A.	$323.02	$965.35
	Olewiler, N.	$324.46	$911.64
	Wilson, S. J.	$1,329.73	$1,329.73
		$208.90	$208.90
	Woodward, R., and Wui, Y.	$224.68	$2,457.18
	Grossman, M.	$8.21	$9.65
	Jenkins, W.A. et al	$546.47	$546.47
		$582.78	$582.78
	Thibodeau, F.R. and Ostro, B.D.	$5,693.90	$5,693.90
	Grossman, M.	$8.21	$9.65

	Jenkins, W.A. et al	$546.47	$546.47
		$582.78	$582.78
	Thibodeau, F.R. and	$5,693.90	$5,693.90
	Ostro, B.D.		
Water regulation	Brander, L.M. et al	$2,632.77	$2,632.77
		$101.44	$101.44
		$1,182.20	$1,182.20
		$677.75	$677.75
	Brander, L.M. et al	$342.06	$342.06
		$1,070.30	$1,070.30
Soil erosion control	Canadian Urban Institute.	$6.22	$6.22
	Wilson, S. J.	$2.38	$2.38
Nutrient cycling	Canadian Urban Institute.	$23.86	$23.86
	Wilson, S. J.	$10.01	$10.01

FRESH WATER

		LOW	HIGH
ECOSYSTEM SERVICE	AUTHOR(S)	$/ACRE/ YEAR	$/ACRE/ YEAR
Water quality	Bouwes, N. W. and Scheider, R.	$1,529.16	$1,529.16
	Young, C. E. and Shortle, J. S.	$2.30	$2.30

APPENDIX B:
FULL REFERENCES FOR VALUE TRANSFER STUDIES

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