ECONOMIC VALUE OF CHEHALIS BASIN ECOSYSTEM SERVICES

APRIL 2020

Resource Dimensions

Resource Dimensions

Economics | Community Solutions | Land Use | Natural Resources | Regulatory Support

Gig Harbor, Washington | www.ecologicalecon.com

Credits and Acknowledgments

This report has been developed and prepared with the assistance of many people, to all of whom we extend sincere thanks. First, thank you to the staff of the Quinault Indian Nation, the Washington State Department of Ecology and the Office of the Chehalis Basin for their support of this project, collaboration, assistance in obtaining certain data and information, and other support vital to the development of this study. We are grateful for their time and knowledge, which was essential to our understanding of the concepts and topics involved, and various analyses.

We are additionally indebted to Dr. Tim Beechie and GIS staff at NOAA Northwest Fisheries Science Center for their data support and review of the land classification system developed for the study.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise. Resource Dimensions gratefully acknowledges the assistance of all following people, who provided important feedback: Tim Abbe, PhD; Karen Allston; Cynthia Carlstad; Larry Lestelle; Gary Morishima, PhD.

Resource Dimensions is responsible for the content of this report.

Resource Dimensions Team:

Julie Ann Gustanski, Ph.D., LLM[1]
Matthew M. Hayes, M.S.
Anna Scofield, M.S.
David A. Scarsella, M.S.

Year: 2020
Suggested Citation:

Gustanski, J. A., Hayes, M.M., Scofield, A., Scarsella, D. 2020. *Economic Value of Chehalis Basin Ecosystem Services*. Resource Dimensions, Gig Harbor, WA.

Cover Credit: Background, River from Willapa Hills Trail (Resource Dimensions)

Lower left, from top down: Chehalis River (Seattle Times); Blueback Salmon (Under Creative Commons License); Aerial view of Chehalis River Surge Plain (Washington Wildlife & Recreation Coalition)

---

[1] Project principal / corresponding author

CONTENTS

List of Figures

List of Tables

List of Abbreviations & Acronyms

AAGR	Average Annual Rate of Growth
ASRP	Aquatic Species Restoration Plan,
BTM	Benefit Transfer Method
CBD	Convention on Biological Diversity
CBO	Congressional Budget Office
C-CAP	National Oceanic and Atmospheric Association's Coastal Change Analysis Program
CICES	Common International Classification of Ecosystem Services
CPI	Consumer Price Index, U.S. Bureau of Labor Statistics
CTCR	Confederated Tribes of the Chehalis Reservation
ESD	Employment Security Department, Washington State
ESV	Ecosystem Services Valuation
FEGS	Final Ecosystem Goods and Services
GIS	Geographical Information System
MEA	Millennium Ecosystem Assessment
NAICS	North American Industry Classification System
NPV	Net Present Value
NLCD	National Land Cover Dataset
NOAA	National Oceanic and Atmospheric Administration
NPV	Net Present Value
OMB	Office of Management and Budget
PES	Payment for Ecosystem Services
PSHWI	Puget Sound HWI method
QIN	Quinault Indian Nation
RCW	Revised Code of Washington
TEEB	The Economics of Ecosystems and Biodiversity
USCB	United States Census Bureau
USD	U.S. Dollars
USDA	U.S. Department of Agriculture
USDA-NASS	USDA, National Agricultural Statistics Service
WDFW	Department of Fish & Wildlife, Washington State
WRIA	Watershed Resource Inventory Areas
WSDE	Department of Ecology, Washington State
WTP	Willingness to pay

Executive Summary

> The Chehalis Basin provides an estimated minimum of $1.1 to upwards of $15.7 billion in ecosystem service benefits annually which provides each of the nearly 193 thousand people living in the watershed an annual minimum benefit of $5,921 to more than $81,400.

The rich, unique and productive natural resources of the Chehalis Basin are irreplaceable assets; through the optics of ecological economics, they are natural capital assets.

Ecological economics explicitly addresses the relationships between natural ecosystems and human economic systems by accounting for the natural environment as a form of natural capital and valuing the goods and services delivered by ecological systems.

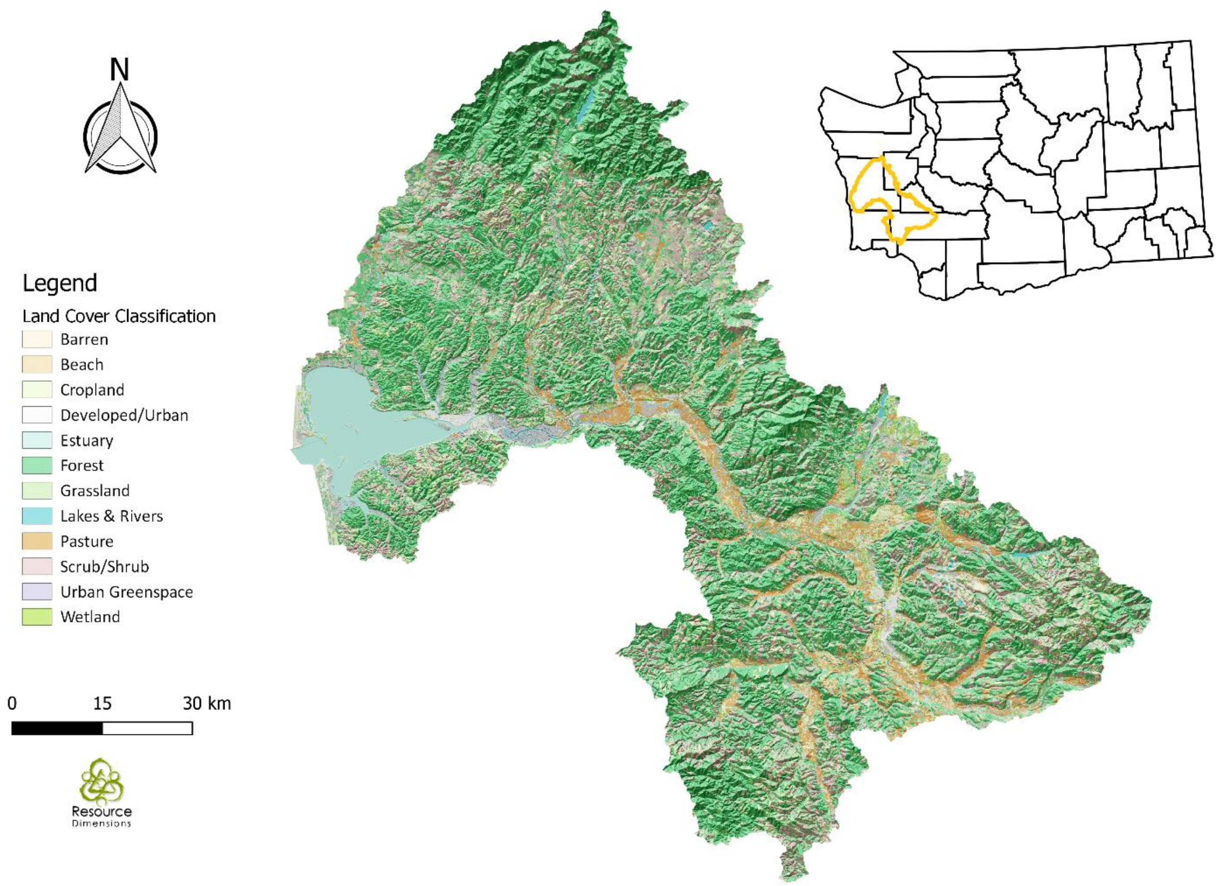
Value is not a single, simple concept. People may use many different concepts of value when assessing the protection of ecosystems and their services. All steps in the ecosystem service valuation process, beginning with problem formulation and continuing through the characterization, representation, and measurement of values, require information and input from a wide variety of disciplines.

From an ecological economics perspective, the goods and services provided by the Chehalis Basin landscapes are both vital to the functioning of the regions ecosystems and contribute significantly to the human welfare of the Basin's residents, and others, both directly and indirectly as forms of natural capital. These assets have supported the region's native people for thousands of years.

Flooding in the Chehalis Basin is a complex and long-standing problem. This study, the first of the economic analyses being conducted by Resource Dimensions related to the evaluation of long-term strategies to reduce flood damages in the Basin, identifies, estimates, and sets the baseline for the economic value of the Chehalis River Basin's natural systems in their current status. Additionally, this study establishes the regional economic lens through which decisions surrounding the Chehalis Flood Damage Reduction Project should be made.

The Chehalis River flows approximately 125 miles and drains an area of about 2,660 square miles in southwestern Washington. The river's Basin, the second largest in the state, contains substantial areas of forest, scrub/shrubland, grasslands, wetlands, rivers and lakes (Figure 1). Trees are but one important natural resource produced by Chehalis Basin forests – the dominant landcover. Along with their commercial value, trees like the western red cedar, used in making canoes and paddles, baskets, hats, split boards for houses, as well as in prayer and ceremony, have deep cultural values to northwest coast peoples. Trees also provide nursery and habitat services to wildlife, play an integral role in capturing pollutants from our water and air, remove carbon from the atmosphere, and more.

Figure 1: Chehalis Basin Land Cover Classification



Source: Resource Dimensions, 2020.

Less easily quantified or monetized, though vitally important to people, are cultural services. Through nature, traditions and ancestral experiences are shared across generations enabling the passing of knowledge, customs and intangible attributes across generations. For example, salmon is a cultural foundation, as well as economic – with important cultural ties to local customs and traditions, identity, and more.

Chehalis Basin Annual Benefits:

$1.1 billion to $15.7 billion

Chehalis Basin Benefits over 100 Years:

$49.1 billion to $233.7 billion

While culturally valuable ecosystem services often cannot be measured in dollars, pounds, acres or similar metrics – the ability to identify cultural value together with the value of other ecosystem services provides a more complete understanding of the intangible benefits and the long-term consequences of decisions affecting the Basin's natural assets.

The benefits described within this study will continue to provide important inputs to Chehalis Basin communities and the regional economy, if actions are taken protect the region's lands and waters.

Several assumptions were required to facilitate this study. Most importantly, the accuracy of findings relies heavily on the methods, analyses and interpretations of findings from external data, and the assumptions that the study authors made regarding the validity of this data. Monetary values were adjusted to 2019 dollars using Consumer Price Index conversion factors.

Using the benefit function transfer method, we estimated the dollar value of ecosystem goods and services provided by ten land cover ecosystems of the Chehalis Basin using two ESV models, lower bound (low) and upper bound (high), developed for this study (Table 1). Benefit transfer involves applying a monetary benefit value per unit estimate (e.g., dollar per acre) from an existing study site to an unstudied area for which a per unit benefit value is needed. To determine the spatial extent and type of different land cover classes for this study, Resource Dimensions completed an in-depth assessment of the National Oceanic and Atmospheric Association's Coastal Change Analysis Program (C-CAP) land cover classification system. Revisions proposed, were reviewed by NOAA researchers and approved for use in the benefit transfer framework by the Quinault Indian Nation and project collaborators from the Washington State Department of Ecology.

Table 1. Summary of Ecosystem Service Values Provided, by Land Cover

		LOW Total Value ($/acre/yr)		HIGH Total Value ($/acre/yr)	
Land Cover Class	**Acres**	Min	Max	Min	Max
Beach	181	$4,505,274	$19,842,969	$4,735,897	$21,095,890
Estuary	59,989	$49,603,557	$974,290,768	$54,723,527	$1,149,545,636
Rivers & Lakes	12,349	$21,786,729	$262,518,378	$25,637,921	$295,506,680
Wetlands	89,636	$381,682,803	$5,414,576,450	$393,290,761	$5,673,477,518
Cropland	14,967	$14,349,924	$39,035,710	$14,893,373	$40,382,763
Forests	887,280	$539,136,435	$7,163,780,868	$588,927,586	$7,854,730,675
Grasslands	136,598	$35,801,102	$259,654,299	$36,982,090	$269,690,666
Pasture	79,036	$11,243,799	$39,713,808	$12,806,181	$43,758,074
Scrub/Shrub	353,956	$54,596,872	$189,616,631	$68,089,678	$231,010,531
Urban Green Space	13,335	$27,677,747	$90,223,491	$30,203,713	$98,725,619
Total	**1,647,328**	**$1,140,384,242**	**$14,453,253,371**	**$1,230,290,727**	**$15,677,924,052**

All values used from existing primary studies, which valued ecosystem services based on market pricing, travel cost, cost avoidance, contingent valuation, replacement cost, and hedonic valuation, were validated. These methods are widely used to monetize things like people's willingness to pay for the preservation of a forest or a heritage site, the correlation between increased property values and proximity to parks and other protected lands, or the value of improvements to water quality delivered by wetlands.

Acknowledging natural capital as a transitory economic asset, similar to roads and other infrastructure, conservatively the asset value of the Basin over 100 years is between $49.1 billion and $206.2 billion at the lower bound, discounted at 2% and 7$ respectively, and between $53 billion and$223.7 billion at the upper bound, discounted at 2% and 7$ respectively (Table 2).

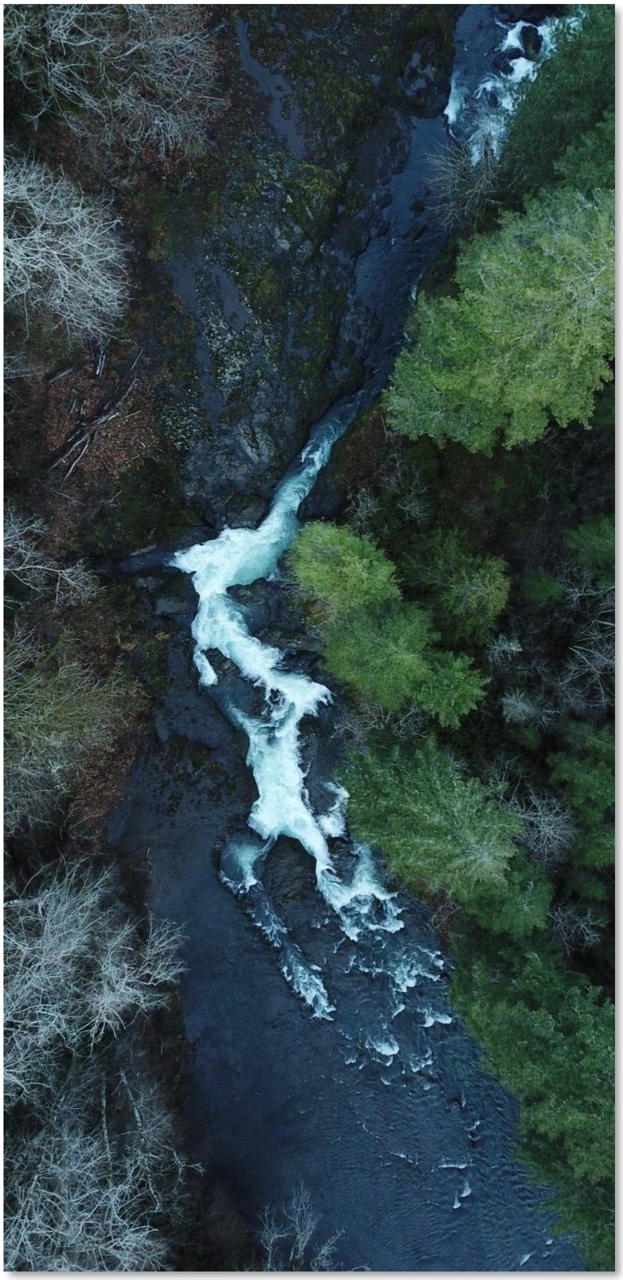
Table 2. Summary Asset Value of the Chehalis Basin

	ASSET VALUE			
	Low		High	
	2%	7%	2%	7%
Minimum	$49,148,681,066	$16,272,428,654	$53,023,502,383	$17,555,326,832
Maximum	$622,911,396,122	$206,237,095,910	$675,692,683,790	$223,712,228,898
Periods (years)	100	100	100	100
Annual Value	***$1,140,384,242***	***$14,453,253,371***	***$1,230,290,727***	***$15,677,924,052***

Source: Resource Dimensions, 2020.

This valuation is not exhaustive and does not include every ecosystem service across every land cover; thus, values should be considered minimums. In addition, monetized values do not directly include cultural values. Yet, as outcomes of the dynamic, complex, physical, or spiritual relationships between ecosystems and humans, across landscapes, and often over long time periods, cultural ecosystem service values are intrinsic constituents of values as (Plieninger e al. 2013; Chan et al. 2012). Although conservative on the low end, these estimates reveal the substantial value of Chehalis Basin natural capital. These significant values show that investment in natural capital can deliver vast long-term benefits if these assets are protected or enhanced. Moreover, investment in natural capital can yield a positive ROI due to the low cost of investment (relative to building new assets).

Report Overview



This report is broken down in to five sections which are: Introduction, Methodology, Natural Capital and Ecosystem Services, Valuation of Ecosystem Services, and Conclusion and Recommendations.

SECTION 1: INTRODUCTION. This section introduces the study area, the goal of this report and provides important baseline information about the social, demographic and economic setting of the Chehalis Basin. Detailed reports of socioeconomics within various sub-units of the Basin are reported. Sub-units that are reported on include county boundaries, reservation boundaries, legislative districts and the broader Basin as a whole.

SECTION 2: METHODOLOGY. The methodology section explains the development of the land cover classification system and how it is used in determining the spatial extent of land cover classes and hence valuation of ecosystem services. Key concepts of natural capital and ecosystem services discussed throughout the report and methods used to assess these values are introduced. Additionally, study limitations are addressed.

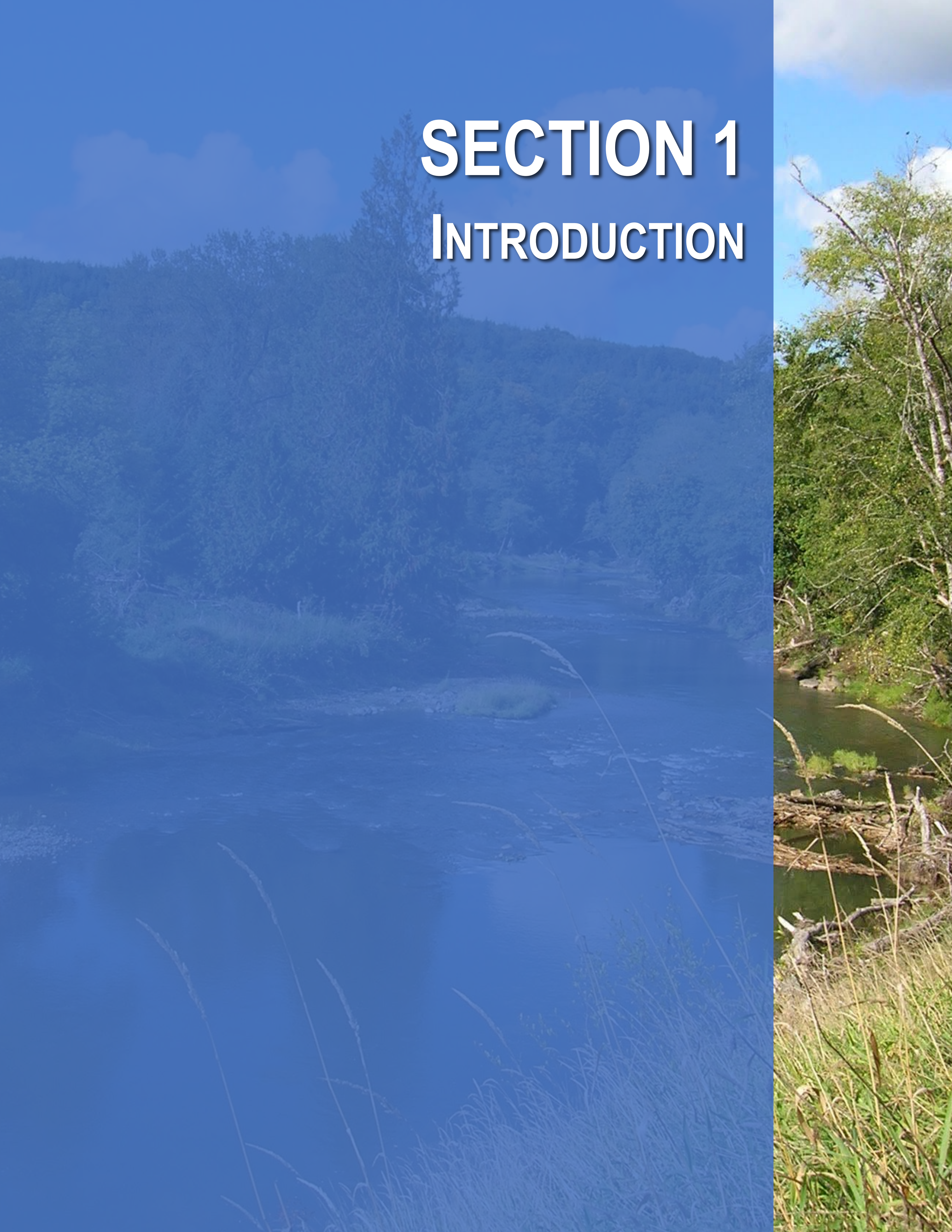
SECTION 3: In the section on Natural Capital and Ecosystem Services we expand greatly on the approach to valuing ecosystem services which was employed for this study. Detailed considerations are covered as well as more in-depth examination of methodology used.

SECTION 4: Is dedicated to presenting the results of the study together with relevant valuation tables and figures to aid in demonstrating the dollar value impact of these ecosystem services and their spatial distribution throughout the Basin.

SECTION 5: This closing section offers study conclusions and recommendations for the future.

In addition to the Reference section, a number of appendices are included. The appendices are cited throughout the text and provide additional and supporting information too voluminous to include in the body of the report.

SECTION 1
INTRODUCTION



SECTION 1: INTRODUCTION

1.1 GOAL OF THIS STUDY

Flooding in the Chehalis Basin is a long-standing, complex problem. Given the complexities of the problem, solutions have proved elusive to communities and government leaders. There is almost universal agreement that solutions must be found to address catastrophic loss of life and property during flood events and the restoration of aquatic species, goals of the Chehalis Basin Strategy. However, there is no broad agreement about potential approaches and the scope of solutions.

Current flood mitigation recommendations acknowledge that alternatives must be analyzed for economic feasibility. Additionally, recommendations include the need to address consequences to aquatic species, tribal and cultural resources, and water quality. These analyses, however, have not addressed the inevitable consequences for ecosystems and the services they provide at a regional scale.

As flood mitigation solutions for the Chehalis Basin move from study to implementation, it is important that economic analysis takes a total economic valuation approach that includes not only the monetary costs and benefits of project alternatives, but also the costs and benefits of impacts to ecosystem functions. Such analysis will help decision-makers incorporate true societal costs as they evaluate whether benefits outweigh costs and settle on solutions.

This review and analysis will provide an independent investigation of the costs and benefits of potential flood mitigation projects that includes impacts to ecosystem services and the economy at a regional scale. This analysis will go beyond the dollars and cents associated with possible alternatives and address the Quinault Indian Nation's unique relationship with, and dependence upon, the Chehalis Basin ecosystems. Incorporation of ecosystem services methods in analysis and evaluation will ensure full consideration of watershed restoration as a potentially viable and cost-effective alternative.

1.2 GEOGRAPHICAL AND LAND USE SETTING

The Chehalis River is Washington's second largest, as is the Chehalis River Basin – extending over portions of eight Southwest Washington counties. Draining an area of approximately 2,700 square miles, the Basin covers all of Grays Harbor county, most of Lewis County, moderate portions of Thurston and Mason counties, and small portions of Pacific, Cowlitz, Wahkiakum, Mason, and Jefferson counties. The Quinault Indian and Chehalis Indian reservations, as well as the Capitol State Forest, parts of Mt. Baker-Snoqualmie National Forest and the Olympic National Forest are also within the Basin boundaries. Aberdeen, Centralia, Hoquiam and Montesano are the Basin's largest cities.

Flowing approximately 125 miles north-northwesterly to Grays Harbor and the Pacific Ocean, the Chehalis River, stretches from its northern boundary in the Olympic Mountains to the Willapa Hills and Cowlitz River Basin to the South; and from the Deschutes River in the East towards Grays Harbor, where the Chehalis river meets the ocean. Many species of fish are found in the Basin's rivers and tributaries, including salmonids such as steelhead and Chinook, coho, and chum salmon. Diverse habitats in and contiguous to the Basin's rivers and streams support the state's most diverse amphibian population, and host of mudminnow, and many other native fish and wildlife species.

With substantial forest and shrub/scrub land cover – only 8.1% of the Chehalis Basin's land has been developed for urban, agricultural and industrial uses while about 72% of the land remains as forest and shrub/scrub. Other significant land cover, as classified for the purposes of this study, include grassland (7.9%), wetland (5.2%), pasture (4.6%) and estuary (3.5%), Table 3. Much of the forested land is managed by commercial timber companies, which supply local jobs and produce regional economic gains to the Basin and the state.

Table 3. Chahalis Basin Land Cover Classifications

Land Cover Class	Acres	Percent
Forest	887,280	53.9%
Scrub/Shrub	353,956	21.5%
Grassland	136,598	8.3%
Wetland	89,636	5.4%
Pasture	79,036	4.8%
Estuary	59,989	3.6%
Cropland	14,967	0.9%
UrbGreen	13,335	0.8%
Lake/River	12,349	0.7%
Beach	181	0.0%
Total Acres	**1,647,328**	**100%**

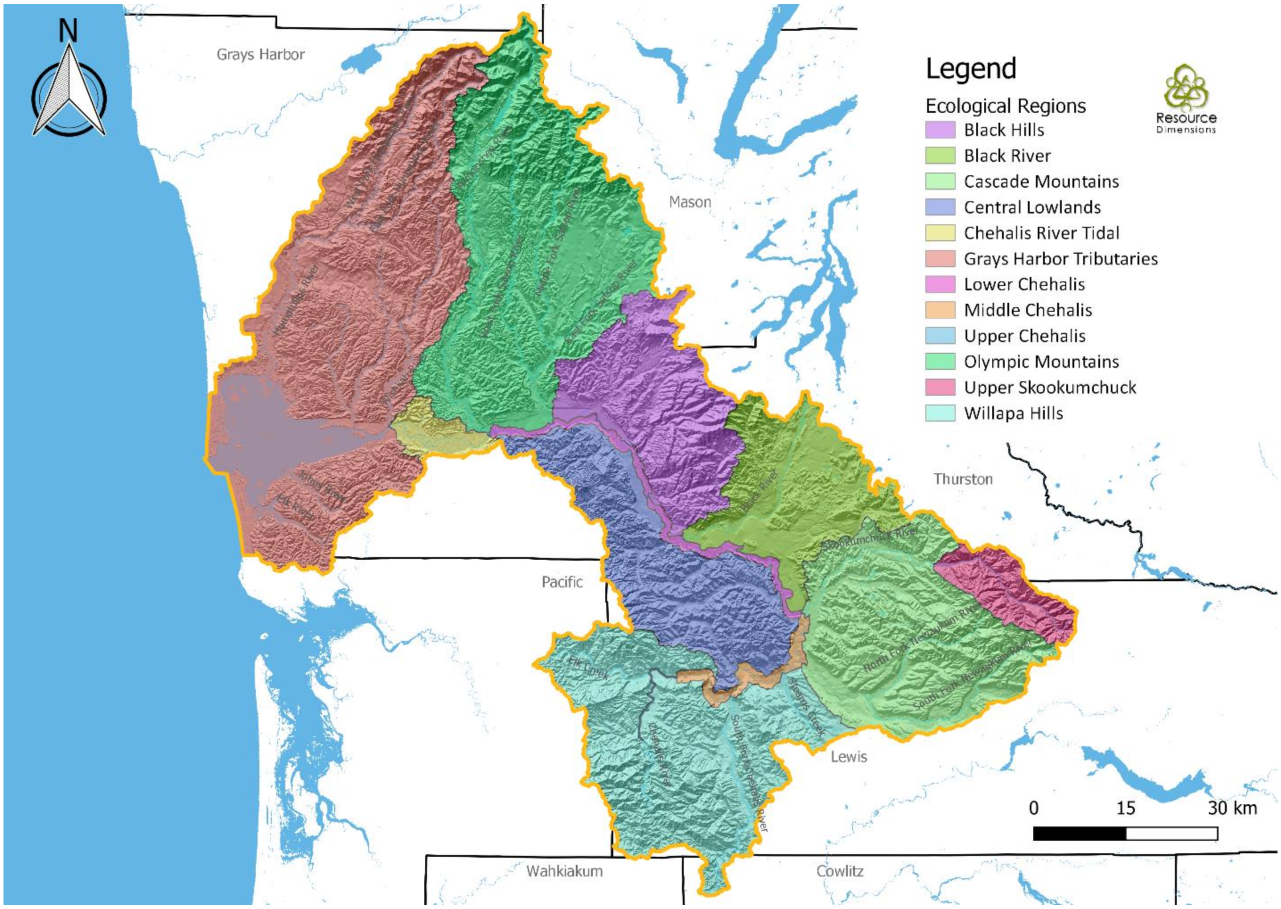
Source: Resource Dimensions, 2020.

While the majority of the Basin's natural value is supplied through its forestlands, the Estuary also provides a great deal of economic and ecological value. Historically, the estuary housed vast eelgrass beds and vegetative species such as beargrass that are important tribal resources (Ryan 2000). Roughly 70% of the estuary is still intact, with most of the loss resulting from damage caused by land conversion (Chehalis Basin Partnership 2004). Today, according to recent studies, eelgrasses provide annual nutrient cycling services worth over $20,000 an acre (Costanza et al. 1997). Additionally, eelgrass beds provide nurseries for crab, shellfish and finfish. Other vegetation types provide value. These include riparian areas supporting salmon spawning grounds, agricultural lands providing crops, and wetlands providing flood protection, to name a few.

The Chehalis Basin contains more than 30 sub-Basins and two major planning districts, known as Watershed Resource Inventory Areas (WRIAs), as authorized under the Water Resources Act of 1971, Revised Code of Washington (RCW) 90.54. These areas are Lower Chehalis (WRIA 22), and Upper Chehalis (WRIA 23).

There are twelve distinct ecological sub-regions, or ecoregions, in the Chehalis Basin (Figure 2).

Figure 2. Ecoregions of the Chehalis Basin



Source: Resource Dimensions, 2020.

Encompassing several unique climates, these ecoregions are home to the greatest diversity of amphibians in the state, crucial nesting grounds for migratory birds, a wildlife corridor connecting the Cascades to the Olympics, and one of the state's most important wild salmon strongholds (Chehalis Basin Strategy ASRP 2019). To provide context, key location-based features (e.g., major cities/owns, sub-Basins, tributaries) for the twelve ecoregions are provided in Table 4.

Table 4. Important Features of Chehalis Basin Ecoregions

Ecological Region	Sub-Basins	Main Cities/Towns	Principal Tributaries
Black Hills	Lower Chehalis, Upper Chehalis	Elma, McCleary, Oakville	Newman Creek, Wildcat Creek, Cloquallum Creek, Porter Creek, Mox Chehalis Creek, Gibson Creek, Cedar Creek, Roundtree Creek
Black River	Deschutes, Puget Sound, Upper Chehalis	Tenino, Grand Mount	Black River, Waddell Creek, Scatter Creek, Prairie Creek
Cascade Mountains	Upper Chehalis	Chehalis, Centralia, Bucoda	Skookumchuck River, Newaukum River, Hanaford Creek, Salzer Creek, Lucas Creek, Dillenbaugh Creek, Stearns Creek
Central Lowlands	Lower Chehalis, Upper Chehalis, Willapa Bay		Bunker Creek, Lincoln Creek, Garrard Creek, Workman Creek, Delezene Creek, Gaddis Creek, Rock Creek, Williams Creek, Davis Creek, Garrard Creek, Independence Creek, Wildcat Creek, Deep Creek, Mill Creek
Chehalis River Tidal	Grays Harbor, Lower Chehalis, Willapa Bay	Cosmopolis, Montesano	Chehalis River, Camp Creek, Van Winkle Creek
Grays Harbor Tributaries	Grays Harbor, Lower Chehalis	Aberdeen, Hoquiam, Humptulips, Ocean Shores, Westport	Chehalis River, Elk Creek, Elk River, Hoquiam River, Humptulips River, Johns River, Wishkah River
Lower Chehalis River	Lower Chehalis, Upper Chehalis	Porter	Chehalis River
Middle Chehalis River	Upper Chehalis	Adna	Chehalis River, Skookumchuck River
Upper Chehalis River	Upper Chehalis		Chehalis River, Elk Creek
Olympic Mountains	Grays Harbor, Lower Chehalis, Puget Sound, Queets-Quinault, Skokomish	Elma	Satsop River, Wynoochee River, East Fork Satsop River, West Fork Satsop River, Middle Fork Satsop River
Upper Skookumchuck	Deschutes, Lower Cowlitz, Upper Chehalis		Skookumchuck River
Willapa Hills	Lower Columbia, Lower Columbia-Clatskanie, Upper Chehalis, Willapa Bay	Pe Ell, Doty, Boistfort	Chehalis River, Elk Creek, Skookumchuck River, Stearns Creek, Rock Creek, Crim Creek, Thrash Creek, Stillman Creek, Cedar Creek, Lake Creek

Source: Resource Dimensions, 2020.

1.3 Economic Setting

1.3.1 Population

The Washington State Employment Security Department (ESD) estimates that the population of Grays Harbor County will increase roughly 3% by 2040 (Table 5) (ESD 2019a). Lewis and Mason County populations are predicted to increase by 12% and 27% respectively, while Thurston County population is predicted to increase by 27% from 2020 to 2040. The state population is estimated to grow by about 22%, 1.7 million, during the same time. Population projections are not reported for the Reservations.

Table 5. Historic and Projected Populations, by County

Year	Grays Harbor	Lewis	Mason	Thurston	Washington
2000	67,194	68,600	49,405	207,355	5,894,143
2010	72,797	75,455	60,699	252,264	6,724,540
2015	73,110	76,660	62,200	267,410	7,061,410
2020	74,375	80,416	66,460	291,661	7,656,393
2025	75,400	83,977	71,729	315,429	8,129,834
2030	76,536	86,178	75,982	335,410	8,555,295
2040	76,613	90,046	84,526	371,204	9,321,926

Source: ESD, 2019a.

ESD estimates that five-year average annual growth rates for Washington state will be average 1.2% for every period from 2015 to 2030 (Table 6). Grays Harbor and Lewis Counties are predicted to grow more slowly over the same time. Mason and Thurston Counties are predicted to outpace the state average, with the fastest growth predicted in Thurston County from 2015-2020.

Table 6. Historic and Projected Average Annual Population Growth Rates, by County

Period	Washington	Grays Harbor	Lewis	Mason	Thurston
2001-2010	1.3%	0.8%	1.0%	2.1%	2.0%
2011-2015	1.0%	0.1%	0.3%	0.5%	1.2%
2016-2020*	1.6%	0.3%	0.9%	1.5%	1.9%
2021-2025*	1.2%	0.3%	0.9%	1.5%	1.6%
2026-2030*	1.0%	0.3%	0.5%	1.2%	1.2%

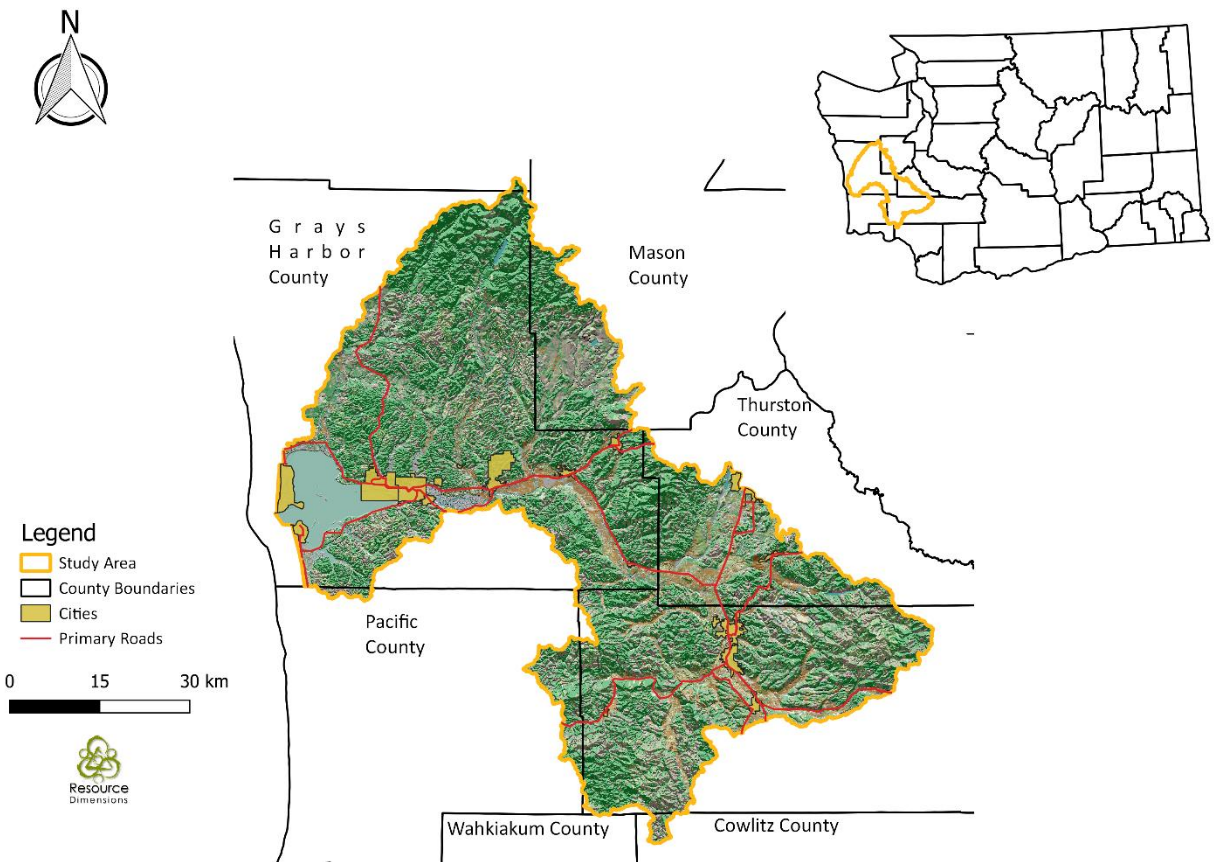
* Projected

Source: ESD, 2019b.

1.3.2 County and Reservation Economies

There are eight counties within the Chehalis Basin: Cowlitz, Grays Harbor, Jefferson, Lewis, Mason, Pacific, Thurston, and Wahkiakum (Figure 3). Grays Harbor, Lewis, Mason, and Thurston Counties comprise more than 97% of the Basin. We provide county-level economic setting summaries for Grays Harbor, Lewis, Mason, and Thurston Counties. We also provide summaries for the Chehalis and Quinault Reservations. Only the Chehalis Reservation is within the study area, but we summarize both to capture the significance of Chehalis Basin resources to both Tribes; the Quinault Indian Nation (QIN) is the only federally recognized tribe with Treaty reserved rights to fish, hunt and gather in the Basin. We provide information for Washington as a comparative reference.

Figure 3. Study Area Boundary and Counties



Source: Resource Dimensions, 2020.

1.3.2.1 Socio-Demographics

Grays Harbor County is the second-largest county in the study area, but is only the third-most populated, Table 7. The median age is older than the state average by five years. Grays Harbor has the largest average family size of the study area counties. Income is lower than the state average and is the second lowest in the study area. Most housing units in Grays Harbor are occupied by owners; median home value is substantially lower than the state average, and second lowest of study area counties. A majority of the population 25 years and older have at least some form of college education.

Lewis County is the largest county in the study area, and the second-most populated while housing density is the lowest of all study area counties. Income is lower than the state average and is the lowest in the study area. Lewis County has the highest number of renter-occupied housing units in the study area; median home value is the second lowest in the study area. Over three-quarters of the 25-and-older population has a high school diploma or some form of college education.

Mason County is the least populated of the study area counties; Mason has the oldest population — eight years older than the state average. Mason County has the second-highest population and housing density; it has the largest household size, slightly larger than the state average. Income is lower than the state average across all metrics but is the second highest in the study area. Mason County has the lowest percentage of occupied homes; median home value is the second lowest in the study area, lower than the state average. Less than 15% of the population over 25 years of age has not attained at least a high school diploma or equivalent.

Thurston County is the smallest county in the study area, but the most populated, giving it the highest population density in the Basin by some margin; population density is over three times the state average. The population is older than the state average, but the youngest of the study area counties. Thurston County has the highest income, beating the state average in median household income and median family income; per capita income is slightly lower than the state average. Housing occupancy is higher than the rest of the study area while median home value is higher than the other study area counties, and only slightly lower than the state average. Most of the population of Thurston County 25 years and older has as at least some college education; Thurston County has the highest percentage of Bachelor's degrees, approaching the state average.

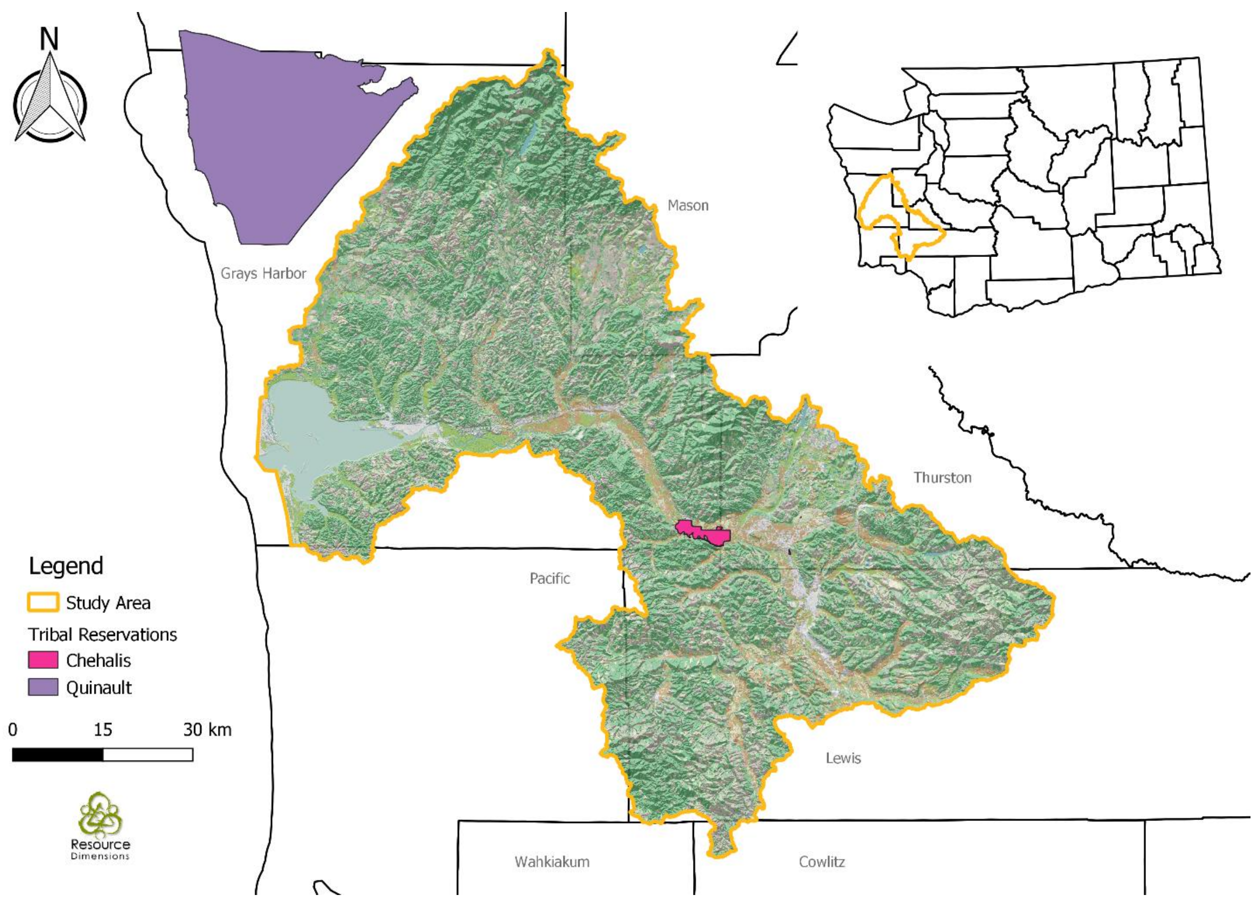
The Quinault Reservation (Figure 4) has substantially lower population density and housing density than the rest of the study area[2]. The Reservation has a higher percentage male than study area counties and the state average. Household and family size is larger than the study area counties but similar to the Chehalis Reservation. Income is considerably lower than the study area counties, and about

[2] While the lands of the Quinault Reservation are not within the geographic boundaries comprising the Chehalis Basin, we appropriately include here. One of four tribes to the 1856 Treaty of Olympia, the Quinault Indian Nation is the only federally recognized tribe with Treaty rights to fish, hunt and gather in the Chehalis Basin. Since time immemorial, the Quinault people have lived on the lands and relied upon the Basin's waters and rich resources. Information provided in this section also supports subsequent related studies.

half of the state average across all income-based metrics. The Reservation has the second-highest percentage of renter-occupied housing units, second only to the Chehalis Reservation; median home value is considerably lower than the study area counties and the state average. The population of the Quinault Reservation over 25 years of age has a higher proportion of people without a high school diploma or equivalent, approaching 15%.

The Chehalis Reservation's housing density and population density are much higher than the Quinault Reservation and is similar to the state average. The Chehalis is predominantly female, with a larger bias in gender than the other study area geographies. Like the Quinault Reservation, household and family size is larger than the rest of the study area. Income is lower than county and state averages across all income-based metrics. The Chehalis Reservation has the highest percentage of renter-occupied housing units; median home values are much higher than the Quinault Reservation, and are similar to the rest of Grays Harbor County. Education patterns are similar to the rest of the state; most of the population 25 and older have at least a high school diploma, while over 40% of the population has some form of college education.

Figure 4. Location of Quinault and Chehalis Reservations



Source: Resource Dimensions, 2020.

Table 7. Select Demographic Statistics, by Reservation, County and State

Population Characteristics	Quinault Reservation	Chehalis Reservation and Off-Reservation	Grays Harbor	Lewis	Mason	Thurston	Washington
Population	1,272	847	71,734	75,382	60,728	259,330	6,899,123
Population density (per sq. mile)[1]	4.1	124.2	38.3	31.4	63.3	349.4	101.2
Housing density (per sq. mile)[1]	1.5	41.1	18.5	14.2	33.9	149.8	43.4
Percent male	53.90%	47.00%	51.40%	50.10%	51.50%	49.00%	49.90%
Percent female	46.10%	53.00%	48.60%	49.90%	48.50%	51.00%	50.10%
Median age (years)	34.3	26.1	42.5	42.6	45.2	38.4	37.4
Average household size[2]	3.19	3.47	2.51	2.52	2.57	2.52	2.55
Average family size[2]	3.97	3.87	3.1	3.02	3.08	3.03	3.13
Economic Characteristics[2]							
Median household income	29,659	39,318	43,379	42,917	49,538	62,286	60,294
Median family income	37,639	41,875	54,407	53,533	58,637	75,361	73,039
Per capita income	14,758	14,662	22,190	22,094	23,965	29,909	31,233
4Housing Characteristics[4]							
Occupied housing units	86.00%	87.10%	77.60%	86.30%	70.90%	92.20%	90.60%
Owned-occupied	61.10%	57.00%	69.00%	67.80%	78.20%	64.90%	62.70%
Renter-occupied	38.90%	43.00%	31.00%	32.20%	21.80%	35.10%	37.30%
Vacant housing units	14.00%	12.90%	22.40%	13.70%	29.10%	7.80%	9.40%
Median home value	$81,400	$152,600	$158,500	$178,200	$204,800	$241,300	$257,200
Educational Attainment (population 25 and olc							
Less than 9th grade	6.70%	2.50%	5.70%	4.10%	4.00%	2.10%	4.10%
9th to 12th grade, no diploma	13.10%	13.20%	7.80%	9.00%	8.70%	4.30%	5.80%
High School graduate (includes equivalency)	34.00%	41.10%	31.40%	32.20%	29.60%	23.20%	23.30%
Some college, no degree	24.00%	27.00%	28.70%	28.90%	30.70%	27.50%	24.90%
Associate's degree	8.10%	6.90%	11.40%	11.60%	9.20%	10.10%	9.70%
Bachelor's degree	9.30%	7.40%	10.50%	8.60%	12.40%	20.10%	20.60%
Graduate or professional degree	4.60%	1.80%	4.60%	5.50%	5.50%	12.80%	11.70%

Sources: USCB 2020a.

[1] *USCB, 2010*
[3] *USCB, 2020b*
[4] *USCB, 2020c*
[5] *USCB, 2020d*

1.3.2.2 Employment and Labor Force

The Grays Harbor County civilian labor force, or non-governmental labor force, ranged from 31,229 in 2005 to 28,109 in 2015 (Table 8). The employed and unemployed labor forces decreased between 2010 and 2015. The unemployment rate decreased from a high of 13.9% in 2010 to a low of 8.9% in 2015.

The Average Annual Rate of Growth (AAGR) in the total labor force was strongly negative between 2010 and 2015 but turned positive from 2015 to 2018 (meaning there was a net increase in the size of the labor force over that period). The AAGR of the employed labor force was negative from 2010 to 2015 but positive by nearly the same amount from 2015 to 2018.

Table 8. Grays Harbor County Civilian Labor Force

Year/Time Period	Total	Employed	Unemployed*	Unemployment Rate
2005	31,229	28,761	2,468	7.9%
2010	31,046	26,723	4,323	13.9%
2015	26,896	24,443	2,453	9.1%
2016	27,224	24,965	2,259	8.3%
2017	27,793	25,833	1,960	7.1%
2018	28,109	26,217	1,892	6.7%
AARG, 2010-2015	-2.65%	-1.89%		
AARG, 2015-2018	0.87%	1.81%		

Note: Employment figures are not seasonally adjusted

* Yearly average

AAGR = Average Annual Growth Rate

Sources: ESD, 2019c; Resource Dimensions, 2020.

The Lewis County civilian labor force was lowest in 2005, at 30,631 (Table 9). The labor force increased between 2005 and 2010 more than any other study area county and fluctuated before reaching near 2010 peak in 2018. The labor force peaked in 2010, at 33,962. The employed labor force was also at its highest in 2018. The unemployment rate decreased from a high of 13.1% in 2010 to a low of 6.3% in 2018.

The AAGR of the total labor force was slightly negative between 2010 and 2015, but largely positive between 2015 and 2018. The AAGR of the employed labor force followed a similar pattern but was less slightly positive between 2010 and 2015.

Table 9. Lewis County Civilian Labor Force

Year/Time Period	Total	Employed	Unemployed*	Unemployment Rate
2005	30,631	28,174	2,457	8.0%
2010	33,962	29,503	4,459	13.1%
2015	31,195	28,552	2,643	8.5%
2016	31,899	29,420	2,479	7.8%
2017	33,049	30,870	2,179	6.6%
2018	33,752	31,630	2,122	6.3%
AARG, 2010-2015	-0.24%	0.65%		
AARG, 2015-2018	2.57%	3.34%		

Note: Employment figures are not seasonally adjusted

* Yearly average

AAGR = Average Annual Growth Rate

Sources: ESD, 2019c; Resource Dimensions, 2020.

The Mason County civilian labor force peaked in 2018, Table 10. The total civilian labor force steadily increased from 2005 to 2018 with a slight reduction in 2015. The employed labor force was highest in 2018. The unemployment rate was highest in 2010 at 9.0%, which was lower than Grays Harbor and Mason Counties, and declined to 4.8% in 2018.

The total labor force AAGR was slightly negative from 2010-2015, and positive from 2015-2018, though not at the magnitude of Grays Harbor and Lewis Counties. The employed labor force AAGR was slightly negative in both periods, also at a smaller magnitude.

Table 10. Mason County Civilian Labor Force

Year/Time Period	Total	Employed	Unemployed*	Unemployment Rate
2005	121,951	115,486	6,465	5.3%
2010	126,948	115,550	11,398	9.0%
2015	125,599	118,055	7,544	6.0%
2016	129,691	122,413	7,278	5.6%
2017	134,060	127,427	6,633	4.9%
2018	137,697	131,144	6,553	4.8%
AARG, 2010-2015	-0.79%	-0.44%		
AARG, 2015-2018	2.82%	3.29%		

Note: Employment figures are not seasonally adjusted

* Yearly average

AAGR = Average Annual Growth Rate

Sources: ESD, 2019c; Resource Dimensions, 2020.

The Thurston County Civilian labor force peaked in 2010, decreased through 2015, then steadily increased through 2018, Table 11. The employed labor force was highest in 2018. The unemployment rate was highest in 2010 at 9.0%, the lowest of all study area counties and continued to decline through 2015.

The AAGR in the total and employed labor forces was slightly positive from 2010-2015. From 2015 to 2018, the total labor force decreased, while the employed labor force also decreased (negative AAGR).

Table 11. Thurston County Civilian Labor Force

Year/Time Period	Total	Employed	Unemployed*	Unemployment Rate
2005	121,380	115,260	6,120	5.0%
2010	126,950	115,550	11,400	9.0%
2011	123,120	112,260	10,860	8.8%
2012	123,144	112,851	10,293	8.4%
2013	122,518	113,173	9,345	7.6%
2014	123,254	115,313	7,941	6.4%
2015	125,603	118,178	7,425	5.9%
AAGR, 2005-2010	0.93%	0.10%		
AAGR, 2010-2015	-0.20%	0.47%		

Note: Employment figures are not seasonally adjusted

* Yearly average

AAGR = Average Annual Growth Rate

Sources: ESD, 2019c; Resource Dimensions, 2020.

1.3.2.3 Industries and occupations

Thurston County reported the highest number of business establishments in 2015, predominantly in health care and social assistance (14%), followed by retail trade (13%), construction (12%), and professional, scientific, and technical services (10.5%) (Table 12). Grays Harbor, Lewis, and Mason Counties had between 70 and 83% fewer business establishments than Thurston County. In Grays Harbor County, the retail trade sector had the highest share of business establishments (16%), followed by accommodation and food service (13%), health care and social assistance, (12%), and construction (10%). Business patterns were identical for Lewis county — retail trade had the highest share of business establishments (16%), followed by accommodation and food service (12%), health care and social assistance (10%), and construction (11%). Mason County business patterns were slightly different, with the highest number of business establishments in construction (16%), followed by retail trade (13%), accommodation and food service (11%), and other services (11%).

[page left intentionally blank]

Table 12. Business Patterns, by NAICS Code and County

2017 NAICS Code	2017 NAICS Code Key	Number of Establishments			
		Grays Harbor	Lewis	Mason	Thurston
00	Total for all sectors	1,628	1,892	1,073	6,233
11	Agriculture, forestry, fishing and hunting	69	79	22	53
21	Mining, quarrying, and oil and gas extraction	0	8	4	3
22	Utilities	3	8	5	11
23	Construction	163	216	212	778
31-33	Manufacturing	81	99	52	158
42	Wholesale trade	44	71	40	215
44-45	Retail trade	278	310	135	792
48-49	Transportation and warehousing	66	88	34	127
51	Information	22	30	11	105
52	Finance and insurance	68	90	48	334
53	Real estate and rental and leasing	76	87	53	341
54	Professional, scientific, and technical services	85	103	70	650
55	Management of companies and enterprises	0	3	0	31
56	Administrative and support and waste management and remediation se	56	71	53	340
61	Educational services	9	15	8	88
62	Health care and social assistance	189	208	106	899
71	Arts, entertainment, and recreation	30	23	17	95
72	Accommodation and food services	227	200	102	560
81	Other services (except public administration)	155	181	99	646
99	Industries not classified	4	0	0	7

Source: USCB, 2020.

In Grays Harbor County, educational services and health care and social assistance employ the highest percentage of the civilian employed population by industry (22.5%) (Table 13), followed by retail trade (12.4%), arts, entertainment, and recreation and accommodation and food services (10.5%), and manufacturing (10.2%). Lewis County patterns are similar, with 21.1% of the workforce employed in educational services and health care and social assistance, followed by retail trade (13.7%), manufacturing, (10.5%), and arts, entertainment, and recreation, and accommodation and food services (8.3%).

Patterns are also almost identical in Mason County, with 19.4% of the workforce employed in educational services and health care and social assistance, followed by retail trade (10.8%), public administration (10.4%), and arts, entertainment, and recreation, and accommodation and food services (9.8%). Thurston County is similar — 22.2% of the workforce is employed in educational services, and health care and social assistance; 16.8% in public administration, 11.6% in retail trade, and 9.5% in both professional, scientific, and management, and administrative and waste management services, and arts, entertainment, and recreation, and accommodation and food services.

Table 13. Percent Workforce by Industry, by County

	Grays Harbor		Lewis		Mason		Thurston	
Industry	**Estimate**	**Percent**	**Estimate**	**Percent**	**Estimate**	**Percent**	**Estimate**	**Percent**
Civilian employed population, 16 years and over	27,388		30,414		24,072		126,581	
Agriculture, forestry, fishing and hunting, and mining	1,244	4.5%	1,710	5.6%	1,801	7.5%	2,572	2.0%
Construction	1,857	6.8%	2,259	7.4%	1,852	7.7%	8,535	6.7%
Manufacturing	2,802	10.2%	3,193	10.5%	2,225	9.2%	6,800	5.4%
Wholesale trade	622	2.3%	792	2.6%	785	3.3%	2,409	1.9%
Retail trade	3,403	12.4%	4,174	13.7%	2,606	10.8%	14,726	11.6%
Transportation and warehousing, and utilities	1,487	5.4%	2,063	6.8%	1,085	4.5%	5,219	4.1%
Information	294	1.1%	356	1.2%	220	0.9%	1,912	1.5%
Finance and insurance, and real estate and rental and leasing	1,174	4.3%	989	3.3%	925	3.8%	6,385	5.0%
Professional, scientific, and management, and administrative and waste management s	1,603	5.9%	2,287	7.5%	1,939	8.1%	12,060	9.5%
Educational services, and health care and social assistance	6,161	22.5%	6,407	21.1%	4,663	19.4%	28,160	22.2%
Arts, entertainment, and recreation, and accommodation and food services	2,889	10.5%	2,528	8.3%	2,352	9.8%	11,056	8.7%
Other services, except public administration	1,128	4.1%	1,397	4.6%	1,125	4.7%	5,472	4.3%
Public administration	2,724	9.9%	2,259	7.4%	2,494	10.4%	21,275	16.8%

Source: USCB, 2020c.

The Quinault Reservation civilian employed population predominantly works in public administration (33.2%), followed by educational services, and health care and social assistance (22.5%), and agriculture, forestry, fishing and hunting, and mining (10.3%) (Table 14). The Chehalis Reservation employment patterns are somewhat similar, with 23.1% working in educational services, and health care and social assistance, 19.2% in public administration, 14.7% in information and 13.9% in arts, entertainment, and recreation, and accommodation and food service.

Table 14. Workforce by Industry, by Reservations

Industry	Quinault Reservation Estimate	Quinault Reservation Percent	Chehalis Reservation Estimate	Chehalis Reservation Percent
Civilian employed population, 16 years and over	377		381	
Agriculture, forestry, fishing and hunting, and mining	39	10.3%	27	7.1%
Construction	14	3.7%	15	3.9%
Manufacturing	28	7.4%	9	2.4%
Wholesale trade	3	0.8%	2	0.5%
Retail trade	13	3.4%	13	3.4%
Transportation and warehousing, and utilities	9	2.4%	15	3.9%
Information	0	0.0%	56	14.7%
Finance and insurance, and real estate and rental and leasing	15	4.0%	4	1.0%
Professional, scientific, and management, and administrative and waste management services	8	2.1%	19	5.0%
Educational services, and health care and social assistance	85	22.5%	88	23.1%
Arts, entertainment, and recreation, and accommodation and food services	31	8.2%	53	13.9%
Other services, except public administration	7	1.9%	7	1.8%
Public administration	125	33.2%	73	19.2%

Source: USCB, 2020c.

By occupation, the four study area counties all employ the highest number of civilian employed (over 16 years old) in management, business, science, and arts occupations (Table 15). In Lewis and Thurston Counties, this is followed by service occupations, and sales and office occupations. In Grays Harbor and Mason Counties, this is reversed — sales and office occupations employ the second-highest percent of the workforce and service occupations the third.

Table 15. Workforce by Occupation, Counties

Occupation	Grays Harbor Estimate	Grays Harbor Percent	Lewis Estimate	Lewis Percent	Mason Estimate	Mason Percent	Thurston Estimate	Thurston Percent
Civilian employed population, 16 years and over	26,808		29,793		23,490		127,821	
Management, business, science, and arts occupations	7,864	29.3%	8,170	27.4%	6,640	28.3%	54,125	42.3%
Service occupations	6,127	22.9%	5,729	19.2%	4,786	20.4%	20,187	15.8%
Sales and office occupations	5,646	21.1%	6,400	21.5%	5,025	21.4%	27,595	21.6%
Natural resources, construction, and maintenance occupations	3,002	11.2%	3,876	13.0%	3,974	16.9%	10,385	8.1%
Production, transportation, and material moving occupations	4,122	15.4%	5,568	18.7%	2,977	12.7%	13,490	10.6%

Source: USCB, 2020c.

Employment by occupation for the Reservations is slightly different than study area counties. The Quinault Reservation civilian employed population is predominantly employed in management, business, science and arts occupations (33.4%), followed by service occupations (25.5%) and sales and office occupations (17.6%) (Table 16). The Chehalis Reservation civilian employed population is predominantly employed in service occupations (33.4%), followed by natural resources, construction, and maintenance occupations (28.9%), management, business, science, and arts occupations (15.6%) and sales and office occupations (15.1%).

Table 16. Workforce by Occupation, Reservations

Occupation	Quinault Reservation Estimate	Quinault Reservation Percent	Chehalis Reservation Estimate	Chehalis Reservation Percent
Civilian employed population, 16 years and over	353		377	
Management, business, science, and arts occupations	118	33.4%	59	15.6%
Service occupations	90	25.5%	126	33.4%
Sales and office occupations	62	17.6%	57	15.1%
Natural resources, construction, and maintenance occupations	46	13.0%	109	28.9%
Production, transportation, and material moving occupations	37	10.5%	24	6.4%

Source: USCB, 2020c.

ESD projects occupational job growth for a ten-year period from current occupational data (2019). Occupational job growth is projected by regions, based on state Workforce Development Councils. The study area is within the Pacific Mountain Region (Table 14), which includes Grays Harbor, Lewis, Mason, Pacific, and Thurston Counties.

From 2017-2022, the highest occupational growth (by AAGR) is in construction and extraction occupations (3.4%; 397 average annual openings), personal care and service (2.4%; 256 average annual openings), healthcare practitioners and technical occupations (2.2%; 232 average annual openings), and healthcare support (2.2%; 131 average annual openings) (Table 17). From 2017-2022, the highest occupational growth (by average annual openings) is in construction and extraction (397), food preparation and serving related occupations (387), education, training and library (263), personal care and service (256) and healthcare practitioners and technical (232).

Table 17. Recent and Projected Job Growth in Selected Occupations for Pacific Mountain Region

Occupational Title	Estimated Employment			Average Annual Growth Rate		Average Annual Openings Due to Growth		Average Annual Total Openings	
	2017	2022	2027	2017-2022	2022-2027	2017-2022	2022-2027	2017-2022	2022-2027
Total, All Occupations	211,666	229,269	241,510	1.6%	1.0%	3,510	2,440	77,362	81,420
Management	12,500	13,569	14,335	1.7%	1.1%	212	155	4,366	4,606
Business and Financial Operations	11,934	12,825	13,497	1.5%	1.0%	178	134	3,662	3,846
Computer and Mathematical	6,766	7,443	7,900	1.9%	1.2%	135	91	2,192	2,321
Architecture and Engineering	2,302	2,458	2,519	1.3%	0.5%	31	10	618	625
Life, Physical, and Social Science	3,233	3,435	3,617	1.2%	1.0%	41	37	839	880
Community and Social Service	4,305	4,710	4,962	1.8%	1.0%	82	49	1,334	1,396
Legal	2,260	2,332	2,424	0.6%	0.8%	14	18	553	577
Education, Training, and Library	14,093	15,425	16,720	1.8%	1.6%	263	256	3,515	3,801
Arts, Design, Entertainment, Sports, and Media	3,143	3,321	3,453	1.1%	0.8%	36	24	1,110	1,154
Healthcare Practitioners and Technical	9,931	11,091	12,225	2.2%	2.0%	232	228	3,382	3,716
Healthcare Support	5,654	6,311	6,928	2.2%	1.9%	131	123	2,352	2,579
Protective Service	5,248	5,560	5,835	1.2%	1.0%	61	53	1,337	1,413
Food Preparation and Serving Related	17,177	19,118	20,436	2.2%	1.3%	387	261	8,283	8,871
Building and Grounds Cleaning and Maintenance	7,828	8,673	9,324	2.1%	1.5%	170	131	3,462	3,719
Personal Care and Service	10,025	11,307	12,330	2.4%	1.7%	256	206	4,611	5,039
Sales and Related	18,763	19,646	20,422	0.9%	0.8%	176	157	6,823	7,085
Office and Administrative Support	28,404	30,245	31,440	1.3%	0.8%	368	240	9,584	9,945
Farming, Fishing, and Forestry	6,707	6,815	6,851	0.3%	0.1%	22	6	3,155	3,172
Construction and Extraction	11,087	13,075	13,394	3.4%	0.5%	397	65	5,539	5,707
Installation, Maintenance, and Repair	8,015	8,511	8,828	1.2%	0.7%	99	61	2,835	2,935
Production	8,764	8,952	9,063	0.4%	0.2%	35	22	2,647	2,680
Transportation and Material Moving	13,527	14,447	15,007	1.3%	0.8%	184	113	5,163	5,353

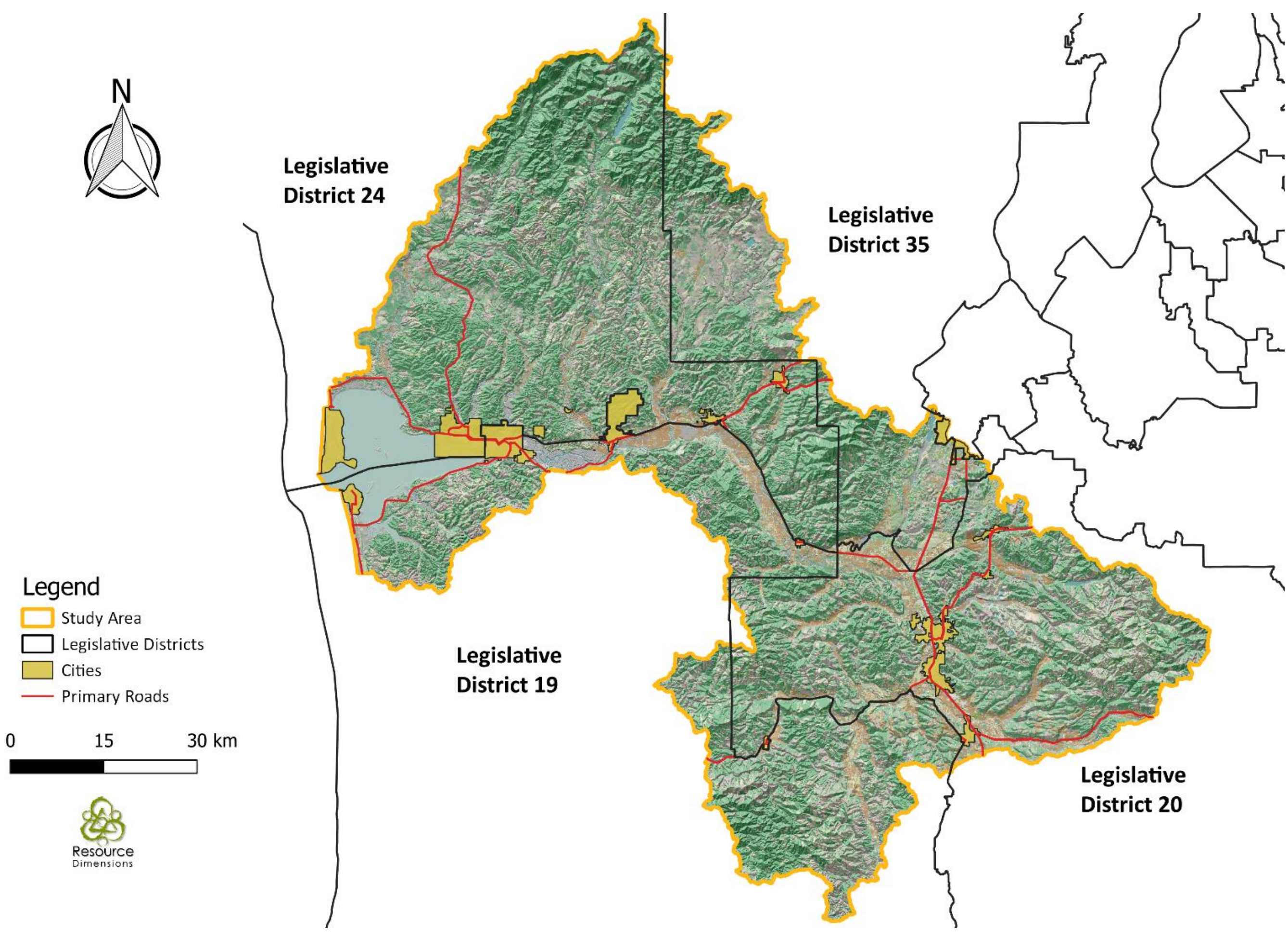
Note: Pacific Mountain Region (Workforce Development Area) includes Grays Harbor, Lewis, Mason, Pacific and Thurston Counties.
Source: ESD, 2019d.

1.3.2 Legislative District Economies

There are five legislative districts within the study area: 19, 20, 24, and 35 (Figure 5). We exclude legislative district 22 from our summary (only a small portion is in the study area; district 22 includes the greater Olympia area and is not representative of the study area).

The Census Bureau collects socio-demographic data at the legislative district level. For data collected by ESD at the county level, we extrapolated county data to the legislative district level based on percent of total county population within each legislative district. We calculated percent of population using census-block level data (the smallest USCB geography). For example, Legislative District 19 is comprised of parts of Cowlitz, Grays Harbor, Lewis, Pacific, Thurston, and Wahkiakum Counties. We used GIS to calculate the total population of each county within Legislative District 19, by census block. We then calculated the percentage of each county's total population within Legislative District 19, and multiplied county-level data by that percentage. The tables for which we used this method are designated with *Resource Dimensions, 2020* in the source line.

Figure 5. Study Area Boundary and Legislative Districts



Source: Resource Dimensions, 2020.

1.3.2.1 Socio-Demographics

Legislative District 19 covers parts of Cowlitz, Grays Harbor, Lewis, Pacific, Thurston, and Wahkiakum Counties. It has the smallest population of the districts that make up the study area (Table 18). The population is similar in age to the other legislative districts but is almost five years older than the state average. Household and family sizes are similar to the other study area legislative districts. It has the lowest income across all metrics. District 19 has the highest percentage of renter-occupied housing units and has the lowest median home value, substantially lower than the state average. Most of the 25-and-over population has a high school diploma but no college degree. Legislative District 19 has the highest percentage of the population over 25 years of age with less than a 9th grade education and the lowest percentage with college degrees of any type.

Legislative District 20 covers parts of Cowlitz, Pacific, Lewis, Pierce, Clark, Thurston, Grays Harbor, Skamania, and Yakima Counties. It is the largest district by population but has the third-lowest population density. District 20 has the largest household size and has a similar family size to other districts. Income is similar to the study area districts and has the highest percentage of occupied housing units. Like Legislative District 19, most of the population has a high school diploma but no college degree. District 20 has the highest percentage of the population with an Associate's degree compared with all legislative districts in the study area.

Jefferson, Island, San Juan, Clallam, Thurston, Grays Harbor, Kitsap, and Mason Counties make up Legislative District 24. It has the lowest population and housing density of the study area legislative districts; District 24 also has the smallest average household size and family size. This district has the third-highest income across; District 24 has the second-highest median home value, still well below the state median. Most of the population has some level of college education. District 24 has the second-highest level of Bachelor's degrees, and the highest level of graduate or professional degrees amongst all the study area legislative districts.

Legislative District 35 covers parts of Jefferson, Pierce, Thurston, Grays Harbor, Kitsap, and Mason Counties and has the highest population and population density among all legislative districts in the study area. District 35 has the second-oldest population of the study area legislative districts and has the highest income across all income-based metrics. This district has the lowest percent of occupied housing units and the highest median home value. Most of the 25-and-over population have some college education, and district 35 has the lowest percent of the population with no college education compared with the other legislative districts.

Table 18. Select Demographic Statistics, by Legislative District

	Legislative Districts			
Population Characteristics	**19**	**20**	**24**	**35**
Population	136,833	141,241	138,708	140,802
Population density (per sq. mile)[1]	52.5	41.2	21.5	96.5
Housing density (per sq. mile)[1]	25.5	18.0	11.5	46.3
Percent male	50.0%	50.1%	49.5%	51.0%
Percent female	50.0%	49.9%	50.5%	49.0%
Median age (years)	42.7	42.5	51.6	43.7
Average household size[2]	2.46	2.58	2.24	2.57
Average family size[2]	3.02	3.02	2.75	3.02
Economic Characteristics[3]				
Median household income	43,748	55,246	48,679	63,275
Median family income	55,871	65,143	62,537	76,033
Per capita income	23,490	26,617	28,805	31,195
Housing Characteristics[4]				
Occupied housing units	80.9%	87.9%	81.8%	79.9%
Owned-occupied	64.0%	74.2%	70.7%	75.9%
Renter-occupied	36.0%	25.8%	29.3%	24.1%
Vacant housing units	19.1%	12.1%	18.2%	20.1%
Median home value	169,100	201,400	226,300	252,300
Educational Attainment (population 25 and older)[2]				
Less than 9th grade	4.3%	3.1%	2.2%	2.7%
9th to 12th grade, no diploma	7.6%	7.6%	6.1%	5.9%
High School graduate (includes equivalency)	32.4%	31.1%	26.8%	27.3%
Some college, no degree	30.1%	29.2%	28.9%	27.7%
Associate's degree	10.1%	12.1%	9.9%	11.1%
Bachelor's degree	9.8%	10.8%	15.6%	16.6%
Graduate or professional degree	5.7%	6.1%	10.5%	8.7%

Sources: USCB 2020a.

[1] USCB, 2010
[2] USCB, 2020
[3] USCB, 2020b
[4] USCB, 2020c
[5] USCB, 2020d

The Washington State ESD estimates that the population of Legislative District 19 will increase by about 11,000 people by 2040, the least of the study area districts (Table 19) (ESD 2019a). Legislative District 35 is predicted to increase by about 57,000 between 2015 and 2040, and Legislative District 24 is predicted to increase by about 21,000 people. Population growth in Legislative District 20 is predicted to be the highest — increasing by about 88,000 between 2015 and 2040.

Table 19. Historic and Projected Populations, **by Legislative District**

Year	District 19	District 20	District 24	District 35
2000	69,078	256,794	140,767	184,362
2010	73,375	297,718	155,776	215,027
2015	74,285	309,431	158,273	223,257
2020	76,902	332,449	164,200	239,705
2025	78,502	353,146	168,566	256,929
2030	79,621	369,549	173,247	271,340
2040	80,919	398,182	179,665	296,891

Source: ESD, 2019a; Resource Dimensions, 2020.

ESD estimates that five-year average annual growth rates for Legislative District 19 will be considerably lower than the state average, with the highest growth from 2016-2020 (Table 20). Legislative District 20 is predicted to grow slightly more, with growth of 0.3% from 2016-2020. Legislative District 24 is predicted to have constant 0.2% growth from 2016 to 2030. Legislative District 35 is predicted to grow the fastest, by 0.4% from 2016-2020, 0.4% from 2021 to 2025, and 0.3% from 2026-2030.

Table 20. Historic and Projected Average Annual Population Growth Rates, **by Legislative District**

Period	District 19	District 20	District 24	District 35
2001-2010	0.1%	0.3%	0.4%	0.5%
2011-2015	0.1%	0.1%	0.1%	0.2%
2016-2020*	0.2%	0.3%	0.2%	0.4%
2021-2025*	0.0%	0.2%	0.2%	0.4%
2026-2030*	0.0%	0.2%	0.2%	0.3%

* Projected

Source: ESD, 2019b; Resource Dimensions, 2020.

1.3.2.2 Employment and Labor Force

The total civilian labor force was quite similar across all study area legislative districts in 2019 (Table 21).[3] The total civilian labor force ranged from 30,356 in Legislative District 19 to 147,872 in Legislative District 20. Legislative District 20 had the largest employed civilian labor force (139,932). Legislative District 19 had the smallest (28,398). Legislative District 19 had the highest unemployment rate, at 6.5%, and Legislative District 35 had the lowest, at 5.1%.

Table 21. Civilian Labor Force and Unemployment, 2019, by Legislative District

Legislative District	Total	Employment	Unemployed	Unemployment Rate
19	30,356	28,398	1,958	6.5%
20	147,872	139,932	7,940	5.4%
24	61,269	57,356	3,914	6.4%
35	104,025	98,742	5,283	5.1%

Source: USCB, 2019c.

1.3.3.3 Industries and Occupations

Business establishments in Legislative District 19 in 2017 were predominantly in the retail trade sector (15%), followed by accommodation and food services (14%), and construction (11%) (Table 22). The retail trade sector also had the highest proportion of business establishments in Legislative District 20 (13%), health care and social assistance (12%), and construction (12%). Legislative District 24 had the highest number of business establishments, predominantly in retail trade (14%), construction (14%), and accommodation and food services assistance (11%). Legislative District 35 had the highest number of business establishments in construction (15%), retail trade (13%), and health care and social assistance (13%).

[3] Extrapolating civilian labor force data for study area legislative districts for all years is outside the scope of this study.

[page left intentionally blank]

Table 22. Business Patterns, by NAICS Code, **by Legislative District**

2017 NAICS Code	2017 NAICS Code Key	Number of Establishments			
		District 19	District 20	District 24	District 35
00	Total for all sectors	1,741	7,211	4,375	4,799
11	Agriculture, forestry, fishing and hunting	91	133	121	49
21	Mining, quarrying, and oil and gas extraction	2	15	6	5
22	Utilities	3	17	12	11
23	Construction	189	908	608	708
31-33	Manufacturing	98	302	210	147
42	Wholesale trade	47	296	111	151
44-45	Retail trade	261	969	622	605
48-49	Transportation and warehousing	63	255	139	101
51	Information	31	122	62	76
52	Finance and insurance	79	370	180	241
53	Real estate and rental and leasing	79	392	205	283
54	Professional, scientific, and technical services	106	611	338	489
55	Management of companies and enterprises	2	32	6	16
56	Administrative and support and waste management and remediation ser	67	357	194	262
61	Educational services	9	82	46	62
62	Health care and social assistance	164	861	484	600
71	Arts, entertainment, and recreation	29	94	84	77
72	Accommodation and food services	237	674	500	437
81	Other services (except public administration)	169	712	429	472
99	Industries not classified	2	9	10	5

Source: USCB, 2019c; Resource Dimensions, 2020.

In Legislative District 19, educational services and health care and social assistance employed the highest percentage of the civilian employed population by industry (23.1%) (Table 23), followed by manufacturing (14.3%), retail trade (12.6%), and arts, entertainment, and recreation, and accommodation and food services (9%). Legislative District 20 is similar, with 19.8% of the workforce employed in educational services and health care and social assistance, followed by retail trade (12.1%), manufacturing, (11.1%), and construction (8.6%). Industry employment patterns are slightly different in Legislative District 24 —23.8% of the workforce is employed in educational services and health care and social assistance, followed by retail trade (11.9%), arts, entertainment, and recreation, and accommodation and food services (11.4%), and public administration (8 %). In Legislative District 35, most of the workforce is employed in educational services and health care and social assistance (21.5%), followed by public administration (13.1%), retail trade (11.4%) and arts, entertainment, and recreation, and accommodation and food services (9.1%).

Table 23. Workforce by Industry, by Legislative District

Industry	District 19 Estimate	District 19 Percent	District 20 Estimate	District 20 Percent	District 24 Estimate	District 24 Percent	District 35 Estimate	District 35 Percent
Civilian employed population, 16 years and over	52,929		59,369		54,102		60,803	
Agriculture, forestry, fishing and hunting, and mining	2,173	4.1%	2,868	4.8%	2,076	3.8%	2,352	3.9%
Construction	3,392	6.4%	5,084	8.6%	4,210	7.8%	4,760	7.8%
Manufacturing	7,547	14.3%	6,596	11.1%	3,545	6.6%	4,909	8.1%
Wholesale trade	1,123	2.1%	1,508	2.5%	903	1.7%	1,692	2.8%
Retail trade	6,682	12.6%	7,199	12.1%	6,417	11.9%	6,958	11.4%
Transportation and warehousing, and utilities	2,794	5.3%	4,389	7.4%	2,869	5.3%	2,560	4.2%
Information	476	0.9%	775	1.3%	819	1.5%	529	0.9%
Finance and insurance, and real estate and rental and leasing	2,137	4.0%	2,419	4.1%	2,540	4.7%	2,538	4.2%
Professional, scientific, and management, and administrative and waste management	3,371	6.4%	4,488	7.6%	4,256	7.9%	5,107	8.4%
Educational services, and health care and social assistance	12,220	23.1%	11,737	19.8%	12,891	23.8%	13,086	21.5%
Arts, entertainment, and recreation, and accommodation and food services	4,746	9.0%	4,720	8.0%	6,194	11.4%	5,529	9.1%
Other services, except public administration	2,710	5.1%	2,814	4.7%	3,034	5.6%	2,832	4.7%
Public administration	3,558	6.7%	4,772	8.0%	4,348	8.0%	7,951	13.1%

Source: USCB, 2019c.

The four-study area legislative districts all employ the highest number of civilians employed (over 16 years old) in management, business, science, and arts occupations (Table 24), as did the study area counties. In Legislative Districts 19, this is followed by service occupations and sales and office occupations. Legislative Districts 20 and 35 employ the second-highest number of civilians employed in sales and office occupations, followed by service occupations. Legislative District 24 employs the second-highest number of civilians in service occupations followed by sales and office occupations.

Table 24. Workforce by Occupation, by Legislative District

Occupation	District 19 Estimate	District 19 Percent	District 20 Estimate	District 20 Percent	District 24 Estimate	District 24 Percent	District 35 Estimate	District 35 Percent
Civilian employed population, 16 years and over	52,929		59,369		54,102		60,803	
Management, business, science, and arts occupations	15,057	28.4%	16,883	28.4%	17,532	32.4%	22,009	36.2%
Service occupations	10,949	20.7%	10,711	18.0%	12,259	22.7%	11,084	18.2%
Sales and office occupations	10,975	20.7%	13,280	22.4%	11,336	21.0%	12,396	20.4%
Natural resources, construction, and maintenance occupations	6,357	12.0%	8,164	13.8%	6,683	12.4%	8,033	13.2%
Production, transportation, and material moving occupations	9,591	18.1%	10,331	17.4%	6,292	11.6%	7,281	12.0%

Source: USCB, 2019c.

[page intentionally left blank]

1.3.3 Chehalis Basin Economy

The Chehalis Basin includes eight counties: Grays Harbor, Lewis, Mason, Thurston, and very small sections of Cowlitz, Jefferson, Pacific, and Wahkiakum. No data is collected by the Census Bureau or ESD at the watershed level. We used methods similar to those for the legislative districts to extrapolate county-level data to the Basin. We multiply county-level data by the percent of total population for each county, by census block, within the Basin. At the census block level, Jefferson and Wahkiakum Counties have zero population within the study area and are excluded.

For all census and ESD data not reported in raw numbers (like medians and average household and family size), the numbers we report are the average of Grays Harbor, Lewis, Mason, and Thurston Counties, as the other four counties represent such a small portion of the county. It is not appropriate to multiply medians or averages by percent of county population in the Basin.

1.3.3.1 Socio-Demographics

The population of the Chehalis Basin is about 193,000 people, which is only 2.6% of Washington's total population (Table 25). The Basin has lower population and housing density than the state average — almost ¾ of the state population density. The population of the Basin is about 9 years older than the state average. Average household size and average family size are similar to the state average. Income is lower than the state average across all metrics. The Basin has a higher percentage of owner-occupied housing units and a higher ratio of owner-occupied to renter-occupied units. Average median home value is substantially lower than the state average. Educational attainment is similar to the study area counties and legislative districts and is generally lower than the state average. Most of the population has a high school education, followed by some college but no degree. The Basin has a lower percentage of the population with college degrees of any kind.

Table 25. Select Demographic Statistics for the Chehalis Basin and the State of Washington

Population Characteristics	Chehalis Basin	Washington
Population	192,881	7,169,967
Population density (per sq. mile)[1]	71.4	100.5
Housing density (per sq. mile)[1]	32.4	44.1
Percent male	50.0%	49.9%
Percent female	50.0%	50.1%
Average median age (years)	46.9	37.6
Average household size[2]	2.4	2.55
Average family size[2]	2.9	3.1
Economic Characteristics[3]		
Average median household income	$ 50,265	$ 66,174
Average median family income	$ 62,055	$ 80,233
Per capita income	$ 26,858	$ 34,869
Housing Characteristics[4]		
Occupied housing units	82.0%	91.1%
Owned-occupied	67.8%	62.7%
Renter-occupied	32.2%	37.3%
Vacant housing units	18.0%	8.9%
Average median home value	$ 207,075	$ 286,800
Educational Attainment (population 25 and older)[2]		
Less than 9th grade	3.7%	3.8%
9th to 12th grade, no diploma	6.7%	5.3%
High School graduate (includes equivalency)	29.5%	22.5%
Some college, no degree	28.0%	24.0%
Associate's degree	11.4%	9.9%
Bachelor's degree	13.4%	21.7%
Graduate or professional degree	7.3%	12.7%

Sources: USCB 2019a; Resource Dimensions, 2020.

[1] USCB, 2010
[2] USCB, 2020
[3] USCB, 2020b
[4] USCB, 2020c
[5] USCB, 2020d

Washington State Employment Security Department (ESD) estimates, extrapolated to the Basin, indicate an increase of about 42,000 people by 2040 (Table 26).[4] This is

[4] Some predicted populations are much larger (Chehalis Basin Watershed Partnership Watershed Facts, for example). Without more details on the methodology of other estimates it is difficult to explain any differences.

similar to the average of the Legislative Districts and Counties, but substantially lower than the highest growth predictions (Legislative District 35 and Thurston County, for example).

Table 26. Historic and Projected Populations of Chehalis Basin

Year	Basin
2000	159,474
2010	185,973
2015	193,179
2020	206,130
2025	218,849
2030	229,412
2040	247,322

Source: ESD, 2019a; Resource Dimensions, 2020.

ESD estimates that five-year average annual growth rates for the Basin will be the highest between 2016 and 2020, at 1.6% (Table 27). This is equal to the state average of 1.6% for the same period.

Table 27. Historic and Projected Average Annual Population Growth Rates of Chehalis Basin and the State of Washington

Period	Chehalis Basin	Washington
2001-2010	2.0%	1.3%
2011-2015	0.8%	1.0%
2016-2020*	1.6%	1.6%
2021-2025*	1.4%	1.2%
2026-2030*	1.1%	1.0%

* Projected

Source: ESD, 2019b; Resource Dimensions, 2020.

1.3.3.2 Employment and Labor Force

The Basin follows a similar pattern in the civilian labor force to the other study area geographies. The total labor force and employed labor force were both highest in 2018 and lowest in 2005. The unemployment rate was highest in 2010 (10.7%), and lowest in 2018 (5.4%) (Table 28).

Table 28. Chehalis Basin Civilian Labor Force

Year/Time Period	Total	Employed	Unemployed*	Unemployment Rate
2005	84,559	79,244	5,315	6.3%
2010	87,775	78,357	9,419	10.7%
2015	83,441	77,586	5,855	7.0%
2016	85,677	80,114	5,563	6.5%
2017	88,259	83,285	4,974	5.6%
2018	90,294	85,418	4,876	5.4%

Note: Employment figures are not seasonally adjusted

* Yearly average

AAGR = Average Annual Growth Rate

Sources: ESD, 2019c; Resource Dimensions, 2020.

1.3.3.3 Industries and Occupations

The retail trade sector has the highest number of business establishments in the Basin (626), followed by health care and social assistance (577), construction (536), and accommodation and food services (458) (Table 29). The pattern is similar to that of the other study area geographies.

Table 29. Business Patterns of the Chehalis Basin, by NAICS Code

2017 NAICS Code	2017 NAICS Code Key	Number of Establishments Chehalis Basin
00	Total for all sectors	4,420
11	Agriculture, forestry, fishing and hunting	95
21	Mining, quarrying, and oil and gas extraction	5
22	Utilities	10
23	Construction	536
31-33	Manufacturing	158
42	Wholesale trade	147
44-45	Retail trade	626
48-49	Transportation and warehousing	128
51	Information	69
52	Finance and insurance	220
53	Real estate and rental and leasing	227
54	Professional, scientific, and technical services	371
55	Management of companies and enterprises	14
56	Administrative and support and waste management and remediation services	210
61	Educational services	49
62	Health care and social assistance	577
71	Arts, entertainment, and recreation	69
72	Accommodation and food services	458
81	Other services (except public administration)	442
99	Industries not classified	9

Source: USCB, 2019c; Resource Dimensions, 2020.

Like the other study geographies, the largest proportion of the Chehalis Basin civilian employed population is in the educational services and health care and social assistance sector (22%) (Table 30), followed by public administration (14%), retail trade (12%), arts, entertainment, and recreation and accommodation and food services (9.1%), and public administration (11.4%), and professional, scientific, and management, and administrative and waste management (8.5%).

Table 30. Workforce by Industry of the Chehalis Basin

Industry	Chehalis Basin Estimate	Chehalis Basin Percent
Civilian employed population, 16 years and over	84,047	
Agriculture, forestry, fishing and hunting, and mining	2,751	3.3%
Construction	5,778	6.9%
Manufacturing	6,041	7.2%
Wholesale trade	1,793	2.1%
Retail trade	10,065	12.0%
Transportation and warehousing, and utilities	3,964	4.7%
Information	1,135	1.4%
Finance and insurance, and real estate and rental and leasing	3,879	4.6%
Professional, scientific, and management, and administrative and waste management	7,124	8.5%
Educational services, and health care and social assistance	18,498	22.0%
Arts, entertainment, and recreation, and accommodation and food services	7,645	9.1%
Other services, except public administration	3,645	4.3%
Public administration	11,730	14.0%

Source: USCB, 2019c; Resource Dimensions, 2020.

Workforce by occupation patterns are also similar to the other study area geographies. Most of the civilian employed population is employed in management, business, science, and arts occupations (37.5%), followed by sales and office occupations (21.7%), and service occupations (18.1%) (Table 31).

Table 31. Workforce by Occupation of the Chehalis Basin

Occupation	Chehalis Basin Estimate	Chehalis Basin Percent
Civilian employed population, 16 years and over	84,047	
Management, business, science, and arts occupations	31,523	37.5%
Service occupations	15,231	18.1%
Sales and office occupations	18,233	21.7%
Natural resources, construction, and maintenance occupation	8,331	9.9%
Production, transportation, and material moving occupations	10,728	12.8%

Source: USCB, 2019c; Resource Dimensions, 2020.

1.3.4 Natural Capital and Ecosystem-based Values

1.3.4.1 Addressing Cultural Value

Cultural services are generally understood, though historically are not adequately defined or integrated within the ecosystem services framework. Closely aligned with human values and behavior, as well as to human institutions and patterns of social, economic, and political organization, cultural services are the nonmaterial benefits that people receive from ecosystems through recreation, reflection, aesthetic experiences, spiritual enrichment, and cognitive development.

Over the past several decades, a substantial body of methods, models, and data relevant to cultural services has been developed within the social and behavioral sciences before and outside of the ecosystem services approach. The Millennium Ecosystem Assessment (2005) or the EPA's Final Ecosystem Goods and Services Classification System (FEGS-CS) (Landers and Nahlik 2013), interpret cultural values in several ways. Contextually, for this study, cultural services and values include the beliefs and tribal values of the Quinault Indian Nation, the Chehalis and other tribal communities of the Chehalis Basin. Thus, nature and the environment are tightly bound to understandings of everyday life, family and community, and societal identity (Amberson et al. 2016).

Through nature, cultural heritage and ancestral experiences are shared across generations enabling the passing of knowledge, customs and intangible attributes across generations (Daniel et al. 2012). From the beginning of time, the natural environment has been marked by human activity. Our world is imprinted both by nature and by the vestiges of civilizations, cultures and technologies past and present.

Referred to as cultural landscapes, the United Nations has long recognized the significance of interactions between people, certain species and natural landscapes in the creation of place (Cuerrier et al. 2015; Wartmann and Purves, 2018). And while nonmarket economic valuation has been successfully applied in a few cultural heritage cases, cultural values such as sense of place and identity remain elusive, and unfeasible to value monetarily. Thus, we approach cultural values associated with tribal communities of the Chehalis Basin in this study as non-monetary goods and services within the themes below.

1.3.4.2 Cultural Services Assessment

Assessment of ecosystem service tradeoffs in both the cultural and biophysical context is essential in providing decision makers and resource managers with important guidance. To date, however, the ecosystem service framework does little to address the range of cultural values relevant to cultural service valuation (Bryce et al. 2015; Kai et al. 2018). In two recent studies, Resource Dimensions successfully assessed cultural values in tandem with ecosystem function and the health of essential biophysical environments central to sustaining subsistence and commercial fisheries relevant to land and water-use decisions (Gustanski and Scarsella 2015; Gustanski et al. 2015; Gustanski et al. 2018).

In addition to the complexities of valuation, efforts to measure cultural values face both procedural difficulties and problems of scale (GCI 2002). Entwined with layers of other ecosystem services, separation is near impossible, in most cases. (Small et al. 2017). For instance, salmon, a central element to tribal culture, are woven throughout tribal economies, and social and religious values.

Salmon require healthy aquatic systems to survive and provide both the cultural value of ceremonial activities and food itself. Across these elements are a complex system of inextricable linkages – each of which on its own present extreme challenges for valuation. Additionally, quantifying cultural ecosystem services across large areas is problematic (Bryce et al. 2016) in part due to the strong association between a particular place and the unique meanings and values held with respect to the nature of that place (Irvine et al. 2016). Thus, attempts to measure cultural value across vast areas run the risk of clustering disparate peoples and communities when unique locations, in fact, carry distinct cultural importance.

In an effort to address such limitations, researchers from the University of Washington's School of Marine and Environmental Affairs and Puget Sound Institute, and Stanford University, in partnership with the Hood Canal Coordinating Council, developed a system to qualitatively assess cultural value relevant to natural resource management for Hood Canal tribes (Biedenweg and Hanein 2013). The goal was to understand how community culture is influenced by land-use decisions and how human wellbeing is improved with access to nearby aquatic resources of the Hood Canal. Similar to the efforts of the Chehalis Basin Strategy, this work was part of a larger effort aimed at informing and evaluating integrated watershed strategies for Hood Canal communities. The approach has since been expanded for use in other environmental management initiatives at the watershed and Basin scale within the Puget Sound (Biedenweg et al. 2014).

For the purposes of this study, we have used this methodology, hereafter referred to as the Puget Sound HWI method (PSHWI), to establish the importance of cultural values to the tribal communities of the Chehalis Basin. The method is well-suited for identifying the range of cultural benefits received by tribes in ways that are otherwise overlooked in the decision-making context. Through the PSHWI method, we validate a comprehensive list of benefits across individuals to illuminate the complement of cultural values that are not characterized monetarily in this study. Given the extent of existing relevant work and study limitations, the PSHWI method was determined to be the most appropriate in context. Other approaches, including in-person interviews, focus groups and workshops, were not feasible for this analysis. The following section outlines the PSHWI method and its implementation in this study.

1.3.4.3 The Puget Sound HWI Method

Social scientists generally define human wellbeing by six distinct domains: psychological, physical, social, cultural, governance and economic. These are the foundational categories used in the PSHWI approach. The initial work, which laid the foundation for the PSHWI method, was developed by interdisciplinary resource social scientists in collaboration with cultural resource specialists and respected tribal community members from the Hood Canal. The goal of the project was to understand how culture and wellbeing were affected by access to river resources like salmon. The methodology entails two steps. The first, included interviews with individual tribal members concerning their daily interactions with various natural resources. The second, used a qualitative approach to transcribe, code and analyze information learned from the interviews. Responses were coded into the six domains.

1.3.4.4 Cultural Values: Chehalis Basin Approach

This study aims to demonstrate the range of cultural value that the Chehalis Basin provides to area tribes. To accomplish this, we have applied an adapted version of the PSHWI method. Any modifications to the procedural approach were made to adjust for differences between the cultural analysis, and the PSHWI approach for the Quinault Nation. Our approach is outlined below.

Given the scope of the overall study, conducting individual interviews was not possible. As an alternative, our assessment relies upon diverse media, narrative, and literary documentation to assess wellbeing indicators. Sources include, online video transcripts, published stories and poetry. Sometimes, tribal stories, and teachings, communicated orally from generation to generation, are the only documented sources that demonstrate how native peoples across the world value natural resources (Alex 2016). Textual analysis, a qualitative method for gathering, processing, and interpreting text-based information, is broadly accepted in many fields of study as an efficient tool for data collection.

Data collected for the cultural analysis consisted of 44 documents, reports, videos, poems and stories, each of which provided many pages of content. All data was collected from public online sources or directly from the tribes themselves. The documentation represents multiple perspectives and generations within each the Quinault Indian Nation and Confederated Tribes of the Chehalis Reservation. Appendix D provides a list of sources.

1.3.4.5 Content Analysis

Textual content analysis is a methodology is an ethnographic approach, used to identify, quantify, and analyze occurrences of specific communications and message characteristics embedded in text. The process involves the systematic analysis of the content of written, spoken and/or visual messages to gain information about how people make sense of and communicate life and life experiences. Analysis involves examining not just the content, but also the structure or design of text and how elements function, often as part of a larger social, historical or cultural context.

Consistent with the PSHWI method, information presented in the sources listed in Appendix G were converted and coded for the Chehalis Basin cultural analysis using MAXQDA[5], into the classifications presented in Table 32. As an example, this sentence is narrative transcribed from video footage (#11 in Appendix G): "*"Outside of the treaty right, we have a unique and profound, cultural and spiritual relationship with this land and territory. We've lived here since time immemorial – these lands are a gift to us, and we have a sacred responsibility to take care of and maintain them."* This sentence was coded using the wellbeing indicator "identity," under the classification "Cultural/Spiritual".

1.3.4.6 Chehalis Basin Human Wellbeing Indicators

As mentioned, the PSHWI method uses the customary human wellbeing domains of psychological, physical health, social health, cultural health, governance and economic. We adopt this classification system in the analysis for the Chehalis Basin. Table 32 shows the breakdown for each domain.

[5] First released in 1989, MAXQDA is a qualitative data analysis software designed for the use in qualitative, quantitative and mixed methods research that allows users to systematically organize, evaluate and interpret textual and multimedia data.

Table 32. Chehalis Basin Cultural Value Analysis – Wellbeing Indicators

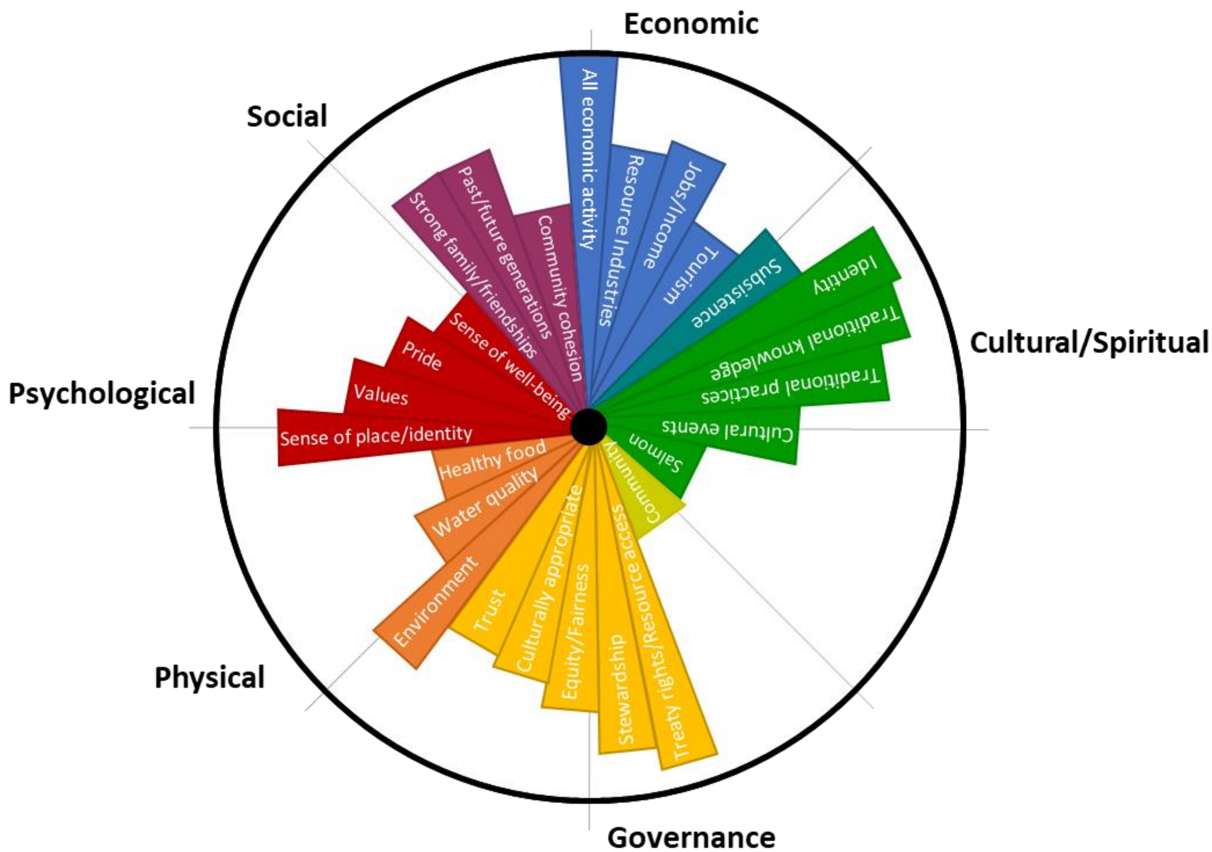
DOMAIN	ATTRIBUTES	FREQUENCY
Economic	All economic activity	113
	Natural resource industries	87
	Jobs/Income	92
	Tourism	71
	Subsistence	81
	Non-extractive/non-tourism	29
Cultural/Spiritual	Identity	109
	Traditional knowledge	101
	Traditional practices	69
	Cultural events/ceremonies	41
	Salmon/Traditional diet	31
	Community	27
Governance	Treaty rights/access to resources	110
	Stewardship	107
	Fairness and equity	89
	Culturally appropriate	49
	Trust	44
Physical	Environment	87
	Water qualtiy	41
	Healthy local foods/salmon access	36
	Outdoor activities	29
Psychological	Sense of place/identity	92
	Values	73
	Pride	66
	Sense of well-being	57
Social	Strong family and friendships	89
	Past and future generations	89
	Community cohesion	77

Source: Resource Dimensions, 2019.

Results: Chehalis Basin Cultural Value Analysis

Shown in Figure 6 are the incidence or frequency with which each identified wellbeing indicator was mentioned within the documentation collected. The most frequently referenced indicators were **economic activity** with significant references to that associated with commercial fishing and shell fishing; **treaty rights** and **access** to important natural resources; **stewardship** both of the environment and its diverse resources and cultural heritage; and, family and personal **identity** within and connected to the natural environment; **traditional knowledge** with significant reference frequency associated with nature, water and water-based resources (e.g., fishing, fisheries, water quality), and land-based resources (e.g., plant material for weaving), and the passing of that knowledge from generation to generation. While the incidence of these references does not imply some indicators have greater value than others, it should be recognized as a gauge of the vast cultural value that tribes and their ancestors place on nature and the Chehalis Basin's natural resources.

Figure 6. Chehalis Basin Human Wellbeing Indicator Frequency Radial



Source: Resource Dimensions, 2019 adapted from Biedenweg, et al. 2013

This analysis reveals the strong association between a general sense of well-being, self-reliance and deeply rooted cultural values uniquely tied to place. The geography and diverse resources of the Chehalis Basin provide a distinctive landscape that has shaped the cultural practices, beliefs, and identity of its people over thousands of years. Monetizing the cultural value of these relationships in the context of ESV across the Chehalis Basin, or otherwise, is complicated at best. To attempt, may lose the inimitable multiplicity of culture specific to the region's tribes. Thus, while not monetized here, within Section 4 of this study related economic contributions and intrinsic values are implicitly included through values used in the ESV models, particularly in relation to provisioning and societal/cultural ecosystem services.

[page intentionally left blank]

SECTION 2
METHODOLOGY

SECTION 2: METHODOLOGY

Since the Millennium Ecosystem Assessment (MEA) was published in 2005, there has been an exponential increase in scientific research addressing a wide range of issues regarding all aspects of implementing the valuation of natural capital and ecosystem services. Appropriately defining and classifying ecosystem services to abate double-counting, accounting for an ecosystem service twice, and relate directly to human beneficiaries the diverse contributions from nature has been the most significant axiological challenge for broad implementation. Over the past two decades Resource Dimensions' principals have developed a refined classification system, backed by leading academic research, to address this challenge, in addition to ensuring that it can be applied at multiple spatial scales; Our methods facilitate development of biophysical metrics that can be measured to directly link ecosystem goods and services to human well-being.

2.1 SCREENING

To identify ecosystem services most appropriate for valuation for the Chehalis River Basin, we employ an iterative screening process. The first step includes a review of recent projects and literature, verifying valuation methodologies and understanding the context and specificities to determine parallels and applicability to the current system. Next, the matrix of potential ecosystem services was reviewed both independently and in a working session with land and resource managers, biologists, hydrologists, fisheries biologists, and other project experts from Washington State Department of Ecology (WSDE), QIN, and the joint consulting team. This regionally knowledgeable panel assisted in narrowing the initial list of 21 ecosystem service types to a final set of 14 for valuation (Table 31, Section 3.1.1). The next step in the process requires refining the ecosystem service combinations by relevance and in their context to the project. Those ecosystem services identified for valuation are then placed in our modified ecosystem services matrix generally structured on the basis of the MEA classification system, with guidance from the Common International Classification of Ecosystem Services (CICES), and the U.S. EPA-developed Final Ecosystem Goods and Services Classification System (FEGS-CS) (Landers and Nahlik, 2013). CICES is widely used for mapping, ecosystem assessment, and natural capital ecosystem accounting, while FEGS-CS provides a foundation for measuring, quantifying, mapping, modeling, and valuing ecosystem services.

The matrix was then used to cross-check information available on the socio-economic context of the project and the feasibility of measurement. Indicators with little or no relevance in connection to project stakeholders and beneficiaries, or which could not be monetized in the context of the project, were not retained.

In summary, the screening approach consists of the following steps:

- Identification of relevant ecosystem types and assessment of their condition.
- Analysis of the human-environment system.
- Selection and quantification of relevant ecosystem services.
- Normalization of ecosystem services values and their inclusion in the matrix.

2.2 Land Cover Approach

We employed a modified version of the National Oceanic and Atmospheric Administration's Coastal Change Analysis Program (C-CAP) Land Cover Atlas (NOAA 2016). The C-CAP Land Cover Atlas is a 30-m spatial resolution product that is a version of the nationwide National Land Cover Dataset (NLCD) specifically modified for coastal areas of the United States. C-CAP Land Cover data is updated every 5 years beginning in 1996 and contains 25 land cover classes. In addition, Resource Dimensions used Washington Department of Ecology shorezone (Appendix A) inventory data to assist in identifying publicly accessible beaches adjacent to estuarine beach in the C-CAP Atlas data.

For our purposes, and in consultation with biologists, hydrologists, land managers and other experts, we reduced the 25 potential classes to 12 classes (Appendix B). Many of these classes provide the same or similar ecosystem services and so were combined for purposes of ecosystem service valuation. Each pixel of land cover, having a cell size of 30m, contains an area of 900 m2 or roughly 0.22 acres, Figure 7.

The following section provides details on how we aggregated the land cover classes for use in the valuation process.

2.2.1 Land Cover Class Definitions

Beach — created by Resource Dimensions by cross-referencing public access beach data and Washington shorezone inventory data with satellite imagery. Includes only beaches with public access adjacent to the estuarine open sandy beach category in the WSDE shorezone inventory data.

Cropland — called Cultivated Crops in C-CAP data. Contains areas intensely managed for production of annual crops. Crop vegetation accounts for > 20% of total vegetation. This class also includes all land being actively tilled.

Estuary — includes a combination of open water within Grays Harbor plus the following classes in the C-CAP data:

Open Water – includes areas of open water, generally with < 25% cover of vegetation or soil.

Unconsolidated Shore – includes material such as silt, sand, or gravel that is subject to inundation and redistribution due to the action of water. Substrates lack vegetation except for pioneering plants that become established during brief periods when growing conditions are favorable. (Except unconsolidated shore re-classified as beach).

Estuarine Aquatic Bed – includes tidal wetlands and deep-water habitats in which salinity due to ocean-derived salts is ≥ 0.5% and which are dominated by plants that grow and form a continuous cover principally on or at the surface of the water. These include algal mats, kelp beds, and rooted vascular plant assemblages. Total vegetation cover is > 80%.

Forest — created by combining the following C-CAP classes:

Deciduous Forest – contains areas dominated by trees generally greater than 5 meters tall and
> 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.

Evergreen Forest – contains areas dominated by trees generally greater than 5 meters tall and
> 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.

Mixed Forest – contains areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are > 75% of total tree cover. *Both coniferous and broad-leaved evergreens are included in this category.*

Grassland — contains areas dominated by graminoid or herbaceous vegetation, generally > 80% of total vegetation. These areas are not subject to intensive management such as tilling but can be utilized for grazing.

Rivers and Lakes — all open inland water outside of Grays Harbor.

Pasture — contains areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle and not tilled. Pasture/hay vegetation accounts for > 20% of total vegetation.

Scrub/Shrub — contains areas dominated by shrubs < 5 meters tall with shrub canopy typically > 20% of total vegetation. This class includes tree shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.

Snow/Ice — includes areas characterized by a perennial cover of ice and/or snow, generally > 25% of total cover.

Urban Greenspace — contains areas with a mixture of some constructed materials, but mostly managed grasses or low-lying vegetation planted in developed areas for recreation, erosion control, or aesthetic purposes. These areas are maintained by human activity such as fertilization and irrigation, are distinguished by enhanced biomass productivity, and can be recognized through vegetative indices based on spectral characteristics. Constructed surfaces account for less than 20% of total land cover. Developed, Open Space in the C-CAP data.

Wetland — created by combining the following C-CAP classes:

Palustrine Forested Wetland – includes tidal and nontidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is < 0.5%. Total vegetation coverage is > 20%.

Palustrine Scrub/Shrub Wetland – includes tidal and nontidal wetlands dominated by woody vegetation less than 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is < 0.5%. Total vegetation coverage is > 20%. *Species present could be true shrubs, young trees and shrubs, or trees that are small or stunted due to environmental conditions.*

Palustrine Emergent Wetland (Persistent) – includes tidal and nontidal wetlands dominated by persistent emergent vascular plants, emergent mosses or lichens, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is < 0.5%. Total vegetation cover is > 80%. *Plants generally remain standing until the next growing season.*

Estuarine Forested Wetland – includes tidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is ≥ 0.5%. Total vegetation coverage is > 20%.

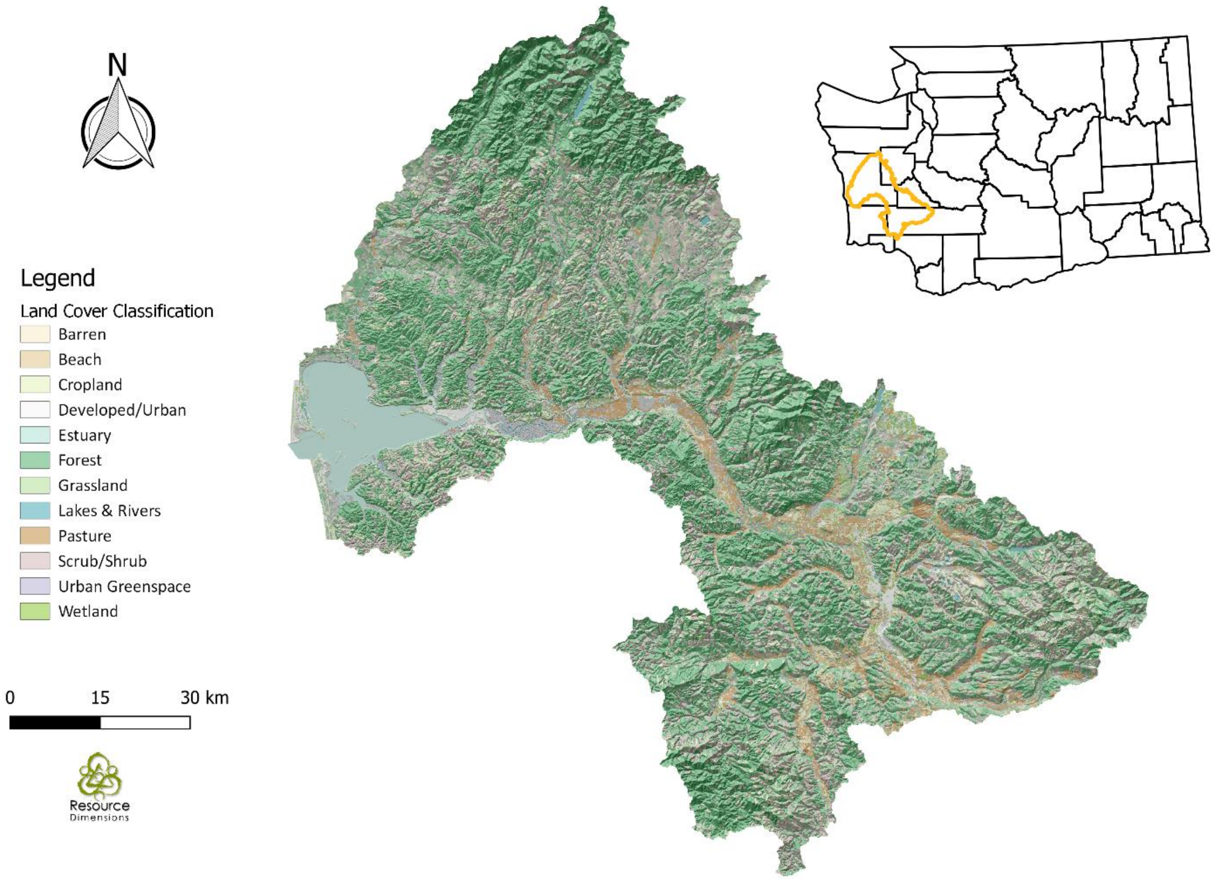
Estuarine Scrub/Shrub Wetland – includes tidal wetlands dominated by woody vegetation less than 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is ≥ 0.5%. Total vegetation coverage is > 20%.

Estuarine Emergent Wetland – includes all tidal wetlands dominated by erect, rooted, herbaceous hydrophytes (excluding mosses and lichens). These wetlands occur in tidal areas in which salinity due to ocean-derived salts is ≥ 0.5 % and are present for most of the growing season in most years. Total vegetation cover is > 80%. *Perennial plants usually dominate these wetlands.*

Palustrine Aquatic Bed – includes tidal and nontidal wetlands and deepwater habitats in which salinity due to ocean-derived salts is below 0.5% and which are dominated by plants that grow and form a continuous cover principally on or at the surface of the water. These include algal mats, detached floating mats, and rooted vascular plant assemblages. Total vegetation cover is
> 80%.

Figure 7 provides a map of the Chehalis Basin land cover typology. Table 33 breaks out the distillation of land covers, by aces, used in the ESV for the Basin. Appendix B-2 provides a detailed accounting of land cover classifications from C-CAP into classes for our analyses.

Figure 7. Chehalis Basin Land Cover Classification Typology



Source: Resource Dimensions, 2020.

Table 33. Landcover Classifications Used for Ecosystem Service Valuation

Land Cover Class (assigned for ESV)	Original C-CAP cover class	Acres
Forest	Evergreen forest Mixed forest Deciduous forest	887,280
Scrub/Shrub	Scrub/Shrub	353,956
Grassland	Grassland	136,598
Wetland	Palustrine Forested Wetland Palustrine Scrub/Shrub Wetland Palustrine Emergent Wetland Persistent Estuarine Scrub/Shrub Wetland Estuarine Emergent Wetland Palustrine Aquatic Bed	89,636
Pasture	Pasture/Hay	79,036
Estuary	Estuary Estuarine Aquatic Bed Unconsolidated shore	59,989
Cropland	Cultivated Crops	14,967
Urban Greenspace	Developed, Open Space	13,335
Lakes & Rivers	Open Water	12,349
Beach	Beach	181
	Total Acres	**1,647,328**

Source: Resource Dimensions, 2020.

2.3 Benefit Transfer

There are many valuation methods commonly used to quantify ecosystem services. For the scope of this study, the benefit function transfer method was used. Benefit transfer involves applying a monetary benefit value per unit estimate (e.g., dollar per acre, dollar per visitor day, dollar per household) from an existing study site to an unstudied area for which a per unit benefit value is needed. Economists define benefits for economic efficiency or benefit-cost analyses as the user's willingness to pay (WTP) in excess of current costs (e.g., net WTP) or consumer surplus. This is the benefit measure used by federal agencies for benefit-cost analysis and natural resource damage assessment (DOI 1994; USEPA 2000; OMB 2000). See Sections 2 and 3 for a more detailed discussion of the method and Section 4 for valuation results for Chehalis Basin ecosystem services.

2.4 Asset Valuation and Net Present Value Approach

Asset valuation is the process of determining the fair market or present value of assets, for example investments in marketable securities (e.g., stocks and bonds), tangible assets (e.g., buildings, equipment, and ecosystem services linked to physical processes), or intangible assets (e.g., brands, patents and trademarks, and ecosystem services linked to human perception). The asset value of manufactured capital can be calculated as the net present value (NPV) of its expected future benefits. If the natural capital of the Chehalis Basin is not further diminished or altogether exhausted, the flow of ecosystem services will continue indefinitely into the future. Thus, as with other assets, we can estimate the NPV of the future stream of income arising from the production of the Basin's ecosystem services that are expected to be transacted in the future.

In the context of valuing ecosystem services, it is necessary to aggregate across the bundle of ecosystem services that an individual ecosystem asset will generate. To do this, we calculate the asset value through a composite assessment of the current land cover, ecological subregions, productive capacities, population, and consumer preferences. Thus, providing an estimate of the anticipated benefit flow for natural capital over time. The NPV formula is used to compare benefits that are produced at different points in time. To accomplish this, we employ both a 2% and 7% discount rate.

The use of an NPV based approach is conceptually sound though raises many questions, including the choice of discount rate, the expected asset life, the expected pattern of future flows, the estimated values of those future flows (especially in light of scarcity and boundary constraints), etc.

Answers to a number of these questions are of interest whether or not an NPV based valuation is attempted. For example, to assess questions of sustainability it is likely to be relevant to determine to what extent a given ecosystem asset has the capacity to produce a set of services into the future. Determining the answer is as much an ecological question as an economic one.

2.5 Limitations

It is important to note that valuation processes have limitations, although these limitations should not undermine the basic finding that natural capital and constituent ecosystems deliver significant economic value to society. Some ecosystem services vital to human well-being, for example nutrient cycling, medicinal plants, and disease control, are regularly under-represented in economic valuation studies.

The results of this study should be regarded as conservative initial estimates of economic value rather than as definitive conclusions. This is, in part, due to the fact that only a portion of all ecosystem services provided by the Chehalis Basin's natural capital are addressed. These deliberate omissions reflect a range of factors, including but not limited to, the absence of applicable peer reviewed studies, lack of or unavailability of primary data, and complications in transference or conversion of values from exiting studies to the CB region. Principal guidance on relevant limitations are presented in the following sections.

2.5.1 General Limitations

Every study has limitations that reflect trade-offs between project resources (ie. time or funding) and study robustness and accuracy. Through this analysis, to the extent possible, we have sought to minimize characteristic limitations associated with ESV efforts of this magnitude and complexity, through our approach and dynamic valuation models. Still, assumptions were made to facilitate the analytical frameworks in this study. These are noted throughout to the extent practicable.

Climate Change. This study does not include climate change in its analyses due to the scarcity of relevant data, the complexity and time required to do accurately incorporate climate change impacts.

Ecosystem Service Valuation. As with any economic analysis, the benefit transfer method used in estimating ecosystem service values has strengths and weaknesses. Some arguments against benefit transfer include:

- Each ecosystem has distinctive qualities. Values drawn from other geographic locations may be extraneous to the study region's ecosystems.
- Within a given ecosystem, per acre values are dependent on the size of the ecosystem. Generally, the greater the area, the greater the per-acre value is. That is, the marginal cost per acre is typically expected to increase as the quantity supplied decreases; thus, an averaged value is not the same as a range of marginal values.

Proponents of such arguments recommend an alternative valuation approach that requires limiting valuation to a single ecosystem in a single location. This method employs only that data developed for the particular ecosystem under study, with no attempt to extrapolate from other ecosystems in other locations. In most cases, the size and landscape complexity of most study regions makes this approach to valuation extremely difficult and costly.

In presenting these results, we reflect the range of values and their distribution. It should be clear from the information presented that the final estimates are not precise. However, they are much better estimates than the alternative of assuming that ecosystem services have zero value, or, alternatively, of assuming they have infinite value.

Data Complexity and Magnitude. It was not possible to incorporate all of the valid data gathered because of its magnitude and the complexity of analyzing such data. The most pertinent data and information is used and discussed. While certain data was not incorporated the resulting analyses or results were not negatively impacted.

Scarcity Value. Valuations contained herein likely underestimate shifts in the relevant demand curves as the supply of natural capital, thus ecosystem service functions, in the Chehalis Basin declines. The values of many ecological services rapidly increase as they become increasingly scarce (Batabyal et al. 2003). Where ecosystem services are scarcer than assumed, their value is underestimated in this study. Reductions in supply are likely as land conversion and development proceed. Climate change may also adversely affect the ecosystems, though the exact impacts are difficult to predict.

Secondary Data. The vast majority of the values used in our ESV models rely upon secondary data – data not collected and analyzed by the authors. While every effort is made to validate the processes employed in these studies, no claim to the veracity of secondary data is made.

Static Analysis. Based on a snapshot in time, the analysis uses a static, partial equilibrium framework. Thus, interdependencies are not accounted for. The significance of any impact on valuations is difficult to gauge.

Uncertainty. The limitations of valuation results are heavily dependent on social, cultural and economic contexts, the boundaries of which may not overlap with the delineation of the relevant ecological systems.

2.5.2 Unique Limitations

2.5.2.1 Benefit Transfer/Database Limitations

Despite the difficulties of transferring valuation approaches and results between geographical regions, the benefit transfer method is a practical and economical way to estimate of the value of ecosystems, particularly when the aim is to assess a number of diverse ecosystem services. The methodology estimates the economic value of a given ecosystem (e.g., forests) from prior studies of that ecosystem type. Correcting values accordingly is required when there are major differences between the sites where the primary values are taken from and the sites to which values are to be transferred.

Limited Coverage. That not all ecosystems have been valued or studied well is the most significant limitation in this analysis. The result is a considerable underestimation of the value of ecosystem services in the Chehalis Basin. More complete coverage would likely increase the values shown in this report; no known valuation studies have reported estimated values of zero or less for an ecosystem service. Table 31 details those ecosystem services identified in the Basin for each land cover type, and of which those that were valued.

Value Bias. Bias can be introduced through the valuation studies selected, as in any evaluation approach. We use high-low value ranges to bound our estimates and marginalize this problem.

2.5.2.2 Primary Study Limitations

Price Distortions. Distortions in the current prices used to estimate ecosystem service values are carried through the analysis. These prices do not reveal environmental externalities and thus are likely underestimates of true values.

2.5.2.3 GIS Limitations

Ecosystem Function. There is the potential that certain ecosystems analyzed via GIS are functioning at a higher level, thus delivering higher values, than those assumed in the primary studies used in the valuation process. In this case, current values will be underestimated. Conversely, if ecosystems are functioning at a lower level, current values will be overestimated.

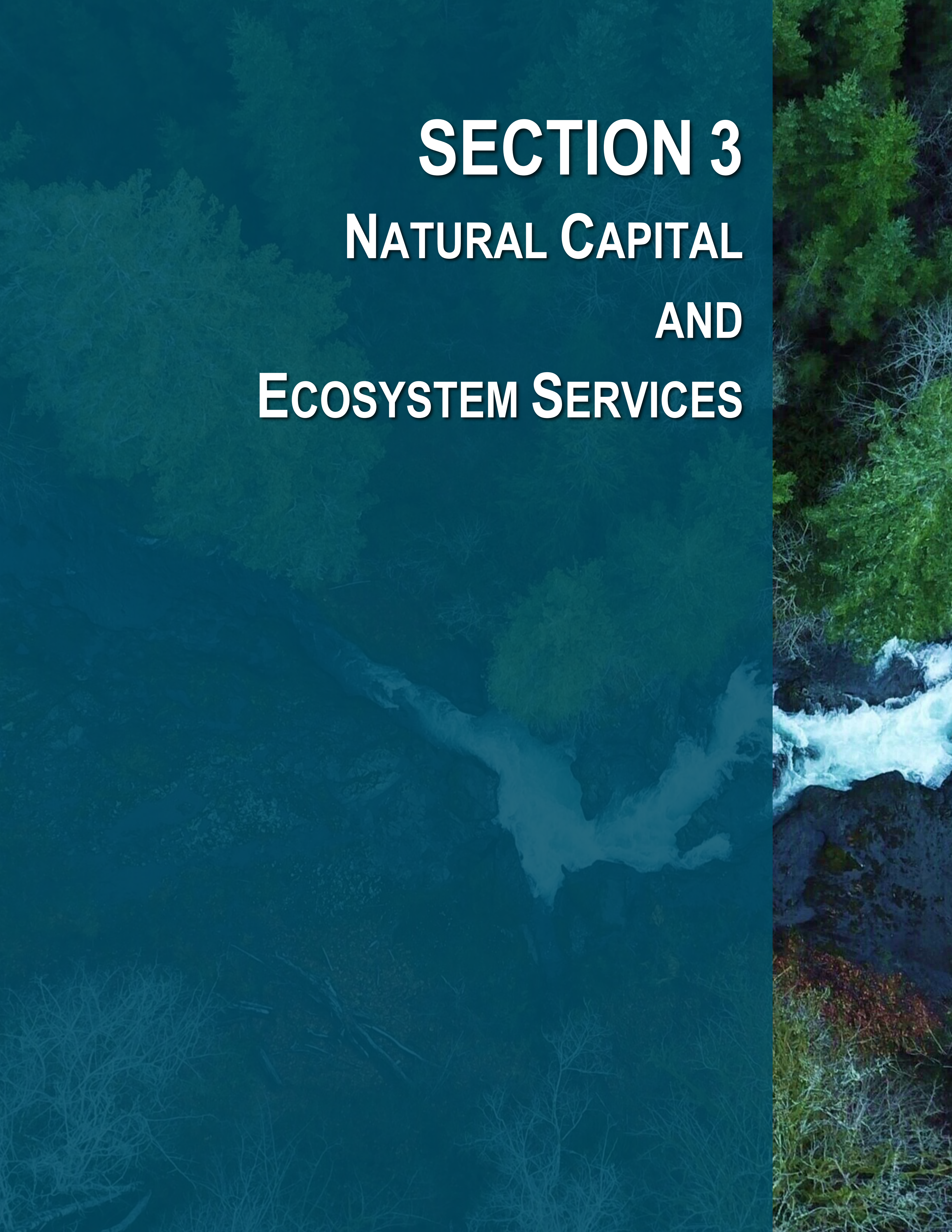
Land Cover Data. Our valuation approach involves the use of benefit transfer methodologies to assign values to land cover types based, at least in some cases, on the context of their surroundings. One of the key issues with GIS quality assurance is reliability and accuracy of the land cover maps used to develop baselines.

Spatial Homogeneity. The subject valuation assumes spatial homogeneity of service provision within ecosystems. For example, each acre of forest produces the same services; thus, the same value. This clearly does not happen. Whether there would be an increase or decrease values is highly dependent on spatial patters and the ecosystem services in question. Dynamic spatial analysis would be required to solve this question, which is outside the scope of this project. However, complex system dynamic studies of ecosystem services show that inclusion of system dynamics and interdependencies results in substantially higher values as changes in ecosystem service levels cascade throughout the economy.

[page intentionally left blank]

SECTION 3

NATURAL CAPITAL AND ECOSYSTEM SERVICES



SECTION 3: NATURAL CAPITAL AND ECOSYSTEM SERVICES

This section presents essential concepts surrounding ecosystem function, natural capital, ecosystem services, and manufactured or built capital; this section is inclusive of how these components deliver value to humans, their communities and the economic systems that support them. The section closes with the methodology used in developing estimates for natural capital and valuation of the ecosystem services in the Chehalis Basin.

Natural capital, ecosystem services and ecosystem-based function, while related, are different concepts for expressing the value of nature. Natural capital and ecosystem services are economic intellections that apply to the array of goods and services that can be valued monetarily. Whereas, the concept of ecosystem-based function is centered on the spectrum of nature's intrinsic values, autonomous from human evaluation – or valuation. Recently, principles of ecosystem-based function were adopted in the efforts to update the Columbia River Treaty (CRITFC 2017).[6] The cultural values of these ecosystems are not characterized monetarily in this study.

Finally, manufactured capital is characterized as natural capital changed by human actions. For example, the construction and operation of agricultural systems, cities, dams and navigational dredging, are all examples of manufactured capital that have reduced the historic natural capital which has sustained tribal communities for thousands of years.

3.1 ECOSYSTEM SERVICES FRAMEWORK

The concept of ecosystem services has shifted our paradigm regarding the value of nature to human societies. Linking biophysical aspects of ecosystems with human benefits through the lens of ecosystem services is essential to assess the trade-offs (ecological, socio-cultural, economic and monetary) involved in the degradation or loss of ecosystem services in a clear and consistent manner.

Ecosystem services are essential to human survival – breathable air, drinkable water, available food, and stable atmospheric conditions are prime examples of ecosystem services. These benefits are similar to other economic benefits typically valued in the economy, such as: skilled workers, buildings, and infrastructure. When ecosystem services are lost, economic impacts can

[6] The Columbia Basin tribes view ecosystem-based function of the Columbia Basin watershed as its ability to provide, protect and nurture cultural resources, traditions, values and landscapes throughout its length and breadth. Clean and abundant water that is sufficient to sustain healthy populations of fish, wildlife, and plants is vital to holistic ecosystem-based function and life itself. According to this definition, ecosystem-based function can include specific management targets, including higher and more stable headwater reservoir levels, higher river flows during dry years, as well as a number of expected results, including increases in juvenile and adult salmon survival (CRITFC, 2017)

be measured in terms of job loss, infrastructure costs, restoration costs, or property loss in the event of storm damage.

Over the past several decades, considerable progress has been made in systematically linking functioning ecosystems with human well-being. The work of De Groot et al. (2002), the Millennium Ecosystem Assessment (MEA; Reid et al. 2005) and The Economics of Ecosystems and Biodiversity (TEEB; TEEB 2010, TEEB 2011) marked key advancements in quantifying ecosystem services; in addition, these studies laid the groundwork for a conceptual framework for valuing natural capital and ecosystem goods and services.

Resource Dimensions approach to ecosystem service valuation is adapted from the MEA's ecosystem service descriptions, with guidance from CICES and FEGS. This modified framework both addresses and values the broad range of essential services and benefits provided by natural capital.

3.1.1 Ecosystem Services Definitions

Ecosystem services are categorized into four main types: provisioning, regulating, societal/cultural, and supporting. Provisioning resources provide directly consumable outputs. Regulating services balance and control ecosystems to create favorable and livable conditions. Societal/cultural services are those with historic, cultural, or spiritual value. Supporting services provide the foundation upon which all other services depend.

The following list defines those services in each category that are proposed for valuation, as defined by the MEA[7], TEEB[8], CICES[9] which has a read-across to MEA and TEEB. For the purposes of this study, in certain cases, we combine or break apart services based on definitions in the economic literature.

Provisioning Service - any type of benefit to people that can be extracted from nature.

- *Food and fiber* — Ecosystems provide the conditions for growing food for human consumption. Food comes from plants, animals, and microbes in agro-ecosystems, marine and freshwater systems, and forests. Wild foods from forests are often underestimated. Produced fiber includes wood, jute, hemp, and silk.
- *Raw materials* — Ecosystems provide a great diversity of materials for construction and fuel including wood, biofuels and plant oils that are directly derived from wild and cultivated plant species.
- *Water Supply* — Ecosystems play a vital role in the global hydrological cycle, as they regulate the flow and purification of water. Vegetation and forests influence the quantity of water available locally.

---

[7] https://www.millenniumassessment.org/en/Global.html

[8] http://www.teebweb.org/resources/ecosystem-services/

[9] http://cices.eu/cices-structure/

Regulating Service – benefits provided by ecosystem processes that moderate natural phenomena.

- *Biological Control* (Disease Control) — Ecosystems are important for regulating pests and vector-borne diseases that attack plants, animals and people. Ecosystems regulate pests and diseases through the activities of predators and parasites. Birds, bats, flies, wasps, frogs and fungi all act as natural controls.
- *Natural Hazards Mitigation* — Extreme weather events or natural hazards include floods, storms, tsunamis, avalanches and landslides. Ecosystems and living organisms create buffers against natural disasters, thereby preventing possible damage. For example, wetlands can soak up flood water whilst trees can stabilize slopes. Coral reefs and mangroves help protect coastlines from storm damage.
- *Gas & Climate Regulation* — Ecosystems influence climate both locally and globally. For example, at a local scale, changes in land cover can affect both temperature and precipitation. At the global scale, ecosystems play a vital role in climate by either sequestering or emitting greenhouse gases.
- *Pollination* — Insects and wind pollinate plants and trees which is essential for the development of fruits, vegetables and seeds. Animal pollination is an ecosystem service mainly provided by insects but also by some birds and bats. Some 87 out of the 115 leading global food crops depend upon animal pollination including important cash crops such as cocoa and coffee.
- *Nutrient Regulation* — Maintenance of bio-geochemical conditions of soils by decomposition/mineralization of dead organic material, nitrification, denitrification etc.), N-fixing and other bio-geochemical processes.
- *Soil Retention/Erosion Control* — Soil erosion is a key factor in the process of land degradation and desertification. Vegetation cover provides a vital regulating service by preventing soil erosion.
- *Soil Formation* — The creation of soil through weathering and decomposition and fixing processes; includes biological, chemical and physical weathering and pedogenesis. [Sometimes *combined* with nutrient regulation, sometimes considered a supporting service.]
- *Waste Treatment* — Ecosystems such as wetlands filter both human and animal waste and act as a natural buffer to the surrounding environment. Through the biological activity of microorganisms in the soil, most waste *is* broken down. Thereby pathogens (disease causing microbes) are eliminated, and the level of nutrients and pollution is reduced.
- *Water Quality* — Ecosystems can be a source of impurities in fresh water but also can help to filter out and decompose organic *wastes* introduced into inland waters and coastal and marine ecosystems.
- *Water Regulation* — Refers *to* the distribution of water maintaining natural hydrologic flows throughout the biosphere.

It is worth noting that the differences between water quality, supply and regulation are a somewhat cloudy area and have been treated slightly differently across studies, depending on the system used for classifying water related services for valuation.[10]

Societal/Cultural Service – Non-material benefit that contributes to the development and cultural advancement of people including:

- *Aesthetic/Amenity* — Language, knowledge and the natural environment have been intimately related throughout *human* history. Biodiversity, ecosystems and natural landscapes have been the source of inspiration for much of our art, culture and increasingly for science.
- *Recreation and Tourism* — People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area.

Supporting Services – The underpinning and vital to the production of all other services. For example, habitat is necessary for food provision and production of oxygen is necessary for climate regulation. The impact on people are often either indirect or provided over a long time and are therefore sometimes called intermediate services. Treatment of these services and consideration of double-counting is study-specific in economic literature.

- *Habitat & Nursery* — Habitats provide everything that an individual plant or animal needs to survive – food, water, and shelter. Each *ecosystem* provides different habitats that can be essential for a species' lifecycle. Migratory species including birds, fish, mammals and insects all depend upon different ecosystems during their movements.
- *Nutrient Cycling* – Nutrient cycles, within ecosystems, consist of the movement and exchange of organic and inorganic matter back *into* the production of living matter. The process is regulated by food web pathways that decompose matter.

These four categories include 21 specific ecosystem services as shown in Table 34, by category.

---

[10] De Groot et al. (2002) include water regulation and water supply as part of regulating functions. Under this system, water supply refers to the filtering, retention and storage of water in streams, lakes and aquifers by the vegetation cover and focuses primarily on the storage capacity of forests rather than the flow of water through the system. The MEA is the most widely used ecosystem services classification framework. Under the MEA, water supply is classed as a provisioning service as it relates to the consumptive use of water by households, agriculture and industry. Whereas, water regulation deals with the influence of natural systems on the regulation of hydrological flows. Ecosystem services derived from the water regulation function, therefore include maintenance of natural irrigation and drainage, buffering of extremes in discharge from rivers (thus flood protection), regulation of channel flow, provision of a medium for transportation, groundwater recharge, water purification and erosion control. De Groot et al.'s (2002) definition of water regulation function is somewhat divergent from the later MEA classification system.

Table 34. Types of Ecosystem Services

GOOD/SERVICE	HUMAN ECONOMIC BENEFIT
PROVISIONING SERVICES are ecosystem services that describe the material or energy outputs from ecosystems.	
Food	Crops, fish, game, fruits and vegetables for human consumption. Includes, wild foods.
Raw Materials	Fuel, including wood, biofuels and plant oils derived from plants; fiber resources for jewelry, arts, etc.; fertilizer, minerals, materials for construction, and energy.
Medicinal Resources	Plants used in traditional medicines, raw materials for the pharmaceutical industry, and nutritional assay organisms.
Water Storage and Supply	Retention and capacity to provide fresh water for diverse uses (e.g., drinking, agricultural production, etc.).
REGULATING SERVICES are services that ecosystems provide by acting as regulators.	
Air Quality	Trees and other plants aid in regulating air quality by removing pollutants from the atmosphere; providing clean, breathable air.
Biological Control	Ecosystems control pests and vector borne diseases that attack plants, animals and people through natural control activities of predators and parasites (e.g., birds, bats, flies, frogs, fungi)
Gas and Climate Regulation	Ecosystems help stabilize climate at the global and regional level by storing and sequestering greenhouse gases.
Natural Hazards Mitigation	Trees, grasses, coral reefs, wetlands, etc. protect against and help prevent natural hazards (e.g., floods, storms, erosion, fires, droughts, landslides, etc.).
Pollination & Seed Dispersal	Insects, animals and wind pollinate plants and trees which is essential for the development of fruits, vegetables, seeds and important cash crops.
Soil Quality and Formation	Ecosystems provide essential foundations for soil creation and maintaining soil fertility and quality for plant growth and agriculture.
Soil Retention	Vegetative cover provides a vital regulating service by preventing soil erosion, thus ensuring slope stability and the retention of arable land.
Water Treatment and Quality	Ecosystems such as wetlands filter human and animal waste, thereby improving water quality by removing disease causing pathogens, and reducing the level of nutrients and pollution.
Water Regulation	Provides for groundwater recharge, river flows, drinking water, agricultural and industrial use.
SOCIETAL/CULTURAL are non-material benefit that contributes to the development and cultural advancement of people.	
Aesthetic Information	Appreciation and enjoyment of nature (e.g., landscapes, scenery, sounds); inspiration for art and design.
Cultural Value	Knowledge, language and nature have been intimately related throughout human history (e.g., cultural symbols, folklore, books, architecture, religious and spiritual purposes).
Recreation and Health	Nature provides an array of opportunities for sports and recreational activities (e.g., biking, hiking, walking, canoeing/kayaking, swimming, camping, hunting, rock climbing, etc.) that help maintain physical and mental health.
Science and Education	Nature and natural systems for education and scientific research.
Spiritual and Sense of Place	Features as forests and mountains have sacred or religious importance to many people and cultures world-wide. Nature is core to all major religions and traditional knowledge, and related customs are key to creating a sense of belonging.
Tourism	Ecosystems are important to many kinds of tourism that in turn provide important economic benefits and are a vital source of income for many communities, states, regions, and countries.
SUPPORTING SERVICES are vital to the production of all other services.	
Habitat and Nursery	Essential requirements for plant and animal survival (food, water, shelter). Each ecosystem provides different habitats vital to varying species' lifecycle and migrations.
Genetic Diversity	Maintaining the variety of genes between and within species populations is important to protecting the health of a population, providing ability to resist diseases, pests and other stresses, and flexibility to adapt.

Source: Resource Dimensions, 2020.

Box 1: Investment in Natural Capital: A Watershed Success Story

The watershed of the Catskills mountains provides New York City's primary source for drinking water. Water is purified as it percolates through the watershed's soil and vegetation. In the late 1990's this water failed EPA standards for drinking water, due both to the degradation of habitat resulting from development in the Catskills, and to increased sewage, fertilizers, and pesticides. The city faced two starkly different choices on how to provide enormous quantities of clean water demanded. It could invest in physical capital and build a water purification plant with a capital cost of more than $6.3 billion plus operating expenses. Or, it could invest in natural capital at a much lower cost, by repairing the integrity of the Catskills watershed through land acquisition and restoration efforts. Choosing the latter, the city presented an "environmental bond issue" to raise just over $1 million. The cost of restoring the ecosystem service of water purification provided a payback period of five to seven years and increased flood protection at no extra charge.

The lesson: investments in natural capital can be more financially profitable than those in physical capital. In addition, investments in natural capital can provide returns in perpetuity.

3.2 Ecosystem Services Valuation

Ecosystem services valuation (ESV) is the process of valuing the effects of changes in ecosystem services against other things supporting human welfare. Understanding and accounting for the value of natural capital assets and the services they provide can reveal the economic benefits of investing in natural capital. Only recently, have natural systems begun to be seen as economic assets that provide society with valuable goods and services.

Studies conducted to date on the value of ecological services produced by nature, for example the state's fish and wildlife habitat, indicate that such habitat is producing services worth many billions of dollars annually. Yet, as with this study, these analyses tend to examine a finite service set, limited to those services upon which a comprehensive valuation has been performed; a comprehensive valuation is done when a detailed analysis is conducted to exhaustively retrieve and uncover the economic value of all assets in a specific region. While the estimated millions in annual economic value generated by the Chehalis Basin study area, seen in Table 36, may seem exorbitant, given the limitations of the study and the fact that many values produced by ecological services are difficult to express in dollar figures, the true value of services is almost certainly underestimated here. Further, services not yet identified, and their value to future generations, is not included in our analysis.

The first step in valuing ecosystem services lies in defining the ecosystem's contribution to human well-being. An ecosystem may be characterized by its physical features (site-specific characteristics such as landscape context, vegetation type, salinity), its goods (vegetation, fish), its services (nutrient cycling, water retention) or its amenities (recreation, bird-watching). These four aspects may not always be complementary. For example, one could manage a wetland for agricultural production at the expense of primary productivity and services. Further, the location of the system is a critical factor of its net utility because location determines the distribution of goods and services. In addition, while an ecosystem's carbon sequestration and biodiversity will be valuable even if far from human populations, its role in pollination and flood control decreases the further from human populations it is. Thus, two identical ecosystems may have very different values depending on their landscape context.

When well-managed, natural systems produce substantial economic value that will provide value in perpetuity to future generations. When natural systems are destroyed, the services they performed are lost and communities pay (City of Portland: Lents Case Study 2004; Appendix C). For example, with the loss of natural storm protection, salmon productivity or water quality and supply services due to habitat degradation or increased urbanization, residents are taxed to pay for levees, storm water systems, hatcheries and filtration plants that must be built. Communities incur real costs to replace services that were previously provided free and, unfortunately, on top of being costly, often replacement services are less capable than the ecosystem services they are replacing. The choice made by New York City in the late 90's provides an excellent example for the way that investments in natural capital can be both more cost effective and return value in perpetuity, Box 1.

To understand the real economic costs of damaged natural systems in policy and decision-making, governments are increasingly considering ecosystems as economic assets. Given that we are unable to provide estimates for the values of all ecosystem services in a region mean that ecosystem service values serve as markers for the minimum value of the true social value of the services provided – thus enabling us to replace the default value of $0.00 historically used in policy and decision-making frameworks (e.g., cost-benefit analysis, programmatic master planning).

3.2.1 On valuing ecosystem services

An ecosystem service is a "service flux," that is, its efficiency is measured as output per unit of time. Intact, healthy ecosystems are self-organizing; they provide valuable services in perpetuity at no cost to humans. The delivery of ecosystem services depends on maintaining a particular structure or arrangement of ecosystem constituents. Yields of ecological service fluxes, such as pollination and water filtration, are distinct from "resource flows," like timber extraction. For example, while a single-species timber plantation might yield resource-flows (wood) for extraction, the timber plantation would not provide the same service-fluxes as an intact natural forest ecosystem. Specifically, service fluxes such as mitigation of floods, decomposition of wastes, renewal of soil, pollination, pest control, translocation of nutrients, and provision of habitat are not yielded by a timber plantation to the same degree as by a natural forest ecosystem. When it comes to generation of ecological services, the elements of the ecosystem, and their relationship to each other, matter.

To describe ongoing fluxes of ecosystem services, scientists and economists often describe the service-flux in terms of the dollar value it generates per unit of area over a given time period. It is also important to note that value is not fixed in time. The values of many ecological services are increasing as they become increasingly scarce (Boumans et al. 2002). In addition, when these valuable goods and services are impaired or lost, people are more susceptible to disasters such as flooding, and the resulting costly expenditures to replace lost services, like water quality. Once services that nature provided for free are damaged, they must be replaced – the costs of which typically land squarely on taxpayers. In some instances, no matter the investment, lost ecosystem goods and services are irreplaceable.

Many ecosystem goods, such as timber, food and water, are currently valued, bought and sold in markets. Though, some ecosystem services, like climate regulation and recreation, are not amenable to markets and have not traditionally been valued. While just two examples of ecosystem services, climate regulation and recreation, that provide immense value, they are essentially unvalued within conventional accounting. To demonstrate, if a river or a body of water such as a harbor, becomes contaminated due to an accidental spill of oil or toxic substances, thereby eliminating, even if for only a period of months or years, commercial and sport fishing or the public's ability to otherwise use the river for recreational purposes, the loss can present local economies with substantial economic damages, through the loss of jobs, reduced expenditures on fishing vessels, gear and related equipment, recreation-based, hotels, restaurants, and more (Gustanski and Scarsella 2015; Gustanski et al. 2015; Gustanski et al. 2018).

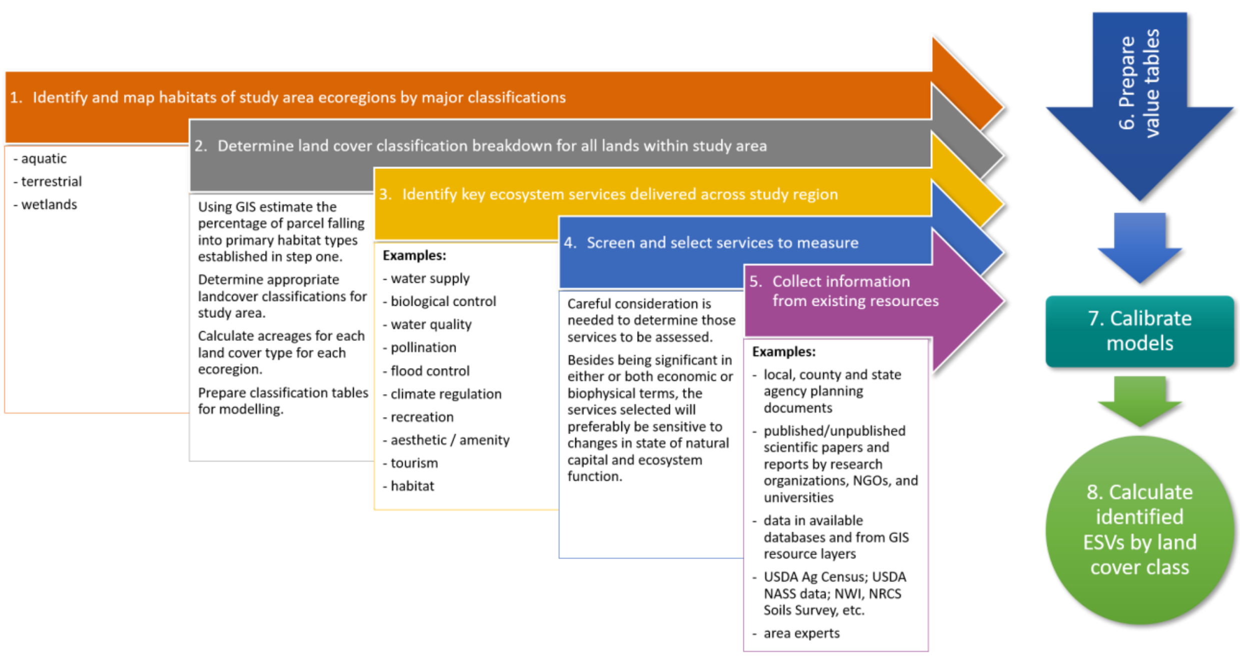
However, when investments are made to safeguard and support ecosystem services, local economies are more resilient and less susceptible to the urgent need for extensive expenditures on disaster mitigation. Resilience is the ability of individuals, communities and governments to deal with shocks and stresses, such as those associated with natural disasters like flooding or contamination of a harbor. In addition to the monetary value associated with avoided costs, natural capital such as a healthy watershed deliver a host of other services, including water supply, regulation and filtration, biodiversity, and more. All ecosystem services provide accumulative economic value.

Neoclassical economics contend that if those in charge of managing the provision of ecosystem services also directly benefit from those services, the market should be able to protect and sustain these services (e.g., provisioning services, such as food, timber, and water). When benefits largely accrue to others in society though (e.g., downstream flood protection), markets often fail to reward the managers (Engel et al. 2008). Additionally, some land uses and management activities provide benefits at a particular location and time, at the expense of society more broadly. In response to this dilemma, the concept of Payment for Ecosystem Services (PES) is gaining attention as a way to pay for the benefits broadly received by society through sustainable management of land and water resources (Nellemann and Corcoran 2010; Balmford et al. 2008). PES offers monetary incentives to individuals or communities to voluntarily adopt behaviors that are not legally obliged, and which improve the provision of well-defined and quantifiable ecosystem services that would otherwise have been economically unviable to provide (Sommerville et al., 2009; Muradian et al. 2013). Wunder (2015) defines five components of PES: 1) voluntary transactions; (2) between service users; (3) and service providers; (4) that are conditional on agreed rules of natural resource management; (5) for generating offsite ecosystem services.

Today, there are recognized economic methods to value natural capital and various non-market ecosystem services, Figure 8. When valued in dollars, these services can be incorporated into a number of economic tools, including cost-benefit analysis, environmental impact statements, asset management plans, conservation prioritization, and return on investment computations. Inclusion of these values can help to strengthen decision-making by providing a clearer picture of the costs associated. When natural capital assets and ecosystem services are not considered in economic analysis, they are effectively valued at zero – thus leading to inefficient capital investments, higher incurred costs, poor asset management, and losses related to cultures, such as tribes that rely on these assets.

In summary, natural capital provides what we need to survive. Without healthy natural capital, many of the services that we freely receive could not exist. Once lost, these services must be replaced with costly, less durable and often less efficient manufactured capital solutions. When we lose natural capital, we also lose the economic and cultural goods and services it provides.

Figure 8. Steps in ecosystem services values assessment



Source: Resource Dimensions, 2020.

3.3 NATURAL CAPITAL

The concept of capital has several different meanings. For this study, it is useful to differentiate between five kinds of capital: financial, natural, produced or manufactured, human, and social. All are stocks that have the capacity to produce flows of economically desirable outputs – goods and services that impact the quality of our lives. The maintenance of all five kinds of capital is necessary to ensure economic and environmental sustainability (Solow 1986). The originator of modern growth theory in economics, Robert Solow, defined economic sustainability as "non-declining per-capita human well-being (utility) over time" (Solow 1986). Importantly, this definition emphasizes wellbeing, not income.

Natural capital is a key input into human well-being. Environmental stocks, and the ecosystem services that they enable and provide, provide both direct benefits (and potentially costs) to consumers and producers and intermediate services that contribute to other forms of natural capital, which in turn may provide other direct and indirect benefits. Direct benefits have been termed "final ecosystem goods and services" or "ecological endpoints" in the literature and are defined as entering directly into the net benefit function of firms and consumers (Ringold, et al. 2013; Boyd and Krupnick 2013). Those goods and services that act as inputs into additional goods are derivatives valued through their relation with the underlying final goods or endpoints. Of course, many forms of natural capital may serve multiple roles. For example, the land and trees that form a national park may provide recreational benefits (an endpoint) and provide habitat for wildlife populations (with habitat as an input that supports valuable populations).

Natural Capital interlaces life, culture and economics and sets the footing for all societies to flourish. Ecosystem services and natural capital have been the foundation for industrial growth—thus, human civilization—yet in many cases continue to be unrecognized and undervalued. The depletion of natural resources is already causing disturbances with dire consequences. The world is grasping the enormity of the situation and groundbreaking developments in the form of the 2030 Agenda for Sustainable Development and the Paris Agreement underscore the importance of conserving limited natural resources for future generations. Other major international initiatives, including the Millennium Development Goals, the Convention on Biological Diversity (CBD), and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, now explicitly link conservation of biological diversity and natural ecosystems with the maintenance of ecosystem services to support sustainable local economic development and reduce poverty (TEEB 2010). With economy boosting sectors like agriculture, fisheries, healthcare, energy, and tourism, both dependent on nature and having the capacity to affect nature positively or negatively, it is vital that we recognize the direct correlation between natural capital conservation and economic growth.

The need to actively restore at least part of the world's natural capital (Reid et al. 2005) or ecological infrastructure to maintain biological diversity and the flow of essential services is becoming increasingly clear (TEEB, 2010, 2011). Information on the socioeconomic importance of ecosystem services helps to increase awareness of the need for investments in restoration efforts and has resulted in significant international commitments to large-scale restoration. However, there is almost no information available on the cost-effectiveness of ecological restoration (Benayas et al. 2009; De Groot et al. 2010; Alexander et al. 2011).

3.4 NATURAL CAPITAL VALUATION APPROACH

3.4.1 Methodology

To develop a current conditions natural capital baseline estimate for the Chehalis Basin we use the three methods ***land cover analysis, benefit transfer analysis*** an***d asset valuation***. The extent of natural capital within the study area was first determined. Using Geographic Information System (GIS) software, the spatial extent of land and water cover types within the Basin were identified. We did not use a historical baseline for natural capital, but instead a representation of what is present in the Basin today to best establish the natural capital baseline. Then, the benefit transfer method was used to develop dollar-per-acre values for ecosystem services. Benefit transfer involves applying a monetary benefit value on a per unit estimate (e.g., per visitor day, per household, per acre) from an existing study site to an unstudied area for which a per unit benefit value is needed. Last, the landcover types and ecosystem service values were combined to estimate the total value of economic benefits provided by the Chehalis Basin. These results were then used to calculate an asset value for the Basin. Details on each methodology are addressed in the following sections.

3.4.2 Land Cover Analysis

We used the same land cover layer, derived for the ecosystem service valuation, as described in section 2.3. Land cover was derived from a version of the C-CAP land cover product modified in consultation with experts from the Washington Department of Ecology and the Chehalis and Quinault tribes.[11] Identifying the spatial attributes of landcover data allows the application of more granular study values and increases accuracy as each attribute provides information that narrows the scope of values and

---

[11] In developing the proposed land cover classification groupings for this study, Resource Dimensions conducted a thorough review of existing primary valuation research and assessed the most recent ecosystem service value coefficients based on ESV units and land cover change estimates from data collected over the past 20 years. Given the importance of accurately defining land cover types for use in the valuation process, a rigorous delineation and verification process was implemented using Landsat, Modis, NAIP and other Earth Engine aerial imagery to ground truth data. The goal for valuation of ecosystem services is to be as certain as possible about land cover and any classification groupings. Related to other work in the Chehalis Basin, another land cover classification system using the same land cover data developed through NOAA's Coastal Change Analysis Program (C-CAP), developed by Tim Beechie at NWFSC, placed original C-CAP land cover classes into six main classes for stratifying small streams in the Chehalis Basin. Resource Dimensions' groupings place original C-CAP land cover classes into twelve main cover classes for valuation of Chehalis Basin ecosystem services. A comparative analysis of the two land classification systems was conducted by Resource Dimensions and reviewed by members of the working group which included WSDE, Office of the Chehalis Basin, QIN, as well as consultants. It was determined that the "finer" groupings of Resource Dimensions classification system provided a better fit for ecosystem service valuation.

mitigates uncertainty. Valuations tend to be more accurate when the spatial distribution of values is considered (Rosenberger and Johnston 2013). The twelve classes that land cover was broken down into allows us to account for spatial variability and granularity of ecosystem function across the Chehalis Basin, Table 35.

Table 35. Landcover Classifications Used for Natural Capital Valuation

Land Cover Class (assigned for valuation)	Acres
Forest	887,280
Scrub/Shrub	353,956
Grassland	136,598
Wetland	89,636
Pasture	79,036
Estuary	59,989
Cropland	14,967
Urban Greenspace	13,335
Lakes & Rivers	12,349
Beach	181
	1,647,328

Source: Resource Dimensions, 2020.

3.4.3 Benefit Transfer Approach

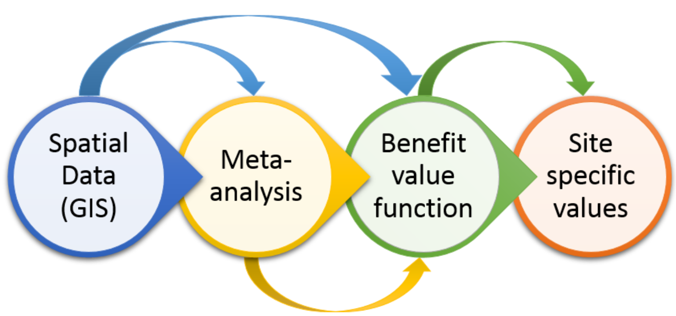
Over the past four decades, several economic methods have been developed to estimate the value of environmental goods and services not traded directly in markets. These approaches to non-market valuation have developed principally within two branches of traditional economics – environmental and natural resource economics. Generally, the methods can be broken into three primary categories – direct market valuation approaches (e.g., market price, avoided and replacement cost, production function), the use of individuals' actual behavior related to environmental services (revealed preference) and information collected in consumer surveys on hypothetical behavior related to environmental services (stated preference). Revealed preference methods include those as travel cost and hedonic pricing. Popular stated preference approaches include contingent valuation, choice modeling or choice experiments, and group valuation.

These valuation methods have been used to estimate values for virtually all ecosystem services for most forms of terrestrial, wetland, and aquatic habitats (Gustanski and Scarsalla 2015; Gustanski et al. 2015). Benefit transfer involves applying a monetary benefit value per unit estimate (e.g., per visitor day, per household, per acre) from an existing study site to an unstudied area for which a per unit benefit value is needed. Economists define benefits for economic efficiency or benefit-cost analyses as the user's willingness to pay in excess of current costs or consumer surplus. This is the benefit measure used by federal agencies for benefit-cost analysis and natural resource damage assessment (USDOI 1994; USEPA 2000; USOMB 2000).

This study uses a meta-analyses function benefit transfer method (BTM) – values are transferred using a value function derived from the results of existing studies. Meta-analyses function transfer provides a comparatively accurate approach to estimating benefit transfer by enabling controls for significant differences in context and site variables. This method produces lower transfer errors than unit value and value function transfer. In addition, this approach is well-suited to valuing diverse policy sites because the value function can be applied to a database containing site-specific information on habitat and relevant socioeconomic characteristics.

Primary elements of a meta-analysis benefit function transfer are shown in Figure 9. The meta-analysis itself consists of a review of the available literature on the value of the ecosystem service of interest. Meta-analysis data is then used to estimate a value function that relates the service value to the characteristics of the ecosystem service. Characteristics might include the type and size of the land covers present, ecosystem functions, proximity to similar ecosystems, and the number of people that benefit (population). In this study, we use GIS to obtain information on some of these characteristics and to develop the acreages for relevant land covers. Lastly, the characteristics of the policy site are plugged into the value function to estimate the value of the ecosystem services produced by the particular region of the Basin.

Figure 9. Components of meta-analyses benefit function transfer



Source: Resource Dimensions, 2020.

Roughly, the BTM is defined as "...the use of existing data or information in settings other than for what it was originally collected." (Rosenberger and Loomis 2003). This method is a proven and well-recognized approach, in the field of resource economics, for indirectly estimating the value of ecological goods or services. BTM can generate reasonable ecosystem services estimates quickly and at a fraction of the cost of conducting localized primary studies.

The first step in the process is to identify primary studies with comparable climate and land cover classifications (wetland, shrubland, forest, etc.) as those of the region under study. Resource Dimensions maintains a systematic repository of more than 2,000 published, peer-reviewed primary valuation studies. Studies were assessed for use based on their similarity to the Chehalis Basin. Primary studies determined to have incompatible assumptions, ecosystem services, or land classification covers were excluded. Primary study values identified were then adjusted and standardized for units of measure, inflation, and land cover classification to ensure validity of use. Primary studies often offer a range of values reflecting uncertainty or variability within the research area. Thus, within this report high and low dollar per acre values in 2019 USD are included for each value provided. See Appendix B for the list of studies used for value transfer estimates.

3.4.4 Asset Valuation

The present value or fair market value of tangible manufactured capital assets like buildings and equipment can be calculated as the net present value (NPV) of its future expected benefits. If we think of ecosystem services as a stream of annual income, then the ecosystems that provide those services can be thought of as part of the Chehalis Basin's total natural capital. The NPV is used to assess benefits produced at different points in time. **Providing the Basin's natural capital is not diminished, the annual stream of ecosystem services will continue indefinitely.** Thus, similar to manufactured capital, we must convert the stream of benefits from the future flow of the Basin's ecosystem services into net present value. This conversion requires some form of discounting.

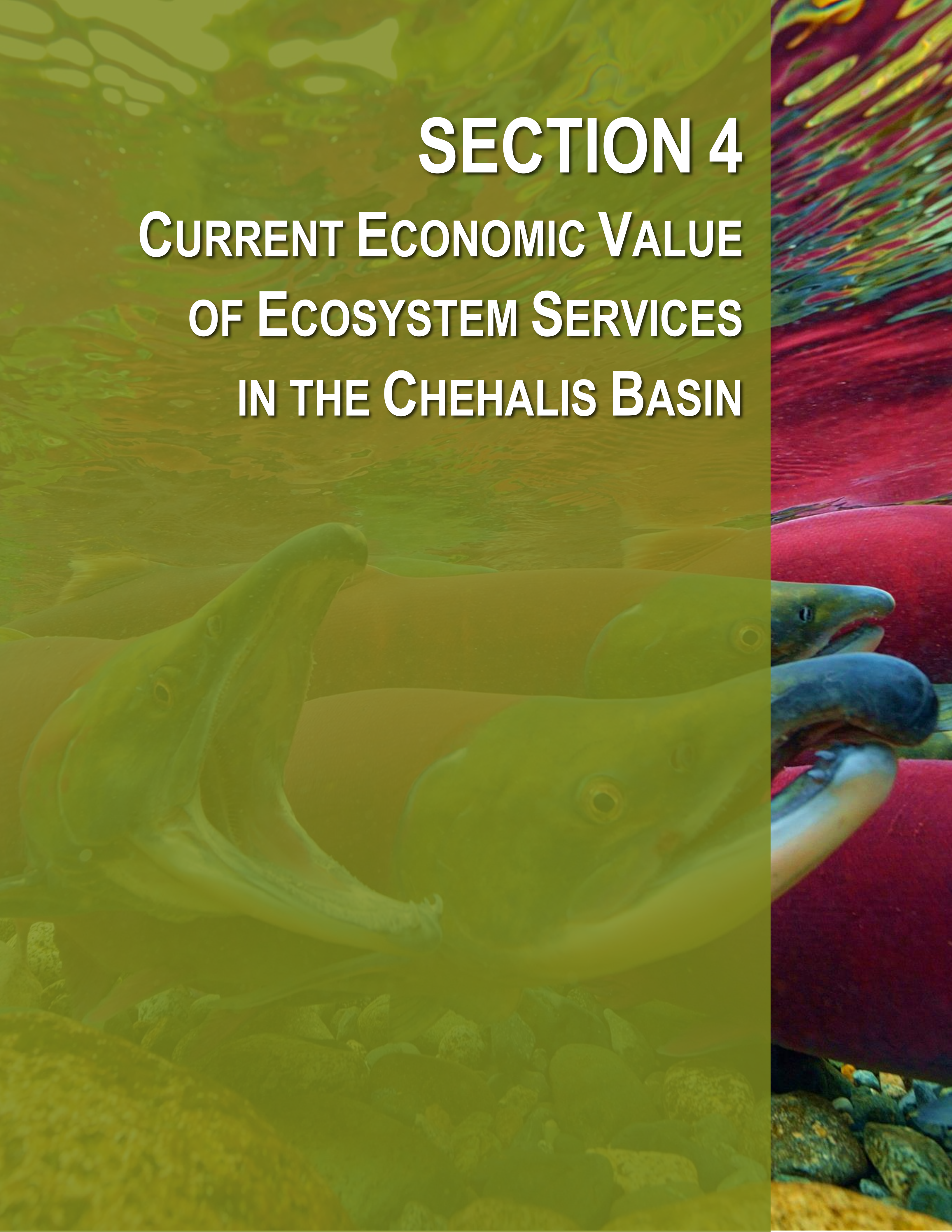
Discounting reflects that people prefer consumption today to future consumption, and that invested capital is productive and provides greater consumption in the future. Discounting adjusts costs and benefits to a common point in time and allows us to compare the sum of money occurring in different time periods by expressing the values in present terms. In other words, discounting shows how much future sums of money are worth today. Discounting is intended to address two major factors – time preference and opportunity cost of investment (Frederick et al. 2002). The computed asset value provides a gauge of the projected benefits flowing from the Basin's natural capital over time. Properly applied, discounting can tell us how much future benefits and costs are worth today.

Although discounting is an important component of asset valuation, experts fail to agree on what discount rate to use for natural capital benefits – the rate at which society as a whole is willing to trade off present for future benefits. Agencies, public and private, differ widely in their guidelines for discount rates. The choice of discount rate is important, however, as it defines the outcome of the present values of benefits that take place over extended periods of time. Since the early 1990's, the federal Office of Management and Budget (OMB) has recommended a 7% discount rate for the analysis of average investments. In establishing the discount rate at 7%, the OMB notes that "this rate approximates the marginal pretax rate of return on an average investment in the private sector" (OMB 1992). The OMB recommended rate assumes that public investments displace both private investments and consumption. Then again, the Congressional Budget Office (CBO) estimates the cost of government borrowing to be 2%, a value used as the social discount rate in their analyses, while the National Oceanic and Atmospheric Administration (NOAA) has adopted a 3% percent discount rate. To analyze the current asset value of the Chehalis Basin, we use two discount rates – 7% and 2%. Lower discount rates better explain the value of long-term assets, as benefits hundreds of years into the future are discounted at a smaller rate.

Present values can be calculated over different timeframes depending on the objective of the analysis or nature of the project. In the case of natural capital valuations, ecosystems, if they remain healthy, demonstrate long-term stability and outputs. This analysis for the Chehalis Basin uses a 100-year timeframe to reflect this fact; which is longer than typical capital projects are valued for. And, even if kept at current health, the Basin's natural assets will provide benefits far beyond 100 years.

SECTION 4

CURRENT ECONOMIC VALUE OF ECOSYSTEM SERVICES IN THE CHEHALIS BASIN



SECTION 4: CURRENT ECONOMIC VALUE OF ECOSYSTEM SERVICES

4.1 ECOSYSTEM SERVICES AND VALUE IN THE CHEHALIS BASIN

The diverse mix of natural systems provide the Basin's residents and visitors a range of goods and services at different spatial and temporal scales. For example, gas and climate regulation are global, while flood protection, water supply, and pollination are local or regional. They also vary with in terms of how directly connected they are with human welfare; services like habitat and nursery are highly indirect, while food, water supply, and recreational opportunities are far more direct.

As discussed in Section 3, ecosystem services are categorized into four main types: provisioning, regulating, societal/cultural, and supporting. Provisioning resources provide sustenance, raw materials such as fuel or timber, and fresh water. Regulating services balance and control ecosystems with outcomes such as improving air and water quality, moderating extreme events, and forming soil. Societal/cultural services are those with social, historic, cultural, or spiritual value. Supporting services keep ecosystems vibrant and sustaining and include habitat and biodiversity.

The following section describes ecosystem services present in the Basin *that are analyzed in this study* (Table 36). Data availability and correlation of existing data to the Chehalis Basin precludes analyzing all ecosystem services on all land classifications.

Table 36. Ecosystem services and land covers assessed (indicated ●)

ECOSYSTEM SERVICES	BEACH	ESTUARY	RIVERS & LAKES	WETLANDS	CROPLAND	FORESTS	GRASSLANDS	PASTURE	SCRUB / SHRUB	GREEN SPACE
Provisioning										
Food	●	●		●	●	●	●	●		
Water Storage/Supply		●	●	●		●	●	●	●	
Regulating										
Biological Control		●			●	●	●	●		
Erosion Control				●	●		●	●	●	
Gas & Climate Regulation				●	●	●	●	●	●	●
Natural Hazards Mitigation	●	●		●		●				
Pollination & Seed Dispersal					●	●	●	●	●	
Soil Formation	●	●	●		●	●	●	●	●	
Waste Treatment			●	●			●	●		
Water Treatment& Quality		●	●	●		●	●	●		
Water Regulation						●	●	●		●
Societal/Cultural										
Aesthetic / Amenity	●	●	●	●	●	●	●	●	●	●
Recreation / Tourism	●	●	●	●		●	●		●	●
Supporting										
Habitat & Nursery		●	●	●	●	●		●	●	
Biodiversity/Genetic Resources				●		●	●	●	●	

Source: Resource Dimensions, 2020.

4.1.1 Provisioning

Provisioning services analyzed in this study include food and fresh water supply. The predominant **Food** ecosystem service in the Chehalis Basin is produced by fisheries in aquatic habitats including beaches, estuaries, rivers, and marine areas. Steelhead, salmon, bass, and trout are example species. Wetland environments also support fisheries. Forests, estuaries, rivers, wetlands and grassland areas contribute to the **Water Supply**. Rivers flowing through Grays Harbor County drain almost 3,500 mi2, which is twice the size of Rhode Island (GHC 2001; Gendaszek 2011). Serving as natural water collection, storage, filtration, and delivery systems, the Chehalis Basin forest and wetland ecosystems play an even more significant role in providing fresh water for human consumption, industry and agriculture. They capture rain and snowfall, cleanse and feed downstream water supplies and recharge groundwater in subsurface aquifers and shallow subsurface flows, the latter of which helps keep water in streams in dry years (GHC 2001). Wetlands also protect the fresh water supply by mediating saltwater intrusion (Boyd 2010). Estuaries also recharge aquifers (Pendleton 2008). Subsurface aquifer recharge is critical because most of the region's water supply comes from precipitation rather than river inflow (GHCC 1992).

4.1.2 Regulating

Regulating studies analyzed for use in this study are air quality, biological control, carbon sequestration and storage, erosion control, gas and climate regulation, natural hazards mitigation, pollination, soil formation, waste treatment, water treatment and quality, and water regulation. **Air Quality** is improved by both forests and marine ecosystems. Forests improve air quality by taking in carbon dioxide, releasing clean oxygen, and trapping particulate matter (Krieger 2001). While air quality was initially assessed for inclusion for ecosystem service valuation, final model indications suggested strong collinearity with several other ecosystem services, thus air quality was not included in valuation. **Biological Control** is an ecosystem service of immense economic value provided by predators, parasitoids and pathogens (Zhang and Swinton 2012; Bengtsson 2015). These beneficial organisms are mobile and local delivery, for example, to field crops, typically depends on the composition and structure of the surrounding landscape (Kremen et al. 2007). **Carbon Sequestration and Storage** is an important function of grasslands and estuaries. Grasslands and estuaries sequester carbon in soils as organic matter (Daily 1997). For example, a conservative estimate of the carbon sequestration capability of the Snohomish Estuary in the Puget Sound is 2.55 million tons over the next 100 years (RAE 2014). Yet, given the complexities involved in accurately estimating the value of carbon sequestration and storage from available primary studies, in addition to collinearity issues with gas and climate regulation, this service was not included in valuation. By protecting soil from wind and water erosion, terrestrial ecosystems as cropland and grasslands, supply **Erosion Control** service, one of the fundamental ecosystem services that ensure human welfare (Pimental et al. 1995). Local costs of erosion include losses of production potential, diminished infiltration and water availability, and nutrient losses. Downstream costs may include disrupted or lower quality water supplies; siltation that impairs drainage and maintenance of navigable river channels, harbors, and irrigation systems; and increased frequency and severity of floods. Greenhouse **Gas and Climate Regulation** is the ecosystem service that regulates processes related to atmospheric chemical composition, the greenhouse effect, the ozone layer, precipitation, air quality, and moderation of temperature and weather patterns (including cloud formation), at both global and local scales (Costanza et al. 1997). In terms of GHG regulation at the global scale, this may include the ability of ecosystems both to emit and absorb chemicals (Forster et al. 2007). Ecosystems can also affect the microclimate locally, through the provision of shade and shelter and the regulation of humidity and temperature. At the local scale, Chehalis Basin forests, grasslands, croplands, shrub/scrublands, urban green space, and wetlands play an important role in moderating the region's microclimates (TEEB 2011b; Smith, et al. 2013). **Natural Hazards Mitigation**, such as flood and storm water control, is provided by beaches, estuaries, forests and wetlands. Forests absorb and slow rainfall; wetlands act like a sponge, reducing peak discharge by slowing and storing rainfall; and beaches and estuaries protect inland areas from storm surge (GHC 2001). Wetlands also reduce storm damage because their structure increases friction, which decreases wind speed, wave height, storm surge height, and slows storm-driven currents (CODH 2013). **Bee Pollination** is a terrestrial service of forests, grasslands, and agricultural lands (cropland and pasture). These land cover types provide plants to pollinate and habitat for bees (Costanza et al. 1997). Alone, Grays Harbor County has at least 133 plants important to pollinators (WNPS, 2015; The Xerces Society 2013a, 2013b). **Soil Formation** across the Basin occurs primarily on grasslands, pasture and croplands, in estuaries, and forests. Grasslands, pastures, forests and estuaries control erosion, capture sediments, and accumulate organic matter (Jenkins and Schaap 2018; Barbier et al. 2011; Daily 1997; Oades 1988). All land types provide some form of **Waste Treatment** services by degrading pollutants and cycling nutrients (MES 2015). To address collinearity issues and minimize possible accumulation errors, we examine lakes and rivers, grasslands and wetlands for valuation. **Water Regulation** refers to maintaining natural hydrologic flows throughout the biosphere (de Groot et al. 2002). All land types contribute to water regulation, but for the purposes of this study and to diminish possible double-counting errors we focus on river, forest and wetland services. Rivers and their riparian areas are an integral part of ensuring water flow for irrigation, industry, and residential water use. **Water Treatment and Quality** are those purification services by which water is cleaned through biological processes provided by forest, wetlands and natural grasslands which act as sponges to slow the movement of water from where it falls as precipitation to where it enters rivers, lakes, and estuaries and undergoes additional treatment processes (Zawadzka. et al. 2019; Keeler et al 2012).

4.1.3 Social / Cultural Services

Societal/Cultural services analyzed are aesthetic/amenity and recreation/tourism. All Chehalis Basin land covers types in the have intrinsic **Aesthetic and/or Amenity** value. Aesthetic or amenity value is a passive use benefit (visual enjoyment) that people derive from experiencing nature and feeling a sense of wellbeing. Covering WRIA 22 and 23, the Chehalis Basin boasts more than 3,300 miles of rivers and tributary streams, some 180 lakes, ponds and reservoirs, one of only two temperate rainforests in the U.S., substantial miles of beaches in Grays Harbor County (GHT 2015). **Recreation** and **Tourism** are important sectors of the region's economy, providing jobs and economic benefits to Chehalis Basin communities. Outdoor recreation is particularly important to the region. Locals and visitors from across the state use the diverse rivers, lakes, beaches, parks, wildlife sanctuaries, and other areas specifically to experience recreation opportunities such as sport fishing, hiking, kayaking, whitewater rafting, beach combing, clam digging, and bird watching, which are all attributable to the Basin's unique natural attributes. Annually, counties and communities of the region host a variety of festivals, runs, cycling and agritourism activities and events tied to ecosystem services, including those as the Sharon Grange Oyster Feed, Grays Harbor Shorebird Festival, McCleary Bear Festival, Centralia Summer Fest, Chehalis Mudder, Ocosta Crab Feed, and more (Discover Lewis County 2019; Visit Grays Harbor 2019; Discover Grays Harbor 2019; and other county references).

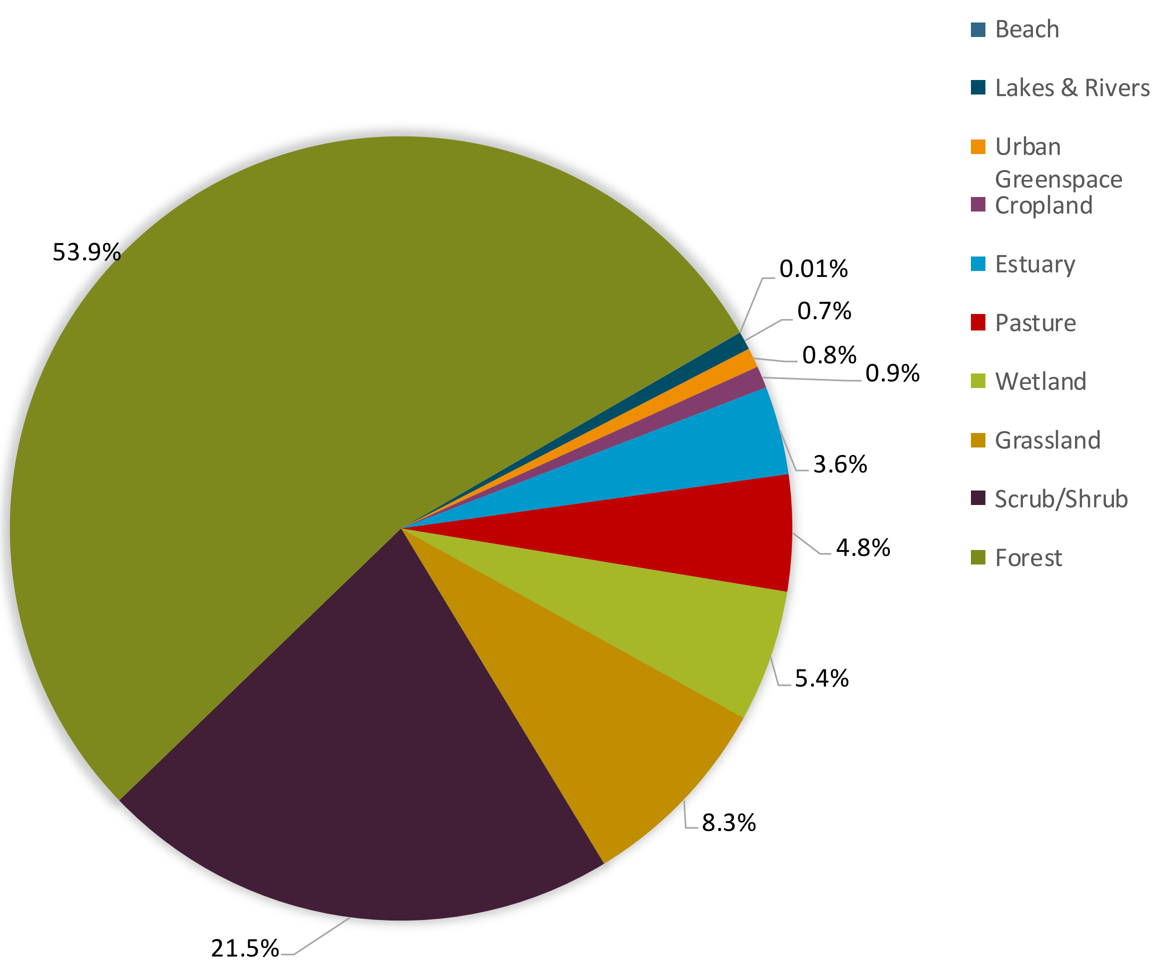
4.1.4 Supporting Services

Supporting services analyzed in this study include habitat and biodiversity resources. WDFW identifies 14 distinct priority **Habitat** types that support over 300 species of fish, shellfish, birds, mammals, amphibians, and reptiles, and at least 19 federally threatened and endangered species (WDFW 2008; WSDE 2013a). Of the 300 species mentioned above, over half are listed as WDFW priority species — those that "require protective measures for their survival due to their population status, sensitivity to habitat alteration, and/or recreational, commercial, or tribal importance. Priority species include State Endangered, Threatened, Sensitive, and Candidate species; animal aggregations considered vulnerable; and species of recreational, commercial, or tribal importance that are vulnerable." The habitats are comprised of 541 native vascular plants (WNPS 2015). We analyze six habitat types that provide essential habitat and are vital for conserving **Biodiversity**.

4.2 Chehalis Basin Ecosystem Service Valuation

The Chehalis Basin is comprised of three predominant land cover types: forest lands (53.9%), scrub/shrub lands (21.5%), and grasslands (8.3%). Figure 10. Wetlands (5.4%), pasture (4.8%), and estuary (3.6%) together cover about 13.8% of the Basin's area. Other land/water cover such as cultivated croplands (0.9%), urban greenspace (0.8%), lakes and rivers (.75%), beach (.009) and perennial snow/ice (0.02%). Figure 10.

Figure 10. Chehalis Basin ESV Land Cover Breakdown



Source: Resource Dimensions, 2020.

Table 37 provides the breakout of land cover types within the Basin, as well as grouped reclassification for the ESV.

Table 37. Chehalis Basin Total Land Cover Area

Land Cover	Chehalis Basin Reclassification	Area SqKM	Area Acres	Percent Cover
Barren Land	Barren Land	159	39,243	2%
Beach	Beach	1	181	0%
Cultivated Crops	Cropland	61	14,967	1%
Developed, Medium Intensity	Developed	38	9,453	1%
Developed, Low Intensity	Developed	128	31,565	2%
Unconsolidated Shore	Estuary	107	26,344	2%
Estuarine Aquatic Bed	Estuary	13	3,328	0%
Estuary	Estuary	123	30,318	2%
Evergreen Forest	Forest	2,921	721,712	42%
Mixed Forest	Forest	382	94,501	5%
Deciduous Forest	Forest	288	71,068	4%
Palustrine Forested Wetland	Wetland	157	38,901	2%
Grassland/Herbaceous	Grassland	553	136,598	8%
Open Water	Lakes & Rivers	50	12,349	1%
Pasture/Hay	Pasture	320	79,036	5%
Scrub/Shrub	Scrub/Shrub	1,432	353,956	20%
Perennial Ice/Snow	Snow/Ice	0	27	0%
Developed, High Intensity	Urban	14	3,424	0%
Developed, Open Space	Urban Greenspace	54	13,335	1%
Palustrine Scrub/Shrub Wetland	Wetland	108	26,743	2%
Palustrine Emergent Wetland Persistent	Wetland	84	20,737	1%
Estuarine Scrub/Shrub Wetland	Wetland	0	1	0%
Estuarine Emergent Wetland	Wetland	12	3,044	0%
Palustrine Aquatic Bed	Wetland	1	210	0%
	Total	7,005	1,731,040	100%

Source: Resource Dimensions, 2020.

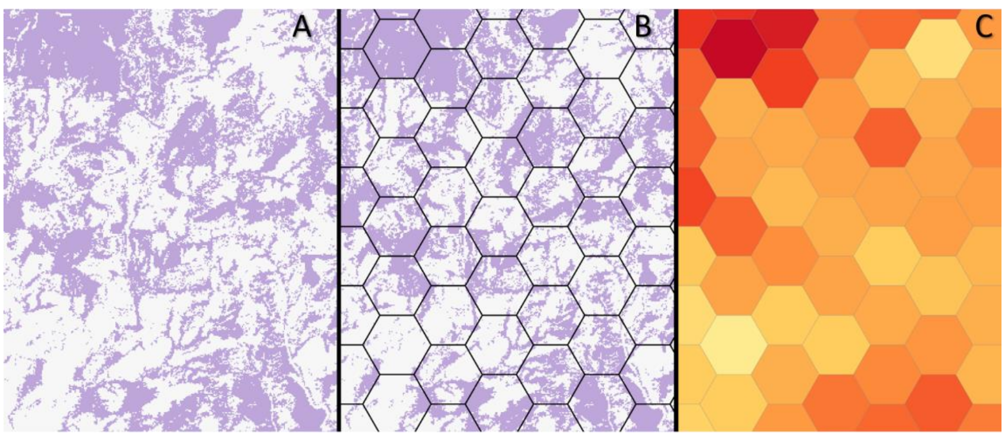
The following section summarizes the distribution of land/water covers and ecosystem services provided by each. For the purposes of the Chehalis Basin ecosystem service valuation perennial ice/snow, urban or built-up areas, roads, barren lands, pits/quarries for extraction of resources (90,411.82 acres) across the Basin are not included. See Appendix F for maps reflecting the location and intensity of these land covers.

4.2.1 Summary Ecosystem Service Values by Landcover

To address the range of complexities of the relationships between ecosystem function ecosystem service delivery across the Chehalis Basin we use spatial modeling to complement benefit function transfer and model calibration. Through the use of spatial modeling we can more accurately assess variable provision, flow, and consumption of ecosystem services across the landscape. In addition to enabling us to address the spatial flow of services, modeling also helped to assess spatial pattern and intensity of ecosystem service provision.

To assist in visualizing the distribution of landcover types and the intensity of where landcovers are located and, hence, ecosystems are, we created a gridded hexagon surface that covered the entire Chehalis Basin, Figure 11. Each hexagonal cell encompasses roughly 500 acres. The grid is created and overlaid with the original land cover map which is a raster grid of 30m x 30m cells. Land cover is coded using binary values (either 0 if absent and 1 if present). Each cell is assigned only one land cover type so each cell is known to contain 900 m^2 of that landcover a sum of 30m cells in the hexagon allows us to calculate relative density of landcover at a coarser resolution. Using two maps to show both where a landcover occurs and then an intensity or density of that landcover across the Basin allows one to see where the concentrations are of that landcover or ecosystem service type with each. This is done for visual affect and does not change the calculation for valuations of landcovers nor does it assist in accounting for connectivity.

Figure 11: Gridding and summarizing land cover distribution using a hexagonal grid.



Panel A shows original land cover distribution, panel B shows overlaying of hexagonal grid and panel C the summarization on the hexagonal grid.

As noted in Section 3, benefit function transfers use a benefit function derived from a primary study or set of prior studies to calculate a welfare estimate calibrated to selected characteristics of the current study site (Loomis 1992; Rosenberger and Loomis 2003). There are two primary requirements. The first requirement is a parameterized function that enables the calculation of the empirical outcome of interest, as a function of variables that include conditions observable at the study site. Second, information on at least a subset of these variables is required for the proposed project site, in order to adjust the transferred function from the primary study site context to the proposed project site context, in this case the Chehalis Basin. Adjusting benefit estimates according to observable differences between the original study site and proposed site contexts leads to more accurate transfer estimates (i.e., lower transfer errors).

There are several types of function transfers. The primary difference between different forms of benefit function transfer is the source of the benefit function. The simplest version uses an econometric model, such as a travel cost model, to calculate a calibrated value for the proposed site as a function of variables describing characteristics of, and people there. Think of a function transfer as the transfer of the econometric parameter estimates from the original study site to the project site, rather than the transfer of an estimated value. The more prominent function transfer is to estimate a meta-equation using the results from a number of studies and then use the estimated function to predict values at the project site. This can be a reduced form specification that lets the data tell the story or a preference function that has a utility specification. Compared to a straight value transfer, function transfers provide greater opportunities to calibrate value predictions to account for conditions at the project site, thus leading to greater accuracy in developing value estimates. Depending on the number of applicable studies for Chehalis Basin land cover-ecosystem service combinations, both methods are used in developing benefit functions.

As a foundation for developing proprietary benefit function models for the Chehalis Basin, we begin with Resource Dimensions ESV matrix database containing more than 3,000 reference transfer values from primary studies conducted world-wide. We then cross tabulated per acre ecosystem service value flow estimates by land cover type and ecosystem service, ensure unit conversion (e.g., hectares to acres, linear miles to acres, etc.) and convert all monetary values using CPI conversion factors to determine values in $2019 USD. For each set of primary ecosystem service values in the matrix, we employ a conservative approach where multiple high and low value estimates derived from each study are averaged to generate a single point minimum and a single point maximum estimate by land cover and ecosystem service category.

Each study and resulting values are validated for appropriateness and fit for use in the current context using these general criteria to assess the quality of primary studies for use:

- Similarity in biophysical conditions at the study and policy/project sites
- Reporting of data and methodology is transparent
- Reporting of site and population characteristics is sufficiently detailed
- Founded in economic theory
- Sound biophysical data or modeling
- Goods or services and quantities/qualities are clearly outlined
- Use accepted empirical/valuation methods
- Data collection methods, sample size, and representativeness are outlined
- Robustness of results
- Evidence of peer review or other recognized quality indicators

Final individual values are then sorted by land cover-ecosystem service combinations (Appendix B).

Once all ecosystem service value data, by land cover, has been verified we assess potential collinearity issues and remove highly correlated predictors from the ESV model, or as appropriate recategorize variables to correct for any potential double-counting to ensure reliability of final ESV values for the Chehalis Basin. Finally, spatially explicit ecosystem service distribution capacity, by land/water cover, is verified against primary study data and models are calibrated by assigning values to determining parameters using contextual information for the quality and extent of landcover, modifications to baseline land cover impacting ecosystem function, degradation of essential habitat, productivity of agricultural lands, and other core attribute differentiating the Chehalis Basin from primary study sites.

In addition to addressing site specific issues and potential double counting, this method accounts for the effects of very high or very low value estimates, averaging very high or low values up to twice, producing a more conservative value estimate. For example, forest cover values were derived by both adjusting for density and age for average percentage of tree cover across the Chehalis Basin for all ecosystem services included for valuation. Thus, adjusting for variables by average cover and ecosystem function in range between 37% for biodiversity/genetic resources and habitat and nursery to 78% for pollination.

Total ecosystem service flow value was estimated in aggregate and broken down by land cover type and ecosystem service. To determine ecosystem service value flows by land cover, we use the following equation.

$$V(ES_i) = \sum_{k=1}^{n} A\,(LC_i)\ \times V(ES_{ki})$$

Where $A(LC_i)$ = area of land/water cover type (i) and $V(ES_{ki})$ = annual value per unit area for ecosystem service type (k) generated by land cover type (i). Total ecosystem service value can be derived by adding up the values for all land cover types. Table 38 and Table 39 reports summary minimum and maximum ESVs for the Chehalis Basin. There were a total of 164 individual studies and 406 valuation records used.

Table 38. Summary of Ecosystem Service Values, by Land Cover – Low Model ($2019)

Land Cover Class	Acres	Value Per Acre ($/acre/yr) Min	Max	Total Value ($/acre/yr) Min	Max
Beach	181	$24,856	$109,478	$4,505,274	$19,842,969
Estuary	59,989	$827	$16,241	$49,603,557	$974,290,768
Lakes & Rivers	12,349	$1,764	$21,258	$21,786,729	$262,518,378
Wetlands	89,636	$4,258	$60,406	$381,682,803	$5,414,576,450
Cropland	14,967	$959	$2,608	$14,349,924	$39,035,710
Forests	887,280	$608	$8,074	$539,136,435	$7,163,780,868
Grasslands	136,598	$262	$1,901	$35,801,102	$259,654,299
Pasture	79,036	$142	$502	$11,243,799	$39,713,808
Scrub/Shrub	353,956	$154	$536	$54,596,872	$189,616,631
Urban Green Space	13,335	$2,076	$6,766	$27,677,747	$90,223,491
Total	**1,647,328**	**$35,906**	**$227,770**	**$1,140,384,242**	**$14,453,253,371**

Source: Resource Dimensions, 2020.

Table 39. Summary of Ecosystem Service Values, by Land Cover – High Model ($2019)

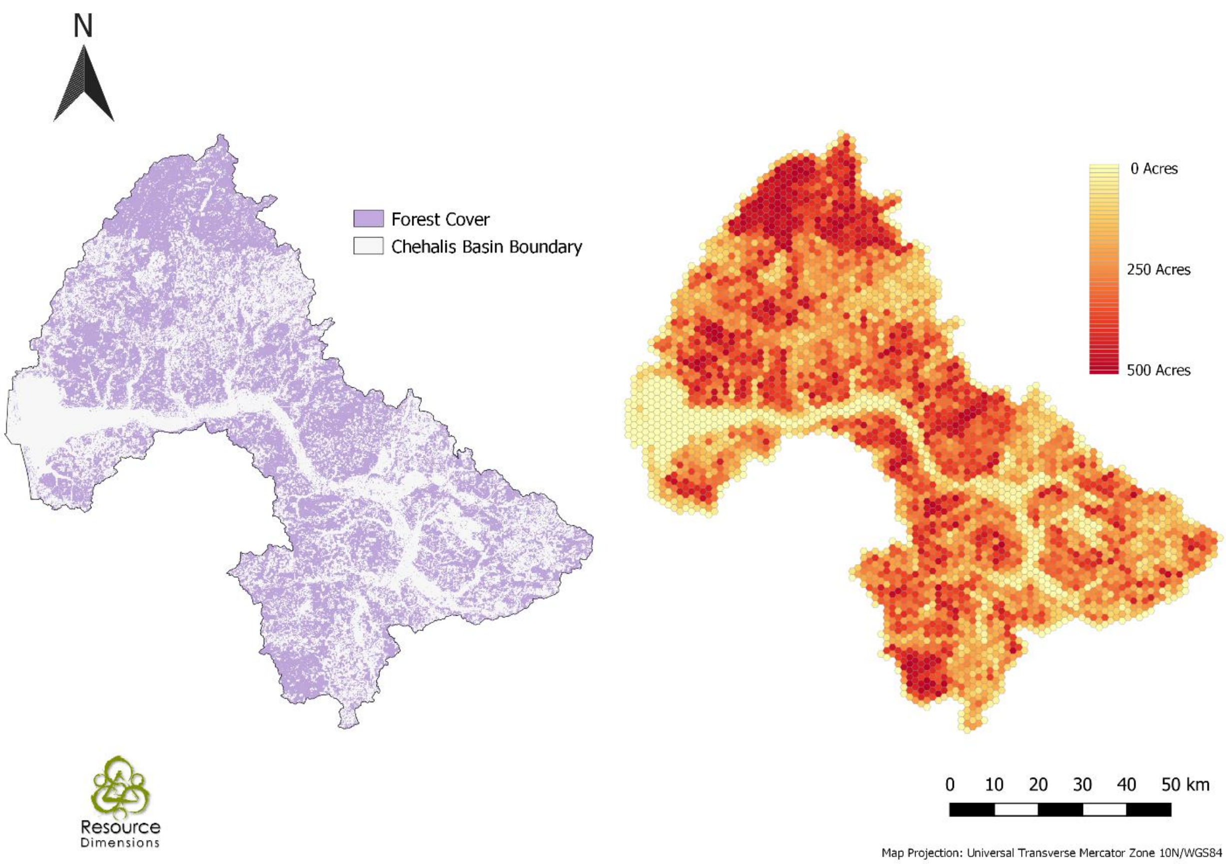
Land Cover Class	Acres	Value Per Acre ($/acre/yr) Min	Max	Total Value ($/acre/yr) Min	Max
Beach	181	$26,129	$116,390	$4,735,897	$21,095,890
Estuary	59,989	$912	$19,162	$54,723,527	$1,149,545,636
Lakes & Rivers	12,349	$2,076	$23,929	$25,637,921	$295,506,680
Wetlands	89,636	$4,388	$63,295	$393,290,761	$5,673,477,518
Cropland	14,967	$995	$2,698	$14,893,373	$40,382,763
Forests	887,280	$664	$8,853	$588,927,586	$7,854,730,675
Grasslands	136,598	$271	$1,974	$36,982,090	$269,690,666
Pasture	79,036	$162	$554	$12,806,181	$43,758,074
Scrub/Shrub	353,956	$192	$653	$68,089,678	$231,010,531
Urban Green Space	13,335	$2,265	$7,403	$30,203,713	$98,725,619
Total	**1,647,328**	**$38,054**	**$244,912**	**$1,230,290,727**	**$15,677,924,052**

Source: Resource Dimensions, 2020.

4.2.1.1 Forests

Forests and trees provide a wide range of environmental and economic benefits. They capture and clean our water and air; reduce air pollution and mitigate climate change; provide shade for buildings and people; and provide endless supplies of oxygen. Forests also play an integral role in the global carbon cycle by storing carbon from the atmosphere. These ecosystems provide large terrestrial banks of carbon and prevent increases in the level of greenhouse gases in the atmosphere. As a result, large amounts of carbon are stored in a forest's trees, plants, roots, and soils. Forestlands are also an important asset from a water resource perspective. Well managed forests provide favorable conditions for water quality and water resource integrity, while healthy riparian forests support salmon and other aquatic species.

Figure 12. Chehalis Basin Forest Distribution and Intensity



Source: Resource Dimensions, 2020.

While forest ecosystems provide a wide range of benefits to the Chehalis Basin, all forested lands are not created equal. For example, a recently cut and planted area does not prevent flooding, nor does it provide water filtration or recreational values in the way that a mature or an old growth forest does. Inherently, this means that forests do not provide the same set, or equal amounts, of ecosystem services. In addition to varying degrees of utility, the biological wealth of a forest is critical to its capacity to deliver ecosystem services. Forests diminished by factors such as development and unsustainable logging practices lead to soil erosion and sediment delivery into streams, habitat fragmentation, fewer trees or species of trees, plants or animals, and make forests more susceptible to extreme weather incidents and disease. This degradation makes the forest less valuable economically, culturally, and in terms of its ability to deliver ecosystem services.

For decades, development, land use management and forest practices across the Chehalis Basin have allowed for degradation of forest, floodplain and riparian habitat throughout the watershed. Some estimates indicate that existing habitat for salmon production has been reduced as much as 87% from historic capacity. To account for the reductions in forest service function and the extent and value of ecosystem services generated we evaluate both low minimum and maximum ESVs and high minimum and maximum ESVs for each landcover and ecosystem service valued using two models – lower bound and upper bound - calibrated for Chehalis Basin conditions. In addition to existing data generated by the EDT model and extensive literature review, we examine characteristics as forest type, age (e.g., early succession, mid-succession, late succession/old growth), density, and complexity to calibrate for the "forest" variable in the ESV model. Lower bound model coefficients range from 0.219 to 0.742, and from 0.226 to 0.821 in the upper bound model. Appendix D contains all ESV coefficient factors, by land cover.

Producing about 50% of the total annual economic contributions through ecosystem services valued for the 887,280 acres of Chehalis Basin forest lands used in this analysis, annual per acre lower bound ESVs range from $608 to $8,074, while upper bound annual ESVs range from $664 to $8,853 per acre. The overall total annual value of Chehalis Basin forests at the lower bound is estimated to range between $539 million and $7.16 billion, and at the upper bound between $589 million to $7.85 billion. The most significant ecosystem services provided by forests of the Chehalis Basin are: water regulation, water treatment and quality, biodiversity/genetic resources, and gas and climate regulation (Table 40).

Table 40. Summary of Chehalis Basin Forests Ecosystem Values ($2019)

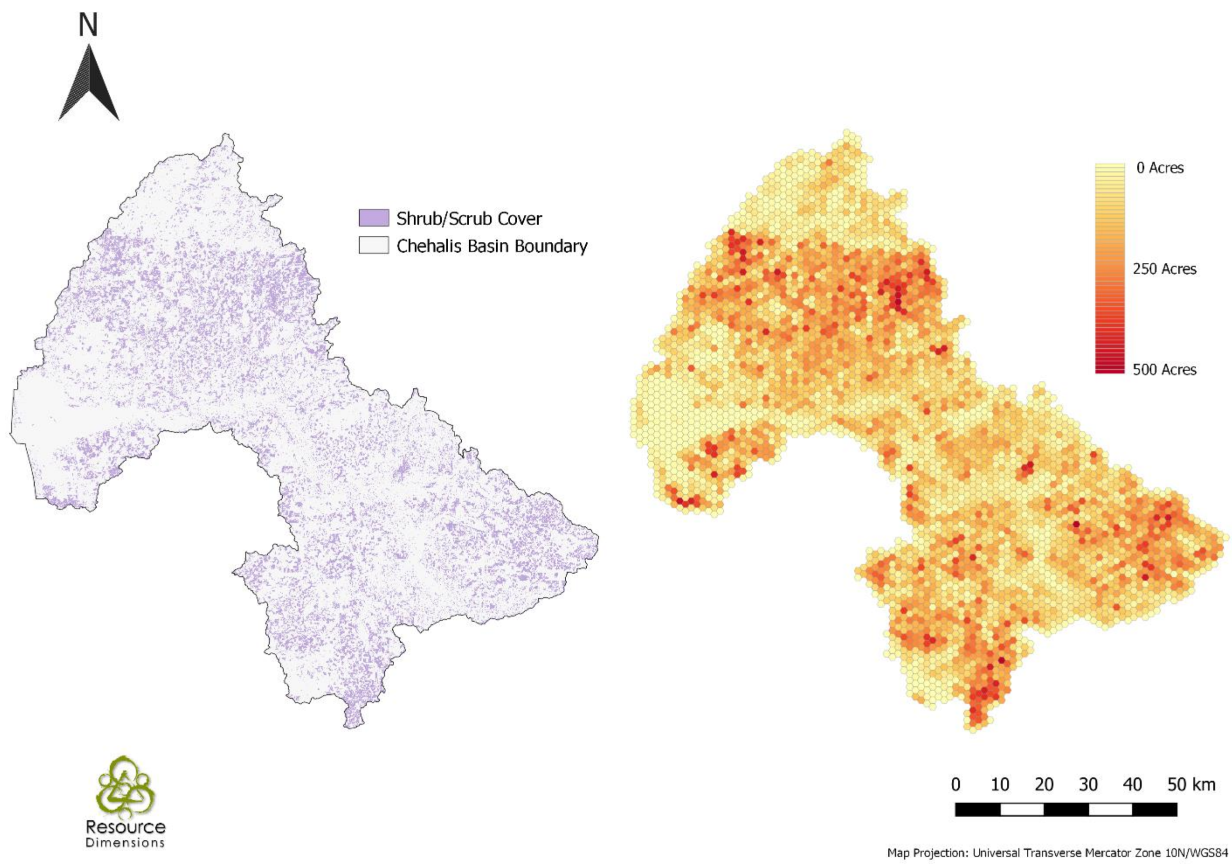
Ecosystem Services Provided		FORESTS			
		Lower		Upper	
		Min	Max	Min	Max
Provisioning					
Food		$0.21	$2	$0.23	$2
Water Supply		$3	$349	$4	$389
Regulating					
Biological Control		$5	$10	$5	$11
Erosion Control		-	-	-	-
Gas & Climate Regulation		$3	$869	$3	$966
Natural Hazards Mitigation		$24	$330	$26	$367
Pollination		$59	$339	$62	$356
Soil Formation		$4	$10	$4	$10
Waste Treatment		-	-	-	-
Water Treatment & Quality		$89	$1,486	$98	$1,673
Water Regulation		$280	$2,545	$310	$2,816
Societal/Cultural					
Aesthetic/Amenity		$21	$514	$23	$554
Recreation/Tourism		$100	$522	$108	$563
Supporting					
Habitat and Nursery		$2	$106	$2	$111
Biodiversity/Genetic Resources		$18	$991	$19	$1,033
Total Acres	***887,280***				
Total Annual Value *($/acre/yr)*		***$608***	***$8,074***	***$664***	***$8,853***
Total Annual Value		***$539,136,435***	***$7,163,780,868***	***$588,927,586***	***$7,854,730,675***

Source: Resource Dimensions 2020.

4.2.1.2 Shrub/Scrub

Scrub-Shrublands, the second most prevalent Chehalis Basin land cover, are generally interspersed throughout the region with significant concentration in the Willapa Hills, Upper Skookumchuck, Cascade Mountains, Central Lowlands, Grays Harbor Tributaries and Olympic Mountains ecoregions (Figure 13). Both conifer-dominated shrublands (e.g., young conifers, evergreen tree shrubs < 5 meters tall) and deciduous riparian scrub-shrublands (e.g., various grasses, willows, red-osier dogwood) are common; each providing some level of service functions, such as nutrient cycling, bank stabilization, sediment filtration, and shading to Chehalis Basin rivers and streams.

Figure 13. Chehalis Basin Scrub/Shrubland Distribution and Intensity



Source: Resource Dimensions, 2020.

Shrubland ecosystems also provide critical regulating services tied to water quality and quantity, including watershed protection, erosion control, flood protection, and ground water recharge, as well as and supporting services as wildlife habitat. Variations in the extent of disruption, composition or community type (e.g., conifer-dominated riparian, deciduous riparian shrubland) and density of the scrub-shrubland cover, influence the level of ecosystem function, thus the value of ecosystem services generated. Coniferous-dominated riparian areas, for example, tend provide much greater structural ecosystem function.

As noted in section 4.2.1.1 above, land use management, development and forest practices throughout the watershed have degraded land cover and related ecosystem functioning over time. Specific to native scrub-shrubland, the primary alteration to the ecosystem has been the direct removal of native vegetation, largely for the purpose of clearing lands for forestry and agricultural uses. The nature of such land disturbances has resulted in habitat loss or fragmentation throughout the Basin.

While healthy intact scrub-shrublands provide significant regulating services, in validating the ESV model across land cover factors and ecosystem variables, strong collinearity existed with wetland cover across services including natural hazards mitigation, waste treatment, water treatment and quality, and water regulation. This is most likely due to the inclusion of palustrine and estuarine scrub-shrubland within the wetland class and the unique association between the land cover classifications. Additionally, primary valuation research specific to shrubland ecosystems is limited, with the majority focused on societal/cultural services (e.g., aesthetic/amenity, recreation, tourism) and supporting services such as nursery and wildlife habitat. Thus, to negate potential double counting errors, variables where the value of the correlations were near ±1 were removed from the scrub-shrubland ESV calculation.

Next, using information from existing literature, September 2019 EDT model output for coho, land cover composition and density, we calibrate for the "scrub-shrubland" variable in the ESV model. Lower bound model coefficients range from -0.00 to 0.99, and from 0.208 to 1.06 in the upper bound model. See Appendix D for ESV model factors.

The 353,956 acres of Chehalis Basin scrub-shrublands produce about 1.5% of the region's total annual ESV contributions. Annual per acre lower bound ESVs range from $154 to $536, while upper bound annual ESVs range from $192 to $653 per acre. The total annual ESV, per acre, for all services valued for Chehalis Basin scrub-shrublands range from about $54.6 million to $189.6 million at the lower bound, and at the upper bound between $68 million and $231 million. Important values for these lands are the provision of nursery and habitat, and gas and climate regulation (Table 41).

Table 41. Summary of Chehalis Basin Scrub/Shrubland Ecosystem Values ($2019)

Ecosystem Services Provided		SCRUB/SHRUBLANDS Lower Min	Lower Max	Upper Min	Upper Max
Provisioning					
Food		-	-	-	-
Water Supply		-	-	-	-
Regulating					
Biological Control		-	-	-	-
Erosion Control		-	-	-	-
Gas & Climate Regulation		$7	$75	$8	$80
Natural Hazards Mitigation		-	-	-	-
Pollination		-	-	-	-
Soil Formation		-	-	-	-
Waste Treatment		-	-	-	-
Water Treatment & Quality		-	-	-	-
Water Regulation		-	-	-	-
Societal/Cultural					
Aesthetic/Amenity		$0.11	$118	$0.13	$142
Recreation/Tourism		$0.22	$0.22	$0.27	$0
Supporting					
Habitat and Nursery		$146	$342	$184	$430
Biodiversity/Genetic Resources		-	-	-	-
Total Acres	***353,956***				
Total Annual Value *($/acre/yr)*		***$154***	***$536***	***$192***	***$653***
Total Annual Value		***$54,596,872***	***$189,616,631***	***$68,089,678***	***$231,010,531***

Source Resource Dimensions, 2020.

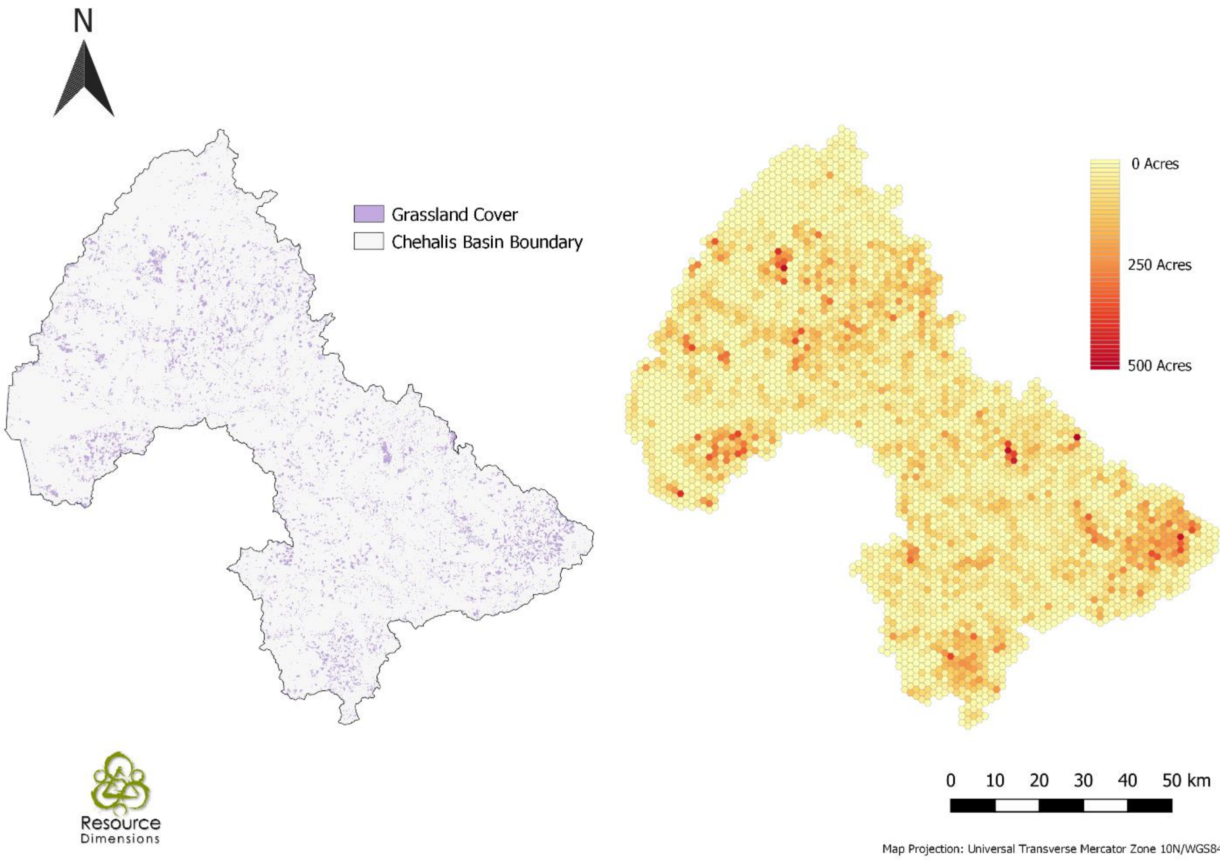
4.2.1.3 Grasslands

Grasslands are widely scattered throughout the Chehalis Basin with the greatest intensity in the Willapa Hills and Upper Skookumchuck ecoregions, and lighter more dispersed distribution at 3% to 6% of land cover across the Cascade Mountains, Central Lowlands, Grays Harbor Tributaries and Olympic Mountains ecoregions (Figure 14).

Covering nearly one-third of the earth's land area, grasslands are a major part of the global ecosystem (Bengtsson et al. 2019). The considerable number of provisioning, regulation, societal/cultural and supporting ecosystem services grasslands can supply are often overlooked. For example, in the

Chehalis Basin, it is estimated that less than 10% of its native grassland prairies remain in some areas (Thurston 2017) while many of the world's natural grasslands have been converted to other uses (e.g., residential development, cropland, grazing), are in poor condition and exhibit signs of degradation.

Figure 14. Chehalis Basin Grassland Distribution and Intensity



Source Resource Dimensions, 2020.

Significant reductions in the extent of Chehalis Basin native grasslands due to conversion and encroachment by trees, invasive species and non-native grasses has contributed to sizeable habitat loss or fragmentation for several region-specific species. Grassland species of concern include the Endangered Species Act (ESA) listed Streaked horned lark, Taylor's checkerspot butterfly and Olympia, Tenino and Yelm mazama pocket gophers, and the Oregon spotted frog, which is proposed for ESA listing (Chehalis Basin Strategy PEIS 2016a,b).

To address the degree of grassland loss and the level of degradation across remaining land cover, we calibrate for the "grassland" variable in the ESV model again using existing data and information from relevant studies of the region, the EDT model, land cover composition and GIS data layers for location and density.

Lower bound model coefficients range from -0.0001 to 0.747, and from -0.038 to 0.792 in the upper bound model. See Appendix D for ESV model factors.

The 136,598 acres of Chehalis Basin grasslands produce about 1.7% of the region's total annual ESVs. Annual per acre lower bound ESVs range from $262 to $1,901, while upper bound annual ESVs range from $271 to $1,974 per acre. The total annual ESV, per acre, for all services valued for Chehalis Basin scrub-shrublands range from about $35.8 million to $259.6 million at the lower bound, and at the upper bound between $37 million and $269.6 million. While grasslands provide a broad array of provisioning, regulation, societal/cultural and supporting ecosystem services, important values for these lands are the provision of habitat and nursery, biodiversity and genetic resources, aesthetic and amenity, and erosion control (Table 42).

Table 42. Summary of Chehalis Basin Grassland Ecosystem Values ($2019)

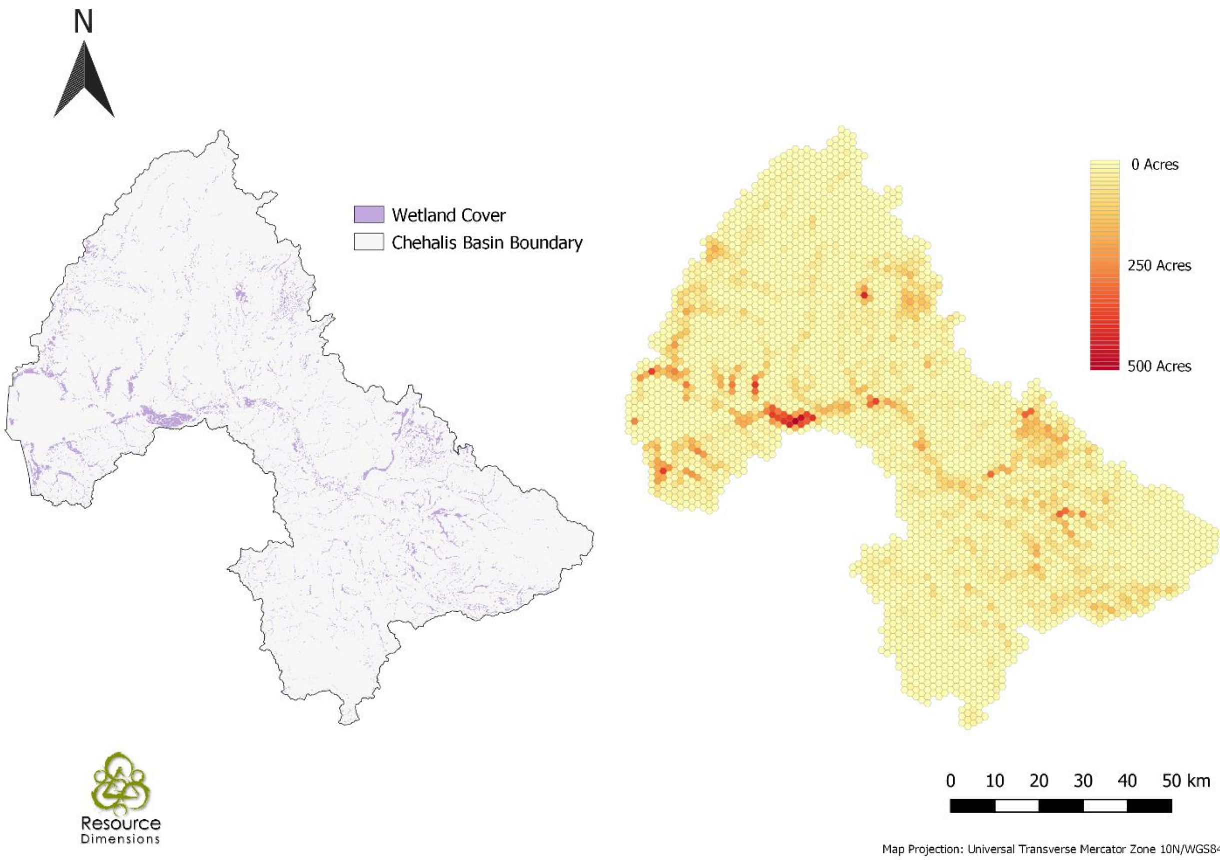
Ecosystem Services Provided		GRASSLANDS			
		Lower		Upper	
		Min	Max	Min	Max
Provisioning					
Food		-	-	-	-
Water Supply		$52.13	$52.13	$55.26	$55.26
Regulating					
Biological Control		$10.52	$10.52	$11.61	$11.61
Erosion Control		$13.06	$149.09	$13.84	$160.03
Gas & Climate Regulation		$4.82	$33.53	$5.17	$35.54
Natural Hazards Mitigation		-	-	-	-
Pollination		$6.31	$15.21	$6.77	$16.33
Soil Formation		$9.32	$34.41	$9.47	$34.96
Waste Treatment		$56.89	$56.89	$57.79	$57.79
Water Treatment & Quality		$1.86	$2.02	$1.92	$2.09
Water Regulation		$2.73	$2.73	$2.82	$2.82
Societal/Cultural					
Aesthetic/Amenity		$99.04	$212.73	$100.47	$215.79
Recreation/Tourism		-	-	-	-
Supporting					
Habitat and Nursery		$1.80	$1,240.37	$1.87	$1,287.44
Biodiversity/Genetic Resources		$3.62	$91.22	$3.75	$94.68
Total Acres	***136,598***				
***Total Annual Value** (\$/acre/yr)*		***$262***	***$1,901***	***$271***	***$1,974***
Total Annual Value		***$35,801,102***	***$259,654,299***	***$36,982,090***	***$269,690,666***

Source: Resource Dimensions, 2020.

4.2.1.4 Wetlands

Palustrine wetlands represent about 97% of the total 97,403 acres of wetlands included for the Chehalis Basin ESV. At 73% of the palustrine subclass, forested and scrub/shrubland wetlands are predominant. Palustrine emergent wetlands (e.g., marshes, wet meadows, bogs, vernal pools, playas) comprise the balance. Estuarine wetlands, present on the deltas and lower reaches of the region’s major rivers, comprise 3% of the total wetland cover (Figure 15).

Figure 15. Chehalis Basin Wetland Distribution and Intensity



Source: Resource Dimensions, 2020.

Home to diverse plants and animals, wetlands in the Chehalis Basin provide essential habitat, breeding, rearing, and feeding grounds for many species of fish and wildlife. Important wetland ecosystems along the Black River and the Chehalis River contain some of the highest quality wetland ecosystems in the state, supporting robust runs of chum, Chinook and coho salmon, as well as steelhead and cutthroat trout.

Well known for the supporting ecosystem services they provide, wetlands also deliver significant essential provisioning, regulating and societal/cultural ecosystem services such as storing, purifying and supplying fresh water, performing flood protection, and absorbing pollutants.

Wetland loss and degradation across the Chehalis Basin is generally associated with the conversion of lands for urban expansion, forestry and agricultural purposes. These actions can have profound consequences, such as altered water quality, quantity, and flow rates, increased pollution, and extinction of species. Development in sensitive wetland areas, for example along the Black River, damage the natural functions of wetland ecosystems and diminish their capacity to provide goods and services, including the water filtration and protection from floods.

To account for loss and degradation impacts to wetland function across the Chehalis Basin we calibrate for the “wetland” variable in the ESV model using historical information about the extent of conversion, data and information from relevant studies, the EDT model, and GIS data layers for location and density. Lower bound model coefficients range from 0.33 to 0.554, and from 0.410 to 0.709 in the upper bound model. See Appendix D for model factors.

Annual per acre lower bound ESVs range from $4,258 to $60,406, while upper bound annual ESVs range from $4,388 to $63,295 per acre. The total annual ESV, per acre, for all services valued for Chehalis Basin scrub-shrublands range from about $370.8 million to $5.3 billion at the lower bound, and at the upper bound between $393.2 million and $5.6 billion. Offering diverse ecosystem services, important economic contributions of Chehalis Basin wetlands include waste treatment, natural hazards mitigation, water regulation, and the provision of habitat and nursery (Table 43).

Table 43. Summary of Chehalis Basin Wetland Ecosystem Values ($2019)

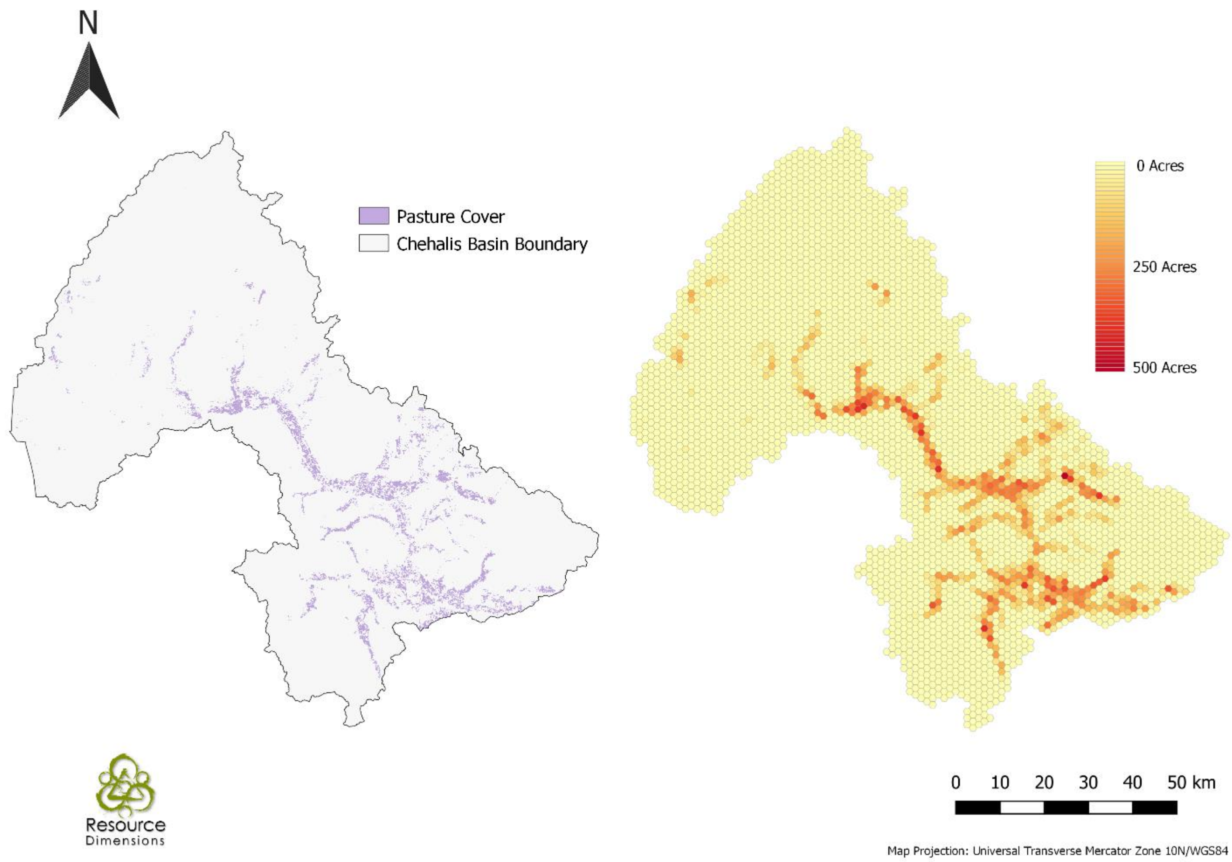
Ecosystem Services Provided		WETLANDS			
		Lower		Upper	
		Min	Max	Min	Max
Provisioning					
Food		$35	$540	$38	$583
Water Supply		$295	$2,000	$360	$2,437
Regulating					
Biological Control		-	-	-	-
Erosion Control		-	-	-	-
Gas & Climate Regulation		$2	$287	$2	$287
Natural Hazards Mitigation		$9	$21,319	$9	$21,228
Pollination		-	-	-	-
Soil Formation		-	-	-	-
Waste Treatment		$103	$21,884	$106	$22,472
Water Treatment & Quality		$77	$243	$80	$262
Water Regulation		$3,684	$3,684	$3,731	$3,731
Societal/Cultural					
Aesthetic/Amenity		$4	$1,945	$5	$2,180
Recreation/Tourism		$7	$3,308	$8	$3,707
Supporting					
Habitat & Nursery		$14	$5,169	$17	$6,376
Biodiversity/Genetic Resources		$26	$26	$32	$32
Total Acres	***89,636***				
***Total Annual Value** (\$/acre/yr)*		***$4,258***	***$60,406***	***$4,388***	***$63,295***
Total Annual Value		**$370,827,245**	**$5,299,004,752**	**$393,290,761**	**$5,673,477,518**

Source: Resource Dimensions, 2020.

4.2.1.5 Pasture

Generally located in the lower Chehalis Basin on the fringes of the floodplains and low-lying valleys adjacent to the Chehalis River and its major tributaries, pasture lands comprise about 4.8% of the ESV landcover (Figure 16). Pasture lands are diverse, predominately containing grasses, legumes, or grass-legume mixtures planted for livestock grazing and dairy production, or the production of seed or hay. Many species of wildlife, ranging from elk to butterflies and nesting songbirds, depend on these lands for food and cover.

Figure 16. Chehalis Basin Pasture Distribution and Intensity



Source: Resource Dimensions, 2020.

Dominant native flora includes western red cedar, red alder, black cottonwood, and willow species. Much of the pasture area contain poorly drained soils. In many areas, drainage has been altered by tilling. Permeability and runoff of this soil is slow, while available water capacity is high. This soil is subject to frequent, brief flooding periods in winter and early spring.

Primary economic outputs of pastureland include livestock production, but wildlife and aesthetic/amenity values are also a major economic consideration for these lands. Scenic, cultural, and historic values of these lands provide not only economic benefits, but also quality of life values cherished by many.

In validating the ESV model across land cover factors and ecosystem variables, strong collinearity existed with grassland and cropland covers across services including water supply, erosion control, gas and climate regulation, waste treatment, water treatment and quality, and water regulation. This is most likely due to the frequent spatial proximity and interrelated nature of these land cover classifications. Also, primary valuation research applicable to pasturelands is both limited and several available studies frequently address these classifications collectively. Study values used in the “pasture” variable focus on biological control, soil formation, pollination and seed dispersal, and aesthetic/amenity values. Thus, to negate potential double counting errors, variables where the value of the correlation is near ±1 were removed from the scrub-shrubland ESV calculation.

To address for impacts to wetland function across the Chehalis Basin we calibrate for the "pasture" variable in the ESV model using historical information about the extent of conversion, data and information from relevant studies, the EDT model, and GIS data layers for location and density. Lower bound model coefficients range from 0.253 to 0.388, and from 0.188 to 0.300 in the upper bound model.

Annual per acre lower bound ESVs range from $142 to $502, while upper bound annual per acre ESVs range from $162 to $554 per acre. The total annual ESV, per acre, for all services valued for Chehalis Basin scrub-shrublands range from about $11.2 million to $39.7 million at the lower bound, and at the upper bound between $12.8 million and $43.7 million. Offering diverse ecosystem services, important economic contributions of Chehalis Basin pasture include waste treatment, natural hazards mitigation, water regulation, and provision of habitat and nursery (Table 44).

Table 44. Summary of Chehalis Basin Pasture Ecosystem Values ($2019)

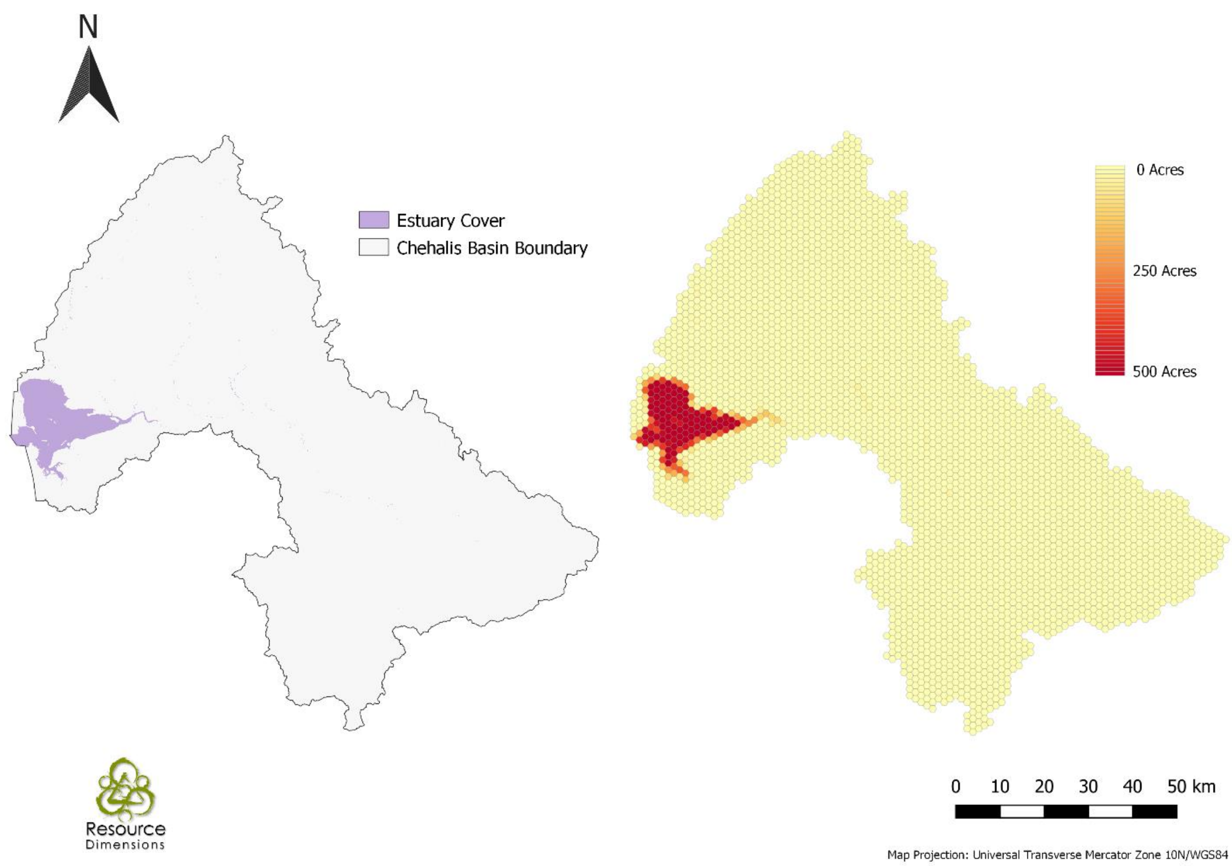
Ecosystem Services Provided		PASTURE			
		Lower		Upper	
		Min	Max	Min	Max
Provisioning					
Food		-	-	-	-
Water Supply		-	-	-	-
Regulating					
Biological Control		$6	$6	$6	$6
Erosion Control		-	-	-	-
Gas & Climate Regulation		-	-	-	-
Natural Hazards Mitigation		-	-	-	-
Pollination		$6	$347	$6	$377
Soil Formation		$128	$128	$147	$147
Waste Treatment		-	-	-	-
Water Treatment & Quality		-	-	-	-
Water Regulation		-	-	-	-
Societal/Cultural					
Aesthetic/Amenity		$2	$21	$2	$24
Recreation/Tourism		-	-	-	-
Supporting					
Habitat and Nursery		-	-	-	-
Biodiversity/Genetic Resources		-	-	-	-
Total Acres	***79,036***				
Total Annual Value *($/acre/yr)*		***$142***	***$502***	***$162***	***$554***
Total Annual Value		***$11,243,799***	***$39,713,808***	***$12,806,181***	***$43,758,074***

Source: *Resource Dimensions, 2020.*

4.2.1.6 Estuary

Several riverine estuaries are present along main reaches and on the deltas of the region's major rivers. The largest, Grays Harbor estuary, one of six major estuary systems on the Pacific Coast, is a large drowned river mouth. Approximately 15 miles long, and at its widest, the Grays Harbor estuary is about 13 miles wide, narrowing to less than 100 yards wide in some places (Gustanski et al, 2015). The estuary is characterized by extensive mudflats, channels, and fringe marshes. Several rivers (Chehalis, Wishkah, Humptulips, Hoquiam, Elk and Johns Rivers) drain into the estuary, as do numerous smaller rivers, creeks and streams (Figure 17).

Figure 17. Chehalis Basin Estuary Distribution and Intensity



Source: Resource Dimensions, 2020.

Providing goods and services that are economically and ecologically indispensable, estuaries are vital resource banks. In addition to the provision of economic and cultural benefits to communities, Chehalis Basin estuaries produce and provide invaluable ecosystem services. The 65,289 acres of mudflats, saltmarshes and open water deliver significant important provisioning, regulating, societal/cultural and supporting ecosystem services such as food, absorption of pollutants, fresh water purification and supply, flood protection, and critical habitat for a variety of resident and migrant fish and wildlife species, including migrating shorebirds, and marine mammals.

Comprising just 3.6% of the Chehalis Basin land cover, the estuary region supports about 7% of the total annual economic contributions made through diverse ecosystem services. These productive ecosystems filter water from the watershed, stabilize shorelines, protect inland habitats and communities from floods and storm surges, absorb excess water during flooding events, provide important buffers that protect water quality by filtering runoff, and offer habitat for species that are valued commercially, recreationally, and culturally.

Habitat and estuary function have been degraded through a series of human activities, including the industrial development of Grays Harbor, removal of salt marshes by shoreline development along terrestrial margins, diking for agricultural uses, and dredging and filling of tidal flats. A 2003 study found a 22% decrease in the Grays Harbor estuary tidal flats since the 19th century (Borde et al. 2003). In addition, development activities can alter erosion regimes and increase riverine sediment loads (Grays Harbor County HMP 2018).

To account for impacts to estuary function we calibrate for the “estuary” variable in the ESV model using historical information about the extent of conversion, data and information from relevant studies, the EDT model, and GIS data layers for location and density. Lower bound model coefficients range from 0.200 to 0.684, and from 0.270 to 0.780 in the upper bound model.

Validation of the ESV model across land cover factors and ecosystem variables determined strong collinearity existed between estuary and wetland and estuary covers across services including gas and climate regulation, water regulation, and genetic resources/biodiversity. Similarly, multicollinearity issues existed between estuary and river/lake covers for services including erosion control, waste treatment and water regulation. This is likely due to the interdependencies and intertwined functions of these land and water cover classifications. To negate potential double counting errors, variables where the value of the correlation is near ±1 were removed from the scrub-shrubland ESV calculation. Thus, transfer values used in the “estuary” variable focus on food, water supply, biological control, natural hazards mitigation, soil formation, water treatment and quality, aesthetic/amenity, and recreation values. Lower bound model coefficients range from 0.200 to 0.694, and from 0.340 to 0.809 in the upper bound model.

Annual per acre lower bound ESVs range from $827 to $16,241, while upper bound annual per acre ESVs range from $912 to $19,162 per acre. The total annual ESV, per acre, for all services valued for the estuary range from about $49.6 million to $974 million at the lower bound, and at the upper bound between $54.7 million and $1.15 billion. Providing vast/significant ecosystem services, principal estuary services include waste treatment, natural hazards mitigation, water regulation, and the provision of habitat and nursery (Table 45).

While estuary ESVs estimated for the region are substantial, it is important to note that the parameters of this study are not a comprehensive economic analysis. To fully understand the enormity of the economic contributions made by the Chehalis Basin estuarine systems requires in-depth analysis of the habitat-fishery-human linkages and an assessment of the substantial economy inputs and cost savings to local, regional and state governments; both of which are outside the scope of this study.

Table 45. Summary of Chehalis Basin Estuary Ecosystem Values ($2019)

Ecosystem Services Provided		ESTUARY			
		Lower		Upper	
		Min	Max	Min	Max
Provisioning					
Food		$19.98	$1,573.98	$21.29	$1,676.64
Water Supply		$4.24	$107.48	$4.24	$107.65
Regulating					
Biological Control		$23.44	$29.79	$27.98	$35.56
Erosion Control		-	-	-	-
Gas & Climate Regulation		-	-	-	-
Natural Hazards Mitigation		$131.71	$167.35	$159.35	$202.48
Pollination		-	-	-	-
Soil Formation		$35.05	$5,743.54	$37.73	$6,183.81
Waste Treatment		-	-	-	-
Water Treatment & Quality		$55.74	$7,268.79	$69.07	$9,174.47
Water Regulation		-	-	-	-
Societal/Cultural					
Aesthetic/Amenity		$545.28	$726.42	$578.88	$771.17
Recreation/Tourism		$8.89	$79.98	$9.35	$84.15
Supporting					
Habitat and Nursery		$2.54	$543.72	$4.33	$926.56
Biodiversity/Genetic Resources		-	-	-	-
Total Acres	***59,989***				
Total Annual Value *($/acre/yr)*		***$827***	***$16,241***	***$912***	***$19,162***
Total Annual Value		***$49,603,557***	***$974,290,768***	***$54,723,527***	***$1,149,545,636***

Source: Resource Dimensions, 2020.

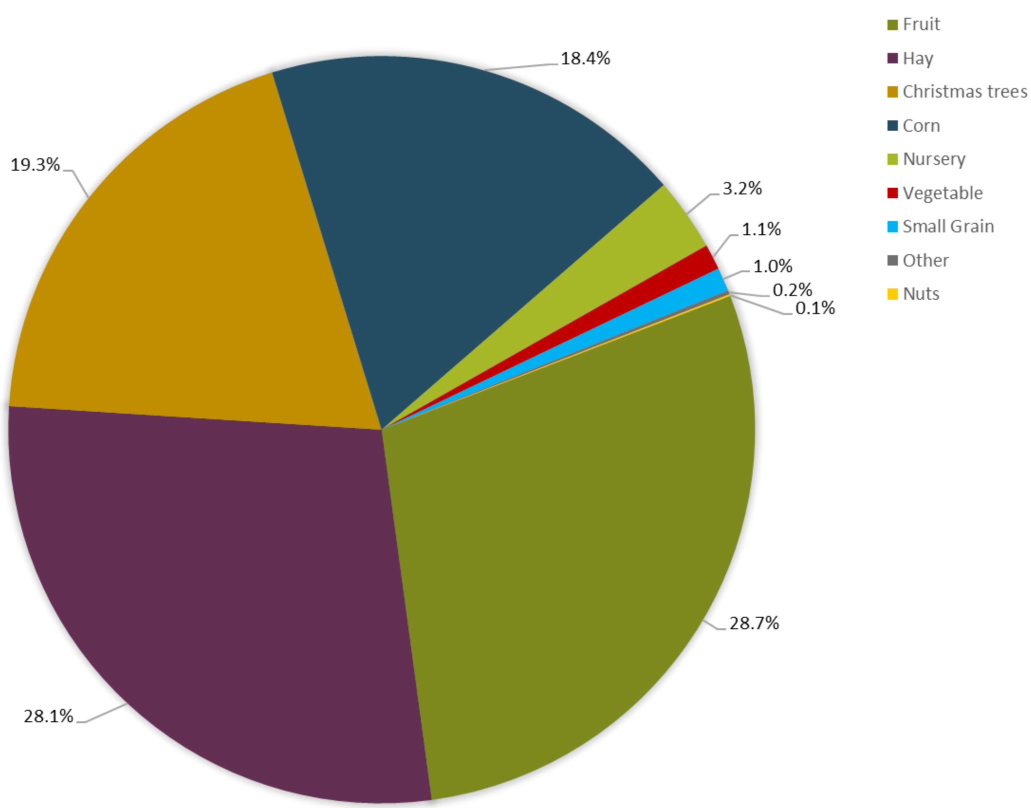
4.2.1.7 Cropland

Located mainly in the lower half of the Chehalis Basin within low-lying valleys adjacent to the Chehalis River and its major tributaries, including the South Fork Chehalis, Newaukum, Skookumchuck, Black, Satsop and Wynoochee Rivers, and Scatter Creek, cultivated cropland represents less than one percent of the land area (Figure 9).

Almost half the land along the main stem of the Chehalis River is agricultural use, though for the purpose of estimating the ESVs cropland is disaggregated from other land use as pasture for livestock, which is covered in section 4.2.1.5.

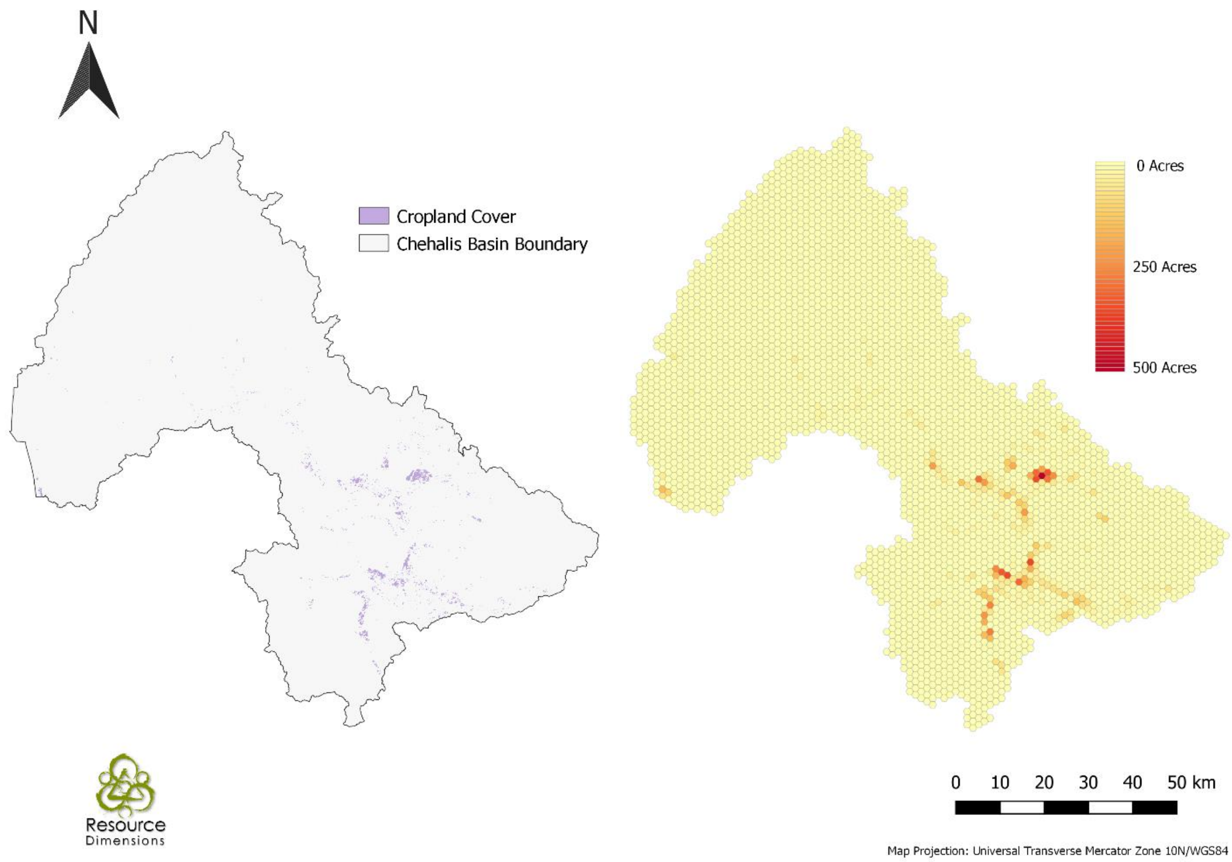
Principal crops include fruits as blueberries, cranberries and rapes, alfalfa, Christmas trees, hay and silage, and corn with some nursey stock, vegetables, and small grains (Figure 18).

Figure 18. Breakdown of Crops Grown in the Chehalis Basin



Source: USDA Cropland Data Layer; Resource Dimensions, 2020.

Figure 19. Chehalis Basin Cultivated Cropland Distribution and Intensity



Source: Resource Dimensions, 2020.

In validating the ESV model across land cover factors and ecosystem variables, strong collinearity existed with cropland and grassland covers across services including water supply, erosion control, gas and climate regulation, waste treatment, water treatment and quality, and water regulation. As noted previously, this is most likely due to the frequent spatial proximity and interrelated nature of these land cover classifications. Also, primary valuation research applicable to croplands is somewhat limited and several available studies frequently address these classifications collectively. Applicable study values used in the "cropland" variable focus on biological control, soil formation, pollination and seed dispersal, and aesthetic/amenity values. Thus, to negate potential double counting errors, variables where the value of the correlation is near ±1 were removed from the cropland ESV calculation.

To address for impacts to wetland function across the Chehalis Basin we calibrate for the "cropland" variable in the ESV model using historical information about the extent of conversion, data and information from relevant studies, the EDT model, and GIS data layers for location and density. Lower bound model coefficients range from 0.186 to 0.467 and from 0.186 to 0.500 in the upper bound model.

Annual per acre lower bound ESVs range from $959 to $2,608, while upper bound annual per acre ESVs range from $995 to $2697 per acre. The total annual ESV, per acre, for all services valued for Chehalis Basin croplands range from about $14.3 million to $39 million at the lower bound, and at the upper bound between $14.9 million and $40.3 million. Offering diverse ecosystem services, important economic contributions of Chehalis Basin croplands include (Table 46).

Table 46. Summary of Chehalis Basin Cropland Ecosystem Values ($2019)

Ecosystem Services Provided		CROPLAND			
		Lower		Upper	
		Min	Max	Min	Max
Provisioning					
Food		$66	$66	$71	$71
Water Supply		-	-	-	-
Regulating					
Biological Control		$17	$17	$19	$19
Erosion Control		$21	$55	$21	$57
Gas & Climate Regulation		$404	$404	$418	$418
Natural Hazards Mitigation		-	-	-	-
Pollination		$2	$1,543	$2	$1,593
Soil Formation		$69	$69	$72	$72
Waste Treatment		-	-	-	-
Water Treatment & Quality		-	-	-	-
Water Regulation		-	-	-	-
Societal/Cultural					
Aesthetic/Amenity		$371	$371	$383	$383
Recreation/Tourism		$2	$41	$3	$44
Supporting					
Habitat and Nursery		$6	$42	$6	$42
Biodiversity/Genetic Resources		-	-	-	-
Total Acres	***14,967***				
Total Annual Value *($/acre/yr)*		***$959***	***$2,608***	***$995***	***$2,697***
Total Annual Value		***$14,349,924***	***$39,035,710***	***$14,892,714***	***$40,371,292***

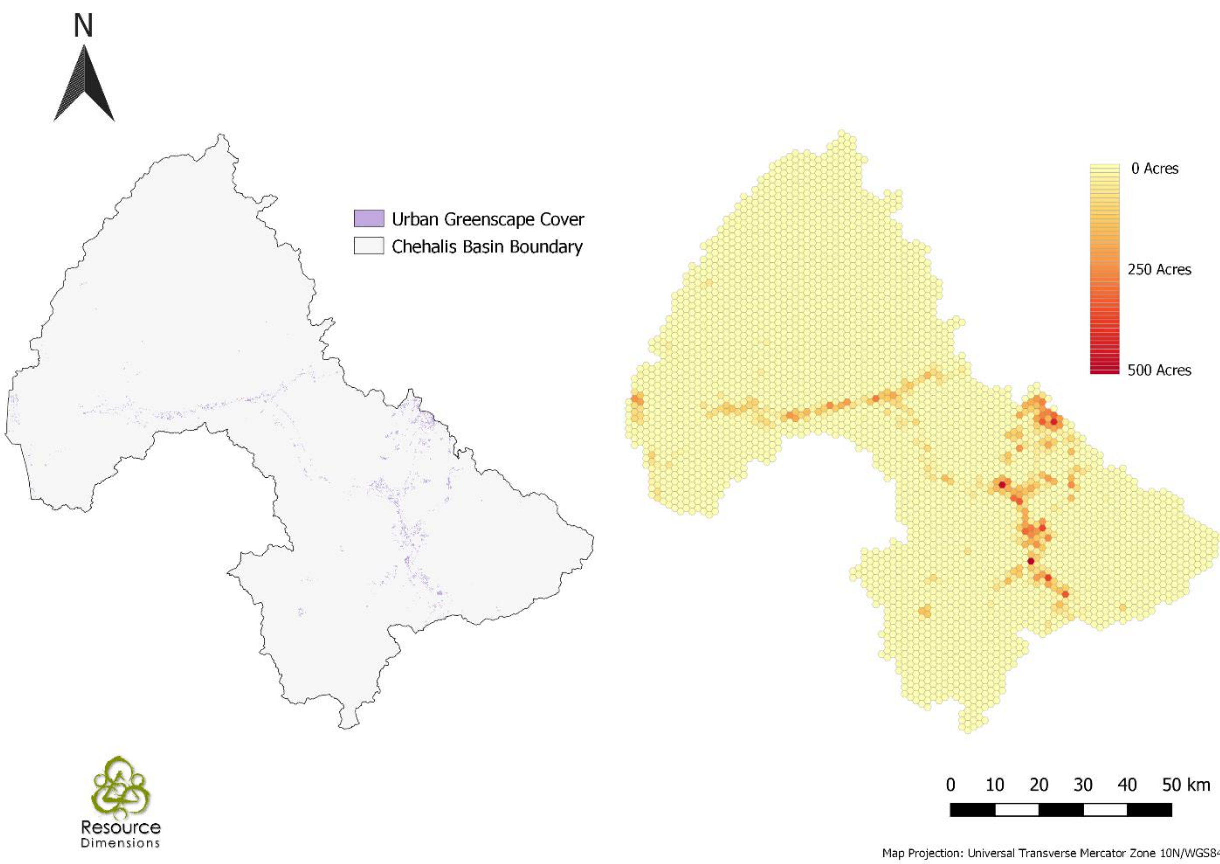
Source: Resource Dimensions, 2020.

4.2.1.8 Urban Greenspace

As of 2015, communities across the Chehalis Basin support approximately 192,881 people (Table 25). Four population centers are located within the Basin—Chehalis, Centralia, Aberdeen, and Hoquiam. Small towns include Adna, Bucoda, Cosmopolis, Elma, McCleary, Mound, Napavine, Oakville, Pe Elle, Porter, Rochester and Tenino.

The Basin is significant to two Tribal Nations: The Confederated Tribes of the Chehalis Reservation and the Quinault Indian Nation. The Reservation of the Confederated Tribes of the Chehalis Reservation is located within the Basin. The Quinault Indian Nation has adjudicated usual and accustomed fishing areas within the Chehalis Basin pursuant to its being a signatory to the Treaty of Olympia (1856). The Quinault Nation also has Treaty-reserved hunting and gathering rights within the Basin. While only about 5% of the Chehalis Basin lands have been developed for urban and industrial use, the majority of all development is concentrated in areas close to important rivers and tributaries. Major transportation routes parallel the Chehalis River, including State Route 6, Interstate 5, Highway 12, and U.S. Highway 101 (Figure 20).

Figure 20. Chehalis Basin Urban Greenspace Distribution and Intensity



Source: Resource Dimensions, 2020.

Along the Chehalis River and its tributaries are diverse recreational access opportunities. These include parks, places to swim, fish, hike, camp, canoe, or to go birdwatching, hunting, whitewater rafting and more. While these activities contribute directly to local and regional economies, they are also key providers of a range of ecosystem services, which in turn contribute to community resilience and sustainability (Bolund and Hunhammer 1999; Tratalos et al. 2007).

Though there are few primary studies examining the ESVs associated with urban green spaces, these important resources do provide various ecosystem services, notably societal and cultural services (Bertram and Rehdanz 2015; Daniel et al. 2012).

The communities of the Chehalis Basin, while relatively small and somewhat rural, are connected to parks, trails, recreational and open spaces. Vegetation in parks has been linked to enhanced air and water quality, as well as gas and climate regulation (Elmquist et al. 2015). These spaces also provide economic benefits to communities by attracting tourism and increasing nearby property values (Nicholls and Crompton 2005; Harnik and Welle 2009).

To address function related to urban green space across the Chehalis Basin we calibrate for the "greenspace" variable in the ESV model using spatial information about the location, size and cover density for parks, trails, open space, and other green infrastructure. Lower bound model coefficients range from 0.302 to 0.578, and from 0.269 to 0.639 in the upper bound model. See Appendix D for model factors.

Annual per acre lower bound ESVs range from $2,076 to $6,766, while upper bound annual ESVs range from $2,265 to $7,403 per acre. The total annual ESV, per acre, for all services valued for Chehalis Basin scrub-shrublands range from about $27.7 million to $90.2 million at the lower bound, and at the upper bound between $30.2 million and $98.7 million. Primary ecosystem services included for Urban Green Space ESV include aesthetic/amenity, recreation/tourism, gas and climate regulation, and water regulation (Table 47).

Table 47. Summary of Chehalis Basin Urban Greenspace Ecosystem Values ($2019)

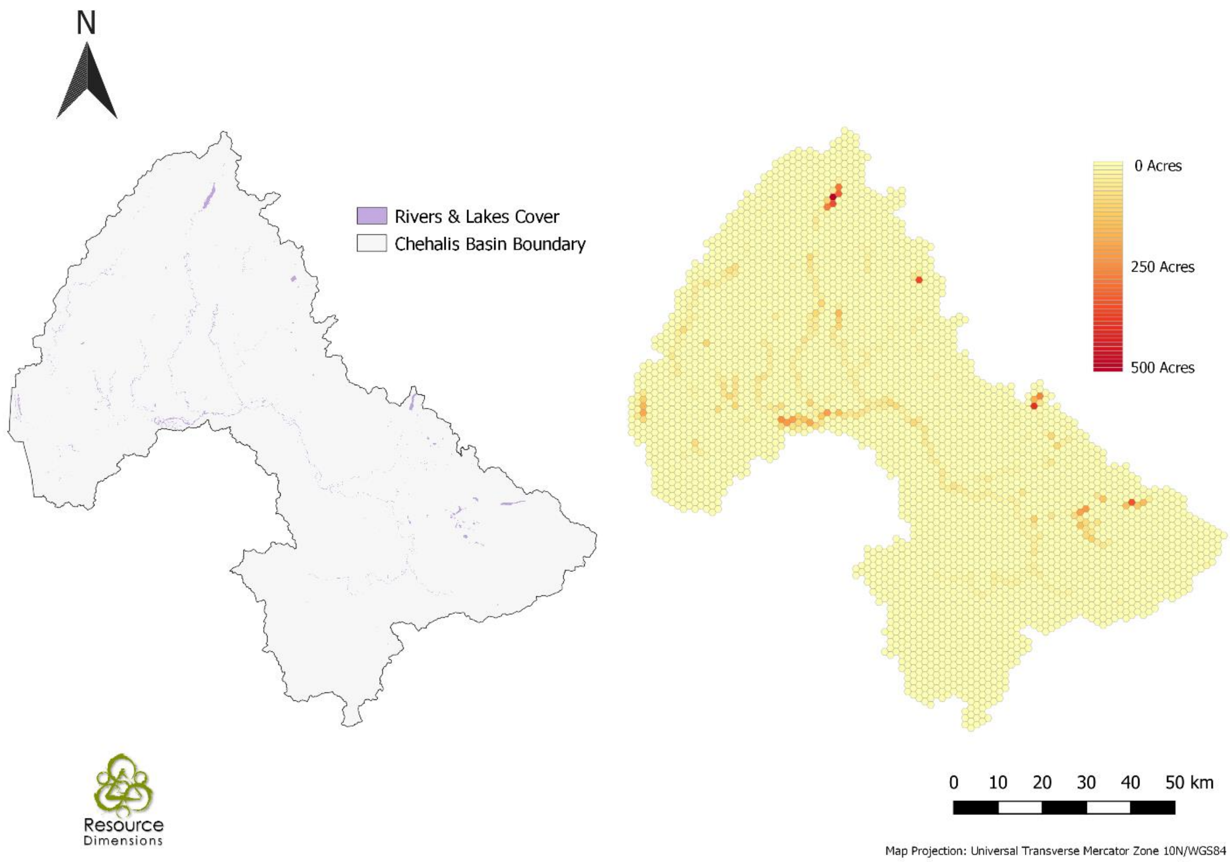
Ecosystem Services Provided		URBAN GREEN SPACE Lower Min	Lower Max	Upper Min	Upper Max
Provisioning					
Food		-	-	-	-
Water Supply		-	-	-	-
Regulating					
Biological Control		-	-	-	-
Erosion Control		-	-	-	-
Gas & Climate Regulation		$19	$627	$22	$705
Natural Hazards Mitigation		-	-	-	-
Pollination		-	-	-	-
Soil Formation		-	-	-	-
Waste Treatment		-	-	-	-
Water Treatment & Quality		-	-	-	-
Water Regulation		$4	$123	$5	$136
Societal/Cultural					
Aesthetic/Amenity		$1,094	$3,207	$1,152	$3,378
Recreation/Tourism		$958	$2,809	$1,087	$3,185
Supporting					
Habitat and Nursery		-	-	-	-
Biodiversity/Genetic Resources		-	-	-	-
Total Acres	***13,335***				
***Total Annual Value** (\$/acre/yr)*		***$2,076***	***$6,766***	***$2,265***	***$7,403***
Total Annual Value		***$27,677,747***	***$90,223,491***	***$30,203,713***	***$98,725,619***

Source: Resource Dimensions, 2020.

4.2.1.9 Rivers and Lakes

Covering a total of about 12,349 acres, the freshwater resources of the Chehalis Basin include 3,350 linear miles of rivers and tributary streams and over 180 lakes, ponds and reservoirs. The 125-mile-long Chehalis River, which drains into the Grays Harbor estuary is the principal river within the system. Other rivers include the Black, Elk, Hoquiam, Humptulips, Johns, Newaukum, Satsop, Skookumchuck, Wishkah, and Wynoochee, and their numerous tributary creeks and streams (Figure 21). These waters provide essential habitat for numerous species of fish and support a diversity of wildlife species, as well as some goods and services regularly considered in terms of their contributions to the local and regional economy, such as commercial and recreational fishing.

Figure 21. Chehalis Basin River and Lake Distribution and Intensity



Source: Resource Dimensions, 2020.

Chehalis Basin freshwater systems also provide a range of vital regulating ecosystem services through processes that move water, energy, nutrients, organisms and sediment across different landscapes and habitats, linking air, land, groundwater and marine systems.

The region's rivers and tributaries support spawning for Chinook, coho, chum and salmon. The anadromous and shellfish resources of the Chehalis Basin are of regional and national significance to tribal, commercial, and sport fishing, and to struggling southern resident killer whale population.

Development throughout the Chehalis Basin is concentrated in areas close to important rivers and tributaries with 42% of the region's population within one mile of the major rivers; this proximity can have adverse impacts on both water quantity and water quality. Associated pollution threats include warm water temperatures, low levels of dissolved oxygen, low pH, toxics, and bacteria.

The main pressures on these ecosystems are habitat destruction. Through a series of human activities, habitat function has been degraded. In addition, development activities can alter erosion regimes and increase sediment loads in area rivers (Grays Harbor County HMP 2018).

To address for habitat degradation and productivity function impacts which have been estimated as high as 87% in some areas (Chehalis Basin Strategy 2016a) we calibrate for the "Rivers & Lakes" variable in the ESV model using current data and information from relevant studies, the 2019 EDT model, and GIS data layers for river and lake location and extent. Lower bound model coefficients range from 0.200 to 0.0.821, and from 0.274 to 0.850 in the upper bound model.

Validation of the ESV model across cover factors and ecosystem variables determined collinearity existed between river/lake and wetland covers across services including gas and climate regulation and natural hazards mitigation. This is likely due to the related nature of these land and water cover classifications. To negate potential double counting errors, variables where the value of the correlation is near ±1 were removed from the river/lake ESV calculation.

Annual per acre lower bound ESVs range from $1,764 to $21,258, while upper bound annual per acre ESVs range from $2,076 to $23,929 per acre. The total annual ESV, per acre, for all services valued for the estuary range from about $21.8 million to $262.5 million at the lower bound, and at the upper bound between $25.6 million and $295.5 million. Providing considerable ecosystem services, principal services for this cover variable include aesthetic/amenity, water treatment, supply and regulation, erosion control, waste treatment, water treatment and quality, and the provision of habitat and nursery resources (Table 48).

Table 48. Summary of Chehalis Basin Rivers/Lakes Ecosystem Values ($2019)

Ecosystem Services Provided		RIVERS & LAKES			
		Lower		Upper	
		Min	Max	Min	Max
Provisioning					
Food		-	-	-	-
Water Supply		$231.08	$1,683.12	$251.10	$1,828.93
Regulating					
Biological Control		-	-	-	-
Erosion Control		$1.51	$1.51	$1.67	$1.67
Gas & Climate Regulation		-	-	-	-
Natural Hazards Mitigation		-	-	-	-
Pollination		-	-	-	-
Soil Formation		-	-	-	-
Waste Treatment		$3.66	$865.77	$4.86	$1,150.43
Water Treatment & Quality		$249.89	$5,352.53	$309.49	$6,629.21
Water Regulation		$1,221.88	$1,221.88	$1,439.78	$1,439.78
Societal/Cultural					
Aesthetic/Amenity		$17.96	$10,472.72	$18.81	$10,971.87
Recreation/Tourism		$18.32	$1,316.88	$19.02	$1,366.93
Supporting					
Habitat and Nursery		$19.94	$343.65	$31.37	$540.54
Biodiversity/Genetic Resources		-	-	-	-
Total Acres	***12,349***				
***Total Annual Value** (\$/acre/yr)*		***$1,764***	***$21,258***	***$2,076***	***$23,929***
Total Annual Value		***$21,786,729***	***$262,518,378***	***$25,637,921***	***$295,506,680***

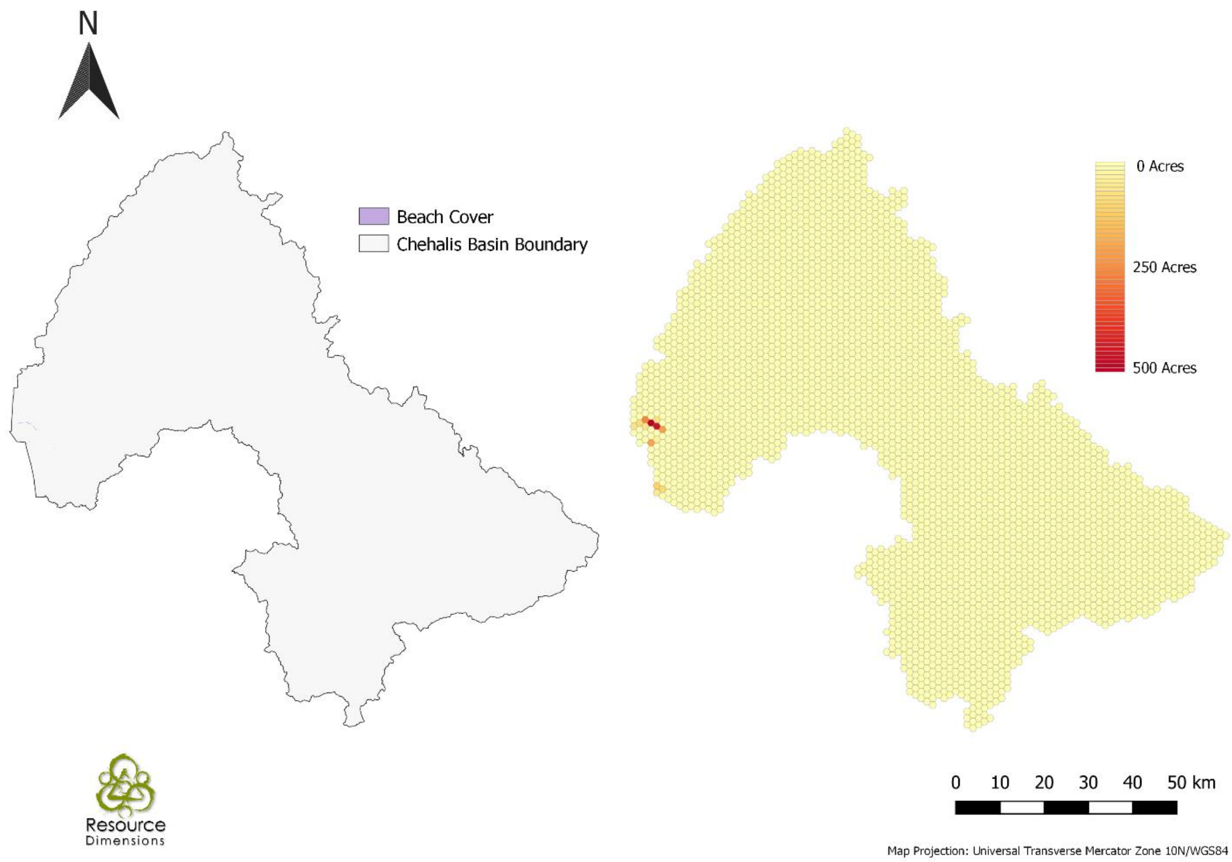
Source: Resource Dimensions, 2020.

4.2.1.10 Beach

Exclusively located in Grays Harbor County, beaches of the Chehalis Basin are primarily fine-grained sandy beaches (WSDE 2013a) —they are home to birds, grasses, crabs, clams, fish, tiny invertebrates, and more. Among the most heavily used recreational beaches in the state, these beaches also deliver many provisioning, regulating, societal/cultural and supporting ecosystem services (Figure 22). Such goods and services include the provision of food resources such as razor clams, natural hazards mitigation in the form of wave dissipation and associated buffering against extreme weather events and dynamic response to sea level rise, water filtration, nutrient cycling, maintenance

of biodiversity and genetic resources, scenic vistas and recreational opportunities, and functional links between terrestrial and marine environments (Defeo et al. 2009).

Figure 22. Beach Distribution and Intensity within the Chehalis Basin



Source: Resource Dimensions, 2020.

At 181 acres, beach cover represents just 0.01% of the Chehalis Basin ESV land/water cover. Yet, with per acre values ranging between $24, 856 to $109,478 in the lower bound model, and $26,129 to $116,390 in the upper bound model, per acre beach cover is the most valuable. This is largely due to the high per acre values attributable to natural hazards mitigation, aesthetic/amenity, and recreation/tourism services (Table 49).

Beach ecosystems here, as elsewhere, are affected by many different types of human pressures, from development to recreation, to coastal armoring and pollution. In addition, chronic stressors such as beach erosion, and extreme events associated with climate change, such as sea level rise and intense storms, can have severe impacts on beach ecosystems and their neighboring communities (Cutter et al. 2008).

To address associated functional impacts across the Chehalis Basin we calibrate for the "beach" variable in the ESV model using historical information about development and land conversion, information from NOAA's National Centers for Ocean and Coastal Science, the 2019 EDT model, and GIS data for location and density. Lower bound model coefficients range from 0.217 to 0.307, and from 0.188 to 0.822 in the upper bound model. See Appendix D for model factors.

The total annual ESV, per acre, for all services valued for Chehalis Basin beach cover range from about $4.5 million to $19.8 million at the lower bound, and at the upper bound between $4.7 million and $21 million (Table 49).

Table 49. Summary of Chehalis Basin Beach Ecosystem Values ($2019)

Ecosystem Services Provided		BEACH			
		Lower		Upper	
		Min	Max	Min	Max
Provisioning					
Food		$673	$673	$706	$706
Water Supply		-	-	-	-
Regulating					
Biological Control		-	-	-	-
Erosion Control		-	-	-	-
Gas & Climate Regulation		-	-	-	-
Natural Hazards Mitigation		$2,685	$31,027	$2,833	$32,740
Pollination		-	-	-	-
Soil Formation		-	-	-	-
Waste Treatment		-	-	-	-
Water Treatment & Quality		-	-	-	-
Water Regulation		-	-	-	-
Societal/Cultural					
Aesthetic/Amenity		$21	$44,241	$22	$47,706
Recreation/Tourism		$21,478	$33,536	$22,568	$35,238
Supporting					
Habitat and Nursery		-	-	-	-
Biodiversity/Genetic Resources		-	-	-	-
Total Acres	***181***				
***Total Annual Value** (\$/acre/yr)*		***$24,856***	***$109,478***	***$26,129***	***$116,390***
Total Annual Value		***$4,505,274***	***$19,842,969***	***$4,735,897***	***$21,095,890***

Source: Resource Dimensions, 2020.

4.2.1 Net Present Value Calculations

Net present value (NPV) is a calculation used to estimate the value—or net benefit—over the lifetime of a particular project, such as a dam or building a new community recreation center. NPV allows decision-makers to compare various alternatives on a similar time scale by converting all options to current dollar figures.

Thus, treating the annual flow of Chehalis Basin ecosystem service benefits as an asset, we calculate the range of asset values for the Basin's natural capital. The general form for calculating the NPV is:

$$NPV = \sum_{t=0}^{\infty} V_t W_t \qquad (2)$$

where V_t = the value of ecosystem services at that time t; W_t = the weight used to discount the service at time t.

For standard exponential discounting, Wt is exponentially decreasing into the future at the discount rate, r.

$$W_t = \left(\frac{1}{1+r}\right)^t \qquad (3)$$

Using a 100-year time horizon, the minimum value of Chehalis Basin ecosystem services amount to $16.9 billion to $213.5 billion using a 7% discount rate, or as high as $51.1 billion to $644.1 billion using a 2% discount rate (Table 50).

Table 50. Net Present Value of Chehalis Basin Natural Capital Over 100 Years

	ASSET VALUE			
	Low		High	
	2%	**7%**	**2%**	**7%**
Minimum	$49,148,681,066	$16,272,428,654	$53,023,502,383	$17,555,326,832
Maximum	$622,911,396,122	$206,237,095,910	$675,692,683,790	$223,712,228,898
Periods (years)	100	100	100	100
Annual Value	***$1,140,384,242***	***$14,453,253,371***	***$1,230,290,727***	***$15,677,924,052***

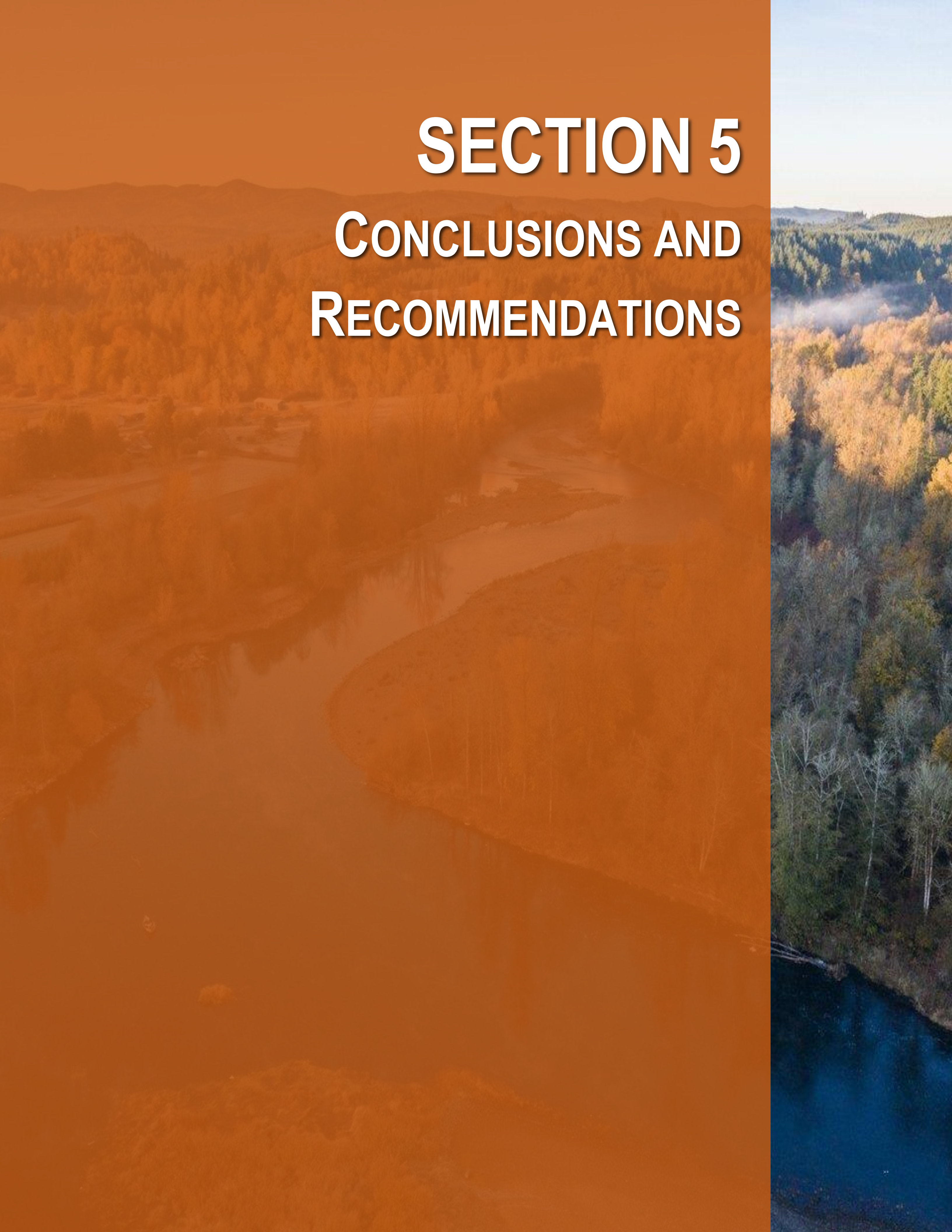
Source: Resource Dimensions, 2020.

This valuation is not exhaustive and does not include every ecosystem service across every land cover; thus, values here should be considered underestimates. Although conservative, these estimates reveal the substantial value of Chehalis Basin natural capital. These significant values show that investment in natural capital can deliver vast long-term benefits if these assets are protected or enhanced. Moreover, investment in natural capital can yield a tremendous ROI due to the low cost of investment (relative to building new assets) and because it supports a suite of ecosystem services and benefits, not just a single benefit.

[page intentionally left blank]

SECTION 5

CONCLUSIONS AND RECOMMENDATIONS



SECTION 5: CONCLUSION AND RECOMMENDATIONS

Recommendation 1

Complete localized valuation studies for the Chehalis Basin

While ESV is but one of the tools that provide the basis for decision-making about actions, it offers a common language and a meaningful way for biologists, ecologists, economists, engineers, communities, and other stakeholders to share values. Additionally, it presents a contextual way for decision-makers to understand and assess the economic trade-offs across potential alternative scenarios, the impacts of policy decisions, investing in natural capital, and establishing priorities for meeting various resource management objectives (e.g., land use decisions, watershed planning, habitat conservation, floodplain management, wetlands restoration projects). Though lagging are policies to forge greater regard and use of ESV and integrate those values into regulatory frameworks and decisions.

Ecosystem service valuation is Inherently interdisciplinary and pluralistic. Depending on the project site and respective goals, beyond the economist, ESV may require the input of a diverse team of experts – as in this study – from fields as biology, ecology, hydrology, forestry, wetland science, as well as stakeholders from the community, and more.

Recommendation 2

Include ESV into decision-making tools

The economy and communities of the Chehalis Basin are dependent upon the region's rich natural capital. Estimates presented in this report demonstrate the enormity of the economic value of the environmental benefits to the region. Despite the magnitude of these values, the full complement of goods and services are likely underestimated, as many invaluable ecosystem services were not able to able to be included. To more completely value the intricate interactions of ecosystem services, a focus of future efforts should include expansion of the work conducted here to a primary study for the Chehalis Basin.

Recommendation 3

Fill existing data gaps

Through the course of this study, a number of key data gaps were identified. Table 36 reflects areas where disparities exist for this ESV. With the evolution of ecosystem service valuation methods over the past several decades, ESV studies are increasingly used to support a variety of resource management, planning, and mitigation. One approach to advancing information of the current study would be to review the ongoing development of peer-reviewed findings in the literature and integrate new data into the ESV models developed for this study – essentially filling gaps as applicable. As mentioned above, there is also a need to invest in essential work to carry out site-specific primary valuation studies. *Areas of* *specific interest for future research and development for many ecosystem service values include scrub-shrublands, rivers and lakes (freshwater), and beach systems.* Table 36 serves as good reference when thinking about which land cover/ecosystem service categories should be given priority for future primary studies.

The largest levers in influencing ecosystem service values within the Basin lie in Beach, Rivers and Lakes, and Wetlands land/water cover classifications, which also hold some of the highest per acre ESV values, although together cover only about 16% of the region. Providing critical habitat for many aquatic species, these land cover classes are also especially susceptible to man-made disturbance and a changing climate. Area tribes also have deep cultural, subsistence and economic ties to the waters, species and resources they offer.

These land and water covers are also attached to the longstanding flooding issues the Chehalis Basin. The work of several local, state and federal agencies, nonprofit organizations, researchers, and area tribes over the past two decades has advanced a suite of approaches to flood damage reduction and aquatic species restoration in the Basin. The outsized cumulative ecosystem service values provided by this group of resource lands show that a more detailed, thorough understanding of the full economic value of this asset groups will be important to assessing and implementing the long-term flood reduction strategy for the Basin. Together, these land and water covers account for nearly 40% of the ecosystem service value in the Basin. Any action taken to alter flooding regimes will inevitably impact the extent and capacity for the provision of flood mitigation services.

Providing significant aesthetic/amenity and recreation/tourism values, beach cover is the single most valuable land cover type analyzed in this study. Ongoing threats to beaches include a changing sea level and encroachment of grasslands. Concerted efforts to maintain and restore existing beach cover will protect the production of ecosystem services into the future.

Forests

Deliver $539 million to $7.8 billion annually in services to the Chehalis Basin

While not the largest *per acre* contributor to the Basin's total annual ESV, forests account for nearly 54% of the land cover and produce nearly 50% the total annual economic contributions through ecosystem service provision. Among the most valuable services produced by the Basin's forest are

Recommendation 4

Conduct detailed assessment of changes in ecosystem service function

water regulation, water treatment and quality, biodiversity and genetic resources, and gas and climate regulation (Table 40).

We note that the scope of this project limited the ability to fully address the integration of methods and tools to enable the assessment, mapping and quantification of social values of ecosystem services, or conducting interviews, surveys, focus groups required to spatially identify and measure cultural ecosystem services in the Basin. *To more fully incorporate cultural values into the ESV process, it will be important that future research include identifying linkages between the existence of cultural value and biophysical services to support decision making with respect to flood damage reduction in the Chehalis Basin and avoid the potential for future cultural loses.*

Recommendation 5

Invest in natural capital

Area tribes have advocated for a comprehensive approach to assessing, planning and implementing flood risk reduction strategies to address the restoration of aquatic species and cumulative impacts associated with proposed approaches to minimize future losses from flooding. Values established in this study provide a baseline for such work. It should also be recognized that the ecosystems of the Basin have been altered over decades – in some areas profoundly degrading natural resources of importance to tribal communities. And, while much effort was given to addressing these issues in the development of this baseline, further work is warranted. The inclusion of ESVs into evaluation of the effects of major infrastructure projects on ecosystem services should be considered. *A detailed assessment of changes in ecosystem function should be conducted for the Basin, inclusive of cumulative effects analysis of ecosystem service change due to development.*

Investment in natural capital is crucial to the resilience, sustainability and health of the Chehalis Basin economy and its natural environment. *Protection of Basin resources should be considered as an important investment opportunity*. Investing in efforts to restore and maintain the region's ecosystems is key to the future health of the region's economy and a first step toward investing in natural capital. These initiatives can be effectively linked to economic resilience, community sustainability, and long-term job creation. *Without this investment and with compounding associated impacts, existing economic assets will be degraded.*

REFERENCES

Alex, R.K., 2016. tinai-Documentation as Ecocultural Ethnography: My Experience with the Mudugar. In Ecocriticism and Indigenous Studies (pp. 206-221). Routledge.

Amberson, S., Biedenweg, K., James, J. and Christie, P., 2016. “The heartbeat of our people”: identifying and measuring how salmon influences Quinault tribal well-being. Society & Natural Resources, 29(12), pp.1389-1404.

Balmford, A., Rodrigues, A., Walpole, M., Ten Brink, P., Kettunen, M., Braat, L. and De Groot, R., 2008. Review on the economics of biodiversity loss: scoping the science. European Commission, Cambridge, UK.

Barbier, E.B., Hacker, S.D., Kennedy, C., Koch, E.W., Stier, A.C. and Silliman, B.R., 2011. The value of estuarine and coastal ecosystem services. *Ecological monographs*, *81*(2), pp.169-193.

Batabyal, A.A., Kahn, J.R. and O'Neill, R.V., 2003. On the scarcity value of ecosystem services. Journal of Environmental Economics and Management, 46(2), pp.334-352.

Benayas, J.M.R., Newton, A.C., Diaz, A. and Bullock, J.M., 2009. Enhancement of biodiversity and ecosystem services by ecological restoration: a meta-analysis. science, 325(5944), pp.1121-1124.

Bengtsson, J., 2015. Biological control as an ecosystem service: partitioning contributions of nature and human inputs to yield. Ecological entomology, 40, pp.45-55.

Bengtsson, J., Bullock, J.M., Egoh, B., Everson, C., Everson, T., O'Connor, T., O'Farrell, P.J., Smith, H.G. and Lindborg, R., 2019. Grasslands—more important for ecosystem services than you might think. Ecosphere, 10(2), p.e02582.

Bertram, C. and Rehdanz, K., 2015. Preferences for cultural urban ecosystem services: Comparing attitudes, perception, and use. Ecosystem Services, 12, pp.187-199.

Biedenweg, K., Hanein, A., Nelson, K., Stiles, K., Wellman, K., Horowitz, J. and Vynne, S., 2014. Developing human wellbeing indicators in the Puget Sound: focusing on the watershed scale. Coastal Management, 42(4), pp.374-390.

Biedenweg, K. and Nelson, K., 2014. Developing Human Wellbeing Indicators in the Hood Canal Watershed.

Bolund, P. and Hunhammar, S., 1999. Ecosystem services in urban areas. Ecological economics, 29(2), pp.293-301.

Borde, A.B., Thom, R.M., Rumrill, S. and Miller, L.M., 2003. Geospatial habitat change analysis in Pacific Northwest coastal estuaries. Estuaries, 26(4), pp.1104-1116.

Boumans, R., Costanza, R., Farley, J., Wilson, M.A., Portela, R., Rotmans, J., Villa, F. and Grasso, M., 2002. Modeling the dynamics of the integrated earth system and the value of global ecosystem services using the GUMBO model. Ecological economics, 41(3), pp.529-560.

Boyd, J., 2010. Ecosystem services and climate adaptation. Issue Brief, pp.10-16.

Boyd, J. and Krupnick, A., 2013. Using ecological production theory to define and select environmental commodities for nonmarket valuation. Agricultural and Resource Economics Review, 42(1), pp.1-32.

Bryce, R., Irvine, K.N., Church, A., Fish, R., Ranger, S. and Kenter, J.O., 2016. Subjective well-being indicators for large-scale assessment of cultural ecosystem services. Ecosystem Services, 21, pp.258-269.

Carey, A.B., Thysell, D.R., Villa, L.J., Wilson, T.M., Wilson, S.M., Trappe, J.M., Colgan, W., Ingham, E.R. and Holmes, M., 1996. Foundations of biodiversity in managed Douglas-fir forests. In In: Peterson, DL; Klimas, CV The role of restoration in the ecosystem. Proceedings of the 2nd Symposium for ecological restoration. Madison, WI: Society for Ecological Restoration: 68-82.

Chan, K.M., Guerry, A.D., Balvanera, P., Klain, S., Satterfield, T., Basurto, X., Bostrom, A., Chuenpagdee, R., Gould, R., Halpern, B.S. and Hannahs, N., 2012. Where are cultural and social in ecosystem services? A framework for constructive engagement. BioScience, 62(8), pp.744-756.

Chehalis Basin Strategy PEIS, 2016a. Washington State Department of Ecology, SEPA Programmatic Environmental Impact Statement, Chapter 3: Affected Environment.

Chehalis Basin Strategy PEIS, 2016b. Washington State Department of Ecology, SEPA Programmatic Environmental Impact Statement, Appendix G Species and Habitat Information.

Chehalis Basin Strategy, 2019. Aquatic Species Restoration Plan (ASRP), Phase I: November 2019. Aquatic Species Restoration Plan Steering Committee. Publication #19-06-009.

Columbia River Inter-Tribal Fish Commission, 2017. Ecosystem-based function (paragraph 1).

Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'neill, R.V., Paruelo, J. and Raskin, R.G., 1997. The value of the world's ecosystem services and natural capital. *nature*, *387*(6630), pp.253-260.

Cuerrier, A., Turner, N.J., Gomes, T.C., Garibaldi, A. and Downing, A., 2015. Cultural keystone places: conservation and restoration in cultural landscapes. Journal of Ethnobiology, 35(3), pp.427-449.

Cutter, S.L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E. and Webb, J., 2008. A place-based model for understanding community resilience to natural disasters. Global environmental change, 18(4), pp.598-606.

Daily, G.C., 1997. *Nature's services* (Vol. 3). Island Press, Washington, DC.

Daniel, T.C., Muhar, A., Arnberger, A., Aznar, O., Boyd, J.W., Chan, K.M., Costanza, R., Elmqvist, T., Flint, C.G., Gobster, P.H. and Grêt-Regamey, A., 2012. Contributions of cultural services to the ecosystem services agenda. Proceedings of the National Academy of Sciences, 109(23), pp.8812-8819.

Defeo, O., McLachlan, A., Schoeman, D.S., Schlacher, T.A., Dugan, J., Jones, A., Lastra, M. and Scapini, F., 2009. Threats to sandy beach ecosystems: a review. Estuarine, coastal and shelf science, 81(1), pp.1-12.

De Groot, R.S., Wilson, M.A. and Boumans, R.M., 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological economics*, *41*(3), pp.393-408.

De Groot, R.D., Fisher, B., Christie, M., Aronson, J., Braat, L., Haines-Young, R., Gowdy, J., Maltby, E., Neuville, A., Polasky, S. and Portela, R., 2010. Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation. In The Economics of Ecosystems and Biodiversity (TEEB): Ecological and Economic Foundations (pp. 9-40). Earthscan, Routledge.

De la Torre, M. ed., 2002. Assessing the values of cultural heritage. Getty conservation institute.

Elmqvist, T., Setälä, H., Handel, S.N., Van Der Ploeg, S., Aronson, J., Blignaut, J.N., Gomez-Baggethun, E., Nowak, D.J., Kronenberg, J. and De Groot, R., 2015. Benefits of restoring ecosystem services in urban areas. Current opinion in environmental sustainability, 14, pp.101-108.

Engel, S., Pagiola, S. and Wunder, S., 2008. Designing payments for environmental services in theory and practice: An overview of the issues. Ecological economics, 65(4), pp.663-674.

ESD (Washington State Employment Security Department). 2019a. County Data Tables, Population Estimates and Projections, 1960-2040. Retrieved March 20, 2020. https://esd.wa.gov/labormarketinfo/county-profiles

ESD (Washington State Employment Security Department). 2019b. County Data Tables, Population Growth Rate Percentages. Retrieved March 20, 2020. https://esd.wa.gov/labormarketinfo/county-profiles

ESD (Washington State Employment Security Department). 2019c. County Data Tables, Labor Area Unemployment Statistics. Retrieved March 20, 2020. https://esd.wa.gov/labormarketinfo/county-profiles

ESD (Washington State Employment Security Department). 2019d. County Data Tables, Pacific Mountain Ten-Year Occupational Employment Projections. Retrieved March 20, 2020. https://esd.wa.gov/labormarketinfo/county-profilesFrederick, S., Loewenstein, G. and O'donoghue, T., 2002. Time discounting and time preference: A critical review. Journal of economic literature, 40(2), pp.351-401.

Forster, P., Ramaswamy, V., Artaxo, P., Berntsen, T., Betts, R., Fahey, D.W., Haywood, J., Lean, J., Lowe, D.C., Myhre, G. and Nganga, J., 2007. Changes in atmospheric constituents and in radiative forcing. Chapter 2. In *Climate Change 2007. The Physical Science Basis*.

Franklin, J.F., Spies, T.A., Van Pelt, R., Carey, A.B., Thornburgh, D.A., Berg, D.R., Lindenmayer, D.B., Harmon, M.E., Keeton, W.S., Shaw, D.C. and Bible, K., 2002. Disturbances and structural development of natural forest ecosystems with silvicultural implications, using Douglas-fir forests as an example. Forest Ecology and Management, 155(1-3), pp.399-423.

Frederick, S., Loewenstein, G. and O'donoghue, T., 2002. Time discounting and time preference: A critical review. *Journal of economic literature*, *40*(2), pp.351-401.

Gendaszek, A.S., 2011. Hydrogeologic framework and groundwater/surfacewater interactions of the Chehalis River Basin, southwestern Washington. US Geological Survey, Tacoma, Washington.

Grays Harbor County (GHC). 2001. Grays Harbor County Comprehensive Flood Management Plan, Section 3. 26 pp. Retrieved August 5th, 2015. http://www.co.grays-harbor.wa.us/info/pub_svcs/CompLandUse/pdf/Volume%202/05_SECTION%203.pdf

Grays Harbor County Commissioners (GHCC). 1992. Grays Harbor County Interim Resource Lands and Critical Areas Designation. 18 pp. Retrieved August 1st, 2015. http://www.co.grays-harbor.wa.us/info/pub_svcs/PlanningDocs/PDF/CriticalAreasDesignation.pdf

Grays Harbor County 2018 Multi-Jurisdiction Hazard Mitigation Plan Update Volume 1: Planning-Area-Wide Elements.

Gustanski, J. A., Scarsella, D., 2015. Economic Impacts of Crude Oil Transport on the Quinault Indian National and the Local Economy. Resource Dimensions, Gig Harbor, WA.

Gustanski, J. A., Scarsella, D., Scofield, A., 2015. Economic Impacts of Crude Oil Transport on the Grays Harbor Economy. Resource Dimensions, Gig Harbor, WA.

Gustanski, J. A., Hayes, M.M., Taylor, D. T., Scofield, A., Coupal, R., Scarsella, D., 2018. Economic Impact Assessment: Effects of Proposed Gateway Pacific Terminal on the Lummi Nation and the Local Economy. Resource Dimensions, Gig Harbor, WA.

Harnik, P. and Welle, B.J., 2009. Measuring the economic value of a city park system. Trust for Public Land.

Irvine, K.N., O'Brien, L., Ravenscroft, N., Cooper, N., Everard, M., Fazey, I., Reed, M.S. and Kenter, J.O., 2016. Ecosystem services and the idea of shared values. Ecosystem Services, 21, pp.184-193.

Jenkins, M. and Schaap, B. Forest Ecosystem Services. Study prepared for the thirteenth session of the United Nations Forum on Forests. April, 2018.

Keeler, B.L., Polasky, S., Brauman, K.A., Johnson, K.A., Finlay, J.C., O'Neill, A., Kovacs, K. and Dalzell, B., 2012. Linking water quality and well-being for improved assessment and valuation of ecosystem services. *Proceedings of the National Academy of Sciences*, *109*(45), pp.18619-18624.

Kremen, C., Williams, N.M., Aizen, M.A., Gemmill-Herren, B., LeBuhn, G., Minckley, R., Packer, L., Potts, S.G., Roulston, T.A., Steffan-Dewenter, I. and Vázquez, D.P., 2007. Pollination and other ecosystem services produced by mobile organisms: a conceptual framework for the effects of land-use change. *Ecology letters*, *10*(4), pp.299-314.

Kumar, P., 2012. The economics of ecosystems and biodiversity: ecological and economic foundations. Routledge.

Landers, D.H. and Nahlik, A.M., 2013. Final ecosystem goods and services classification system (FEGS-CS). Anonymous EPA United States Environmental Protection Agency. Report Number EPA/600/R-13/ORD-004914.

Loomis, J.B., 1992. The evolution of a more rigorous approach to benefit transfer: benefit function transfer. Water Resources Research, 28(3), pp.701-705.

Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Muradian, R., Arsel, M., Pellegrini, L., Adaman, F., Aguilar, B., Agarwal, B., Corbera, E., Ezzine de Blas, D., Farley, J., Froger, G. and Garcia-Frapolli, E., 2013. Payments for ecosystem services and the fatal attraction of win-win solutions. Conservation letters, 6(4), pp.274-279.

National Oceanic and Atmospheric Administration, Office for Coastal Management, 2016. "C-CAP Regional Land Cover" Coastal Change Analysis Program (C-CAP) Regional Land Cover. Charleston, SC: NOAA Office for Coastal Management. Accessed January 2018 at www.coast.noaa.gov/ccap.ftp.

National Research Council (NRC), 2013. An ecosystem services approach to assessing the impacts of the Deepwater Horizon oil spill in the Gulf of Mexico. National Academies Press.

Nellemann, C. and Corcoran, E., 2010. Dead planet, living planet: Biodiversity and ecosystem restoration for sustainable development: a rapid response assessment. UNEP/Earthprint.

Nicholls, S. and Crompton, J.L., 2005. The impact of greenways on property values: Evidence from Austin, Texas. Journal of Leisure Research, 37(3), pp.321-341.

Oades, J.M., 1988. The retention of organic matter in soils. *Biogeochemistry*, *5*(1), pp.35-70.

OMB, United States. 1992. Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs. OMB Circular A-94. Washington, D.C. Accessed January 20, 2020

OMB, United States, 2000. Guidelines to Standardize Measures of Costs and Benefits and the Format of Accounting Statements.

Pendleton, L.H., 2009. The economic value of coastal and estuary recreation. The economic and market value of coasts and Estuaries: What's at stake, pp.140-175.

Pimentel, D., Harvey, C., Resosudarmo, P., Sinclair, K., Kurz, D., McNair, M., Crist, S., Shpritz, L., Fitton, L., Saffouri, R. and Blair, R., 1995. Environmental and economic costs of soil erosion and conservation benefits. *Science*, *267*(5201), pp.1117-1123.

Plieninger, T., Dijks, S., Oteros-Rozas, E., Bieling, C., 2013. Assessing, mapping, and quantifying cultural ecosystem services at community level. Land Use Policy 33:118–29

Reid, W.V., Mooney, H.A., Cropper, A., Capistrano, D., Carpenter, S.R., Chopra, K., Dasgupta, P., Dietz, T., Duraiappah, A.K., Hassan, R. and Kasperson, R., 2005. Ecosystems and human well-being-Synthesis: A report of the Millennium Ecosystem Assessment. Island Press.

Ringold, P.L., Boyd, J., Landers, D. and Weber, M., 2013. What data should we collect? A framework for identifying indicators of ecosystem contributions to human well-being. Frontiers in Ecology and the Environment, 11(2), pp.98-105.

Rosenberger, R.S., Johnston, R., 2013. Benefit Transfer. In: Encyclopedia of Energy, Natural Resource, and Environmental Economics. Elsevier, Amsterdam: 327–333.

Rosenberger, R., Loomis, J., 2003. Benefit Transfer, in: Champ, P., Boyle, K., Brown, T. (Eds.), A Primer on Nonmarket Valuation. Kluwer Academic Publishers, Boston.

Ruggerio, L.F., Aubry, K.B., Carey, A.B. and Huff, M.H., 1991. General technical report PNW-GTR-285. Wildlife and vegetation of unmanaged Douglas-fir Forests.

Ryan, Teresa Loa., 2000. Defining cultural resources: Science, law, and resource management for sweetgrass (Schoenoplectus pungens) in Grays Harbor, Washington.

Small, N., Munday, M. and Durance, I., 2017. The challenge of valuing ecosystem services that have no material benefits. Global Environmental Change, 44, pp.57-67.

Smith, P., Ashmore, M.R., Black, H.I., Burgess, P.J., Evans, C.D., Quine, T.A., Thomson, A.M., Hicks, K. and Orr, H.G., 2013. The role of ecosystems and their management in regulating climate, and soil, water and air quality. *Journal of Applied Ecology*, *50*(4), pp.812-829.

Solow, R.M., 1986. On the intergenerational allocation of natural resources. The Scandinavian Journal of Economics, pp.141-149.

Sommerville, M.M., Jones, J.P. and Milner-Gulland, E.J., 2009. A revised conceptual framework for payments for environmental services. Ecology and society, 14(2).

TEEB, 2010. The Economics of Ecosystem Services and Biodiversity. Earthscan, London

TEEB, 2011. The Economics of Ecosystem Services and Biodiversity. Earthscan, London

Thurston County Voluntary Stewardship Program Work Plan. Appendix H – Watershed Plans and Baseline Conditions (2017)

Tratalos, J., Fuller, R.A., Warren, P.H., Davies, R.G. and Gaston, K.J., 2007. Urban form, biodiversity potential and ecosystem services. Landscape and urban planning, 83(4), pp.308-317.

Turner, K., Badura, T. and Ferrini, S., 2019. Natural capital accounting perspectives: a pragmatic way forward. Ecosystem Health and Sustainability, 5(1), pp.237-241.

USCB (United States Census Bureau). 2010. American Fact Finder, Census Summary File 1, Population, Housing Units, Area, and Density: 2010-State-County/County Equivalent. Retrieved March 20, 2020.

USCB (United States Census Bureau). 2020. American Fact Finder, 2014 Geographic Identifiers. Retrieved March 20, 2020.

USCB (United States Census Bureau). 2020a. 2013-2018 5-Year American Community Survey, ACS Demographic and Housing Estimates. Retrieved March 20, 2020. https://www.census.gov/acs/www/data/data-tables-and-tools/data-profiles/2015/

USCB (United States Census Bureau). 2020b. 2013-2018 5-Year American Community Survey, Selected Social Characteristics. Retrieved March 20, 2020.

USCB (United States Census Bureau). 2020c. 2013-2018 5-Year American Community Survey, Selected Economic Characteristics. Retrieved March 20, 2020.

USCB (United States Census Bureau). 2020d. 2013-2018 5-Year American Community Survey, Selected Housing Characteristics. Retrieved March 20, 2020.

USCB (United States Census Bureau). 2016. American Fact Finder, 2016 Business Patterns. Retrieved Retrieved March 20, 2020.

USDOI (U.S. Department of Interior). 1994. Natural Resource Damage Assessments; Final Rule. 43 CFR Part 11. Federal Register 59 (58):14262-14288.

USEPA (United States Environmental Protection Agency).2000. Guidelines for Preparing Economic Analyses. 227 pp. Retrieved January 20, 2020.

Wartmann, F.M. and Purves, R.S., 2018. Investigating sense of place as a cultural ecosystem service in different landscapes through the lens of language. Landscape and Urban Planning, 175, pp.169-183.

WSDE (Washington State Department of Ecology). 2010. 2010 Statewide Landuse. Retrieved May 11, 2017. http://www.ecy.wa.gov/services/gis/data/data.htm

Wunder, S., 2015. Revisiting the concept of payments for environmental services. Ecological Economics, 117, pp.234-243.

Zawadzka, J., Gallagher, E., Smith, H. and Corstanje, R., 2019. Ecosystem services from combined natural and engineered water and wastewater treatment systems: Going beyond water quality enhancement. Ecological Engineering: X, 2, p.100006.

Zhang, W. and Swinton, S.M., 2012. Optimal control of soybean aphid in the presence of natural enemies and the implied value of their ecosystem services. Journal of environmental management, 96(1), pp.7-16.

APPENDICES

APPENDIX A. SPATIAL INVENTORY

Table A-1. Spatial Data Sources For Chehalis Basin Study

Data Type	Title	FileName	FileFormat	URL
State Boundary	USGS National Boundary Dataset (NBD) for WashingtonWashington 20161027 State or Territory Shapefile	GOVTUNIT_53_Washington_GU_STATEORTERRITORY	Shapefile	https://prd-tnm.s3.amazonaws.com/StagedProducts/GovtUnit/Shape/GOVTUNIT_53_Washington_GU_STATEORTERRITORY.zip
Elevation	USGS NED n47w124 1/3 arc-second 2013 1 x 1 degree IMG	n47w124	IMG	https://prd-tnm.s3.amazonaws.com/StagedProducts/Elevation/13/IMG/n47w124.zip
Elevation	USGS NED n47w123 1/3 arc-second 2013 1 x 1 degree IMG	n47w123	IMG	https://prd-tnm.s3.amazonaws.com/StagedProducts/Elevation/13/IMG/n47w123.zip
Elevation	USGS NED 1/3 arc-second n48w124 1 x 1 degree IMG 2015	USGS_NED_13_n48w124_IMG	IMG	https://prd-tnm.s3.amazonaws.com/StagedProducts/Elevation/13/IMG/USGS_NED_13_n48w124_IMG.zip
Elevation	USGS NED n47w125 1/3 arc-second 2013 1 x 1 degree IMG	n47w125	IMG	https://prd-tnm.s3.amazonaws.com/StagedProducts/Elevation/13/IMG/n47w125.zip
Elevation	USGS NED n48w123 1/3 arc-second 2013 1 x 1 degree IMG	n48w123	IMG	https://prd-tnm.s3.amazonaws.com/StagedProducts/Elevation/13/IMG/n48w123.zip
Elevation	USGS NED 1/3 arc-second n48w125 1 x 1 degree IMG 2015	USGS_NED_13_n48w125_IMG	IMG	https://prd-tnm.s3.amazonaws.com/StagedProducts/Elevation/13/IMG/USGS_NED_13_n48w125_IMG.zip
Structures	USGS National Structures Dataset (NSD) for Washington 20160728 State or Territory Shapefile	STRUCT_53_Washington_GU_STATEORTERRITORY	Shapefile	https://prd-tnm.s3.amazonaws.com/StagedProducts/Struct/Shape/STRUCT_53_Washington_GU_STATEORTERRITORY.zip
Structures	USGS National Structures Dataset (NSD) for Washington 20160728 State or Territory Shapefile	STRUCT_53_Washington_GU_STATEORTERRITORY	Shapefile	https://prd-tnm.s3.amazonaws.com/StagedProducts/Struct/Shape/STRUCT_53_Washington_GU_STATEORTERRITORY.zip
Structures	USGS National Structures Dataset (NSD) for Oregon 20160728 State or Territory Shapefile	STRUCT_41_Oregon_GU_STATEORTERRITORY	Shapefile	https://prd-tnm.s3.amazonaws.com/StagedProducts/Struct/Shape/STRUCT_41_Oregon_GU_STATEORTERRITORY.zip
Structures	USGS National Structures Dataset (NSD) for Oregon 20160728 State or Territory Shapefile	STRUCT_41_Oregon_GU_STATEORTERRITORY	Shapefile	https://prd-tnm.s3.amazonaws.com/StagedProducts/Struct/Shape/STRUCT_41_Oregon_GU_STATEORTERRITORY.zip

Data Type	Title	FileName	FileFormat	URL
Structures	USGS National Structures Dataset (NSD) for Oregon 20160728 State or Territory Shapefile	STRUCT_41_Oregon_GU_STATEORTERRITORY	Shapefile	https://prd-tnm.s3.amazonaws.com/StagedProducts/Struct/Shape/STRUCT_41_Oregon_GU_STATEORTERRITORY.zip
Roads	53_Washington_Shape	53_Washington_Shape	Shapefile	ftp://rockyftp.cr.usgs.gov/vdelivery/Datasets/Staged/FSRoads/Shape/53_Washington_Shape.zip
Roads	USGS National Transportation Dataset (NTD) for Washington 20160402 State or Territory Shapefile	TRAN_53_Washington_GU_STATEORTERRITORY	Shapefile	https://prd-tnm.s3.amazonaws.com/StagedProducts/Tran/Shape/TRAN_53_Washington_GU_STATEORTERRITORY.zip
Roads	53_Washington_FileGDB_10	53_Washington_FileGDB_10	FileGDB 10.1	ftp://rockyftp.cr.usgs.gov/vdelivery/Datasets/Staged/FSRoads/GDB/53_Washington_FileGDB_10.1.zip
Roads	53_Washington_Shape	53_Washington_Shape	Shapefile	ftp://rockyftp.cr.usgs.gov/vdelivery/Datasets/Staged/FSRoads/Shape/53_Washington_Shape.zip
Roads	53_Washington_FileGDB_10	53_Washington_FileGDB_10	FileGDB 10.1	ftp://rockyftp.cr.usgs.gov/vdelivery/Datasets/Staged/FSRoads/GDB/53_Washington_FileGDB_10.1.zip
Roads	USGS National Transportation Dataset (NTD) for Washington 20160402 State or Territory FileGDB 10.1	TRAN_53_Washington_GU_STATEORTERRITORY	FileGDB 10.1	https://prd-tnm.s3.amazonaws.com/StagedProducts/Tran/GDB/TRAN_53_Washington_GU_STATEORTERRITORY.zip
Roads	USGS National Transportation Dataset (NTD) FileGDB 10.1	National_Transportation	FileGDB 10.1	https://prd-tnm.s3.amazonaws.com/StagedProducts/Tran/GDB/National_Transportation.gdb.zip
Landcover	C-CAP Regional Land Cover and Change	CCAP 2016	IMG	https://coast.noaa.gov/htdata/CCAP/ccap_regional_dates/WA_2016_CCAP_land_cover_20180215.zip
Shorezone Boundaries	Washington Shorezone Dataset	Shorezone	Shapefile	https://opendata.arcgis.com/datasets/36fc7f33340c4d9ca5497d2ab8e2984a_51.zip?outSR=%7B%22latestWkid%22%3A3857%2C%22wkid%22%3A102100%7D
NHD Flowline	Washington High Resolution National Hydrography Dataset	NHD	Shapefile	https://fortress.wa.gov/ecy/gispublic/DataDownload/ECY_WAT_NHDWA.zip
NHD Waterbody	Washington High Resolution National Hydrography Dataset	NHD	Shapefile	https://fortress.wa.gov/ecy/gispublic/DataDownload/ECY_WAT_NHDWA.zip
Ecoregions	High Resolution Ecoregions	Ecoregions	Shapefile	Tim Beechie Email in Email Docs

APPENDIX B. LAND COVER CLASSIFICATION

Table B-1. Resource Dimensions Land Cover Grouping For Valuation

Land Cover Class (assigned for ecosystem service valuation)	Original C-CAP cover class	Acres
Barren	Bare Land	39,270
	Perennial Ice/Snow	
Beach	Beach	181
Cropland	Cultivated Crops	14,967
Developed/Urban	Developed, High Intensity	44,442
	Developed, Medium Intensity	
	Developed, Low Intensity	
Estuary	Estuary	59,989
	Estuarine Aquatic Bed	
	Unconsolidated shore	
Forest	Evergreen forest	887,280
	Mixed forest	
	Deciduous forest	
	Palustrine Forested Wetland*	
	Estuarine Forested Wetland*	
Grassland	Grassland	136,598
Lakes & Rivers	Open Water	12,349
Pasture	Pasture/Hay	79,036
Scrub/Shrub	Scrub/Shrub	353,956
Urban Greenspace	Developed, Open Space	13,335
Wetland[2]	Delta scrub/shrub wetland	89,636
	Delta Emergent Wetland	
	Palustrine Forested Wetland*	
	Palustrine Scrub/Shrub Wetland	
	Palustrine Emergent Wetland	
	Estuarine Forested Wetland*	
	Estuarine Scrub/Shrub Wetland	
	Estuarine Emergent Wetland	
	Palustrine Aquatic Bed	
	Total Acres	**1,731,040**

Table B-2. NOAA Landcover Groupings for Stratification of Stream Reaches

Land Cover Class (assigned for monitoring program)	**Original C-CAP cover class**	**Acres**
Bare Land	Bare Land	528,635
	Grassland	
	Scrub/shrub	
	Snow/Ice	
	Tundra	
	Unclassified	
Agriculture	Cultivated Land	94,114
	Pasture/Hay	
Forest	Deciduous forest	927,956
	Evergreen forest	
	Mixed forest	
	Palustrine forested wetland	
	Estuarine forested wetland	
Developed	Developed, Open Space	57,098
	Developed, High Intensity	
	Developed, Medium Intensity	
	Developed, Low Intensity	
Water/Other	Open water	72,771
	Unconsolidated shore	
	Palustrine aquatic bed	
	Estuarine aquatic bed	
Wetland	Palustrine scrub/shrub wetland	50,465
	Palustrine emergent wetland	
	Delta scrub/shrub wetland	
	Delta emergent wetland	
	Total Acres	**1,731,040**

APPENDIX C. VALUE TRANSFER STUDY REFERENCES

Allen, J., 1992. *The Value of California Wetlands: An Analysis of their Economic Benefits*.

Alvarez-Farizo, B., 1999. Estimating the benefits of agri-environmental policy: econometric issues in open-ended contingent valuation studies. *Journal of Environmental Planning and Management*, *42*(1), pp.23-43.

Amacher, G.S., Brazee, R.J., Bulkley, J.W. and Moll, R.A., 1989. *Application of wetland valuation techniques: Examples from Great Lakes Coastal wetlands* (No. PB-90-112319/XAB). Michigan State Univ., East Lansing, MI (USA). Inst. of Water Research.

Anderson, G.D. and Edwards, S.F., 1986. Protecting Rhode Island's coastal salt ponds: an economic assessment of downzoning. *Coastal Management*, *14*(1-2), pp.67-91.

Anielski, M. and Wilson, S., 2005. Counting Canada's natural capital. *Assessing the real value of Canada's boreal ecosystems. The Pembina Institute. Saatavissa: http://pubs. pembina. org/reports/Boreal_FINAL. pdf.[Viitattu 26.3. 2009]*.

Apsalyamova, S.O., Khashir, B.O., Khuazhev, O.Z., Tkhagapso, M.B. and Bgane, Y.K., 2015. The economic value of forest ecosystem services. *Journal of Environmental Management & Tourism*, *6*(2 (12)), p.291.

Armstrong, D.A., Rooper, C. and Gunderson, D., 2003. Estuarine production of juvenile Dungeness crab (Cancer magister) and contribution to the Oregon-Washington coastal fishery. *Estuaries*, *26*(4), p.1174.

Azar, C. and Sterner, T., 1996. Discounting and distributional considerations in the context of global warming. *Ecological Economics*, *19*(2), pp.169-184.

Barrow, C.J., 1991. *Land degradation: development and breakdown of terrestrial environments*. Cambridge University Press.

Batie, S.S. and Wilson, J.R., 1978. Economic values attributable to Virginia's coastal wetlands as inputs in oyster production. *Journal of Agricultural and Applied Economics*, *10*(1), pp.111-118.

Bell, F.W., 1989. Application of wetland valuation theory to Florida fisheries. *Tallahassee, Florida: Department of Economics, Florida State University*.

Bell, F.W., 1997. The economic valuation of saltwater marsh supporting marine recreational fishing in the southeastern United States. *Ecological Economics*, *21*(3), pp.243-254.

Bennett, R., Tranter, R., Beard, N. and Jones, P., 1995. The value of footpath provision in the countryside: a case-study of public access to urban-fringe woodland. *Journal of Environmental Planning and Management*, *38*(3), pp.409-418.

Bergstrom, J.C., Stoll, J.R., Titre, J.P. and Wright, V.L., 1990. Economic value of wetlands-based recreation. *Ecological economics*, *2*(2), pp.129-147.

Birdsey, R.A., 1996. Regional estimates of timber volume and forest carbon for fully stocked timberland, average management after final clearcut harvest. *Forests and global change*, *2*, pp.309-334.

Bishop, K., 1992. Assessing the benefits of community forests: an evaluation of the recreational use benefits of two urban fringe woodlands. *Journal of environmental planning and management*, *35*(1), pp.63-76.

Bockstael, N.E., McConnell, K.E. and Strand, I.E., 1989. Measuring the benefits of improvements in water quality: the Chesapeake Bay. *Marine Resource Economics*, *6*(1), pp.1-18.

Bouwes, N.W. and Schneider, R., 1979. Procedures in estimating benefits of water quality change. *American Journal of Agricultural Economics*, *61*(3), pp.535-539.

Boxall, P.C., McFarlane, B.L. and Gartrell, M., 1996. An aggregate travel cost approach to valuing forest recreation at managed sites. *The Forestry Chronicle*, *72*(6), pp.615-621.

Breaux, A., Farber, S. and Day, J., 1995. Using natural coastal wetlands systems for wastewater treatment: an economic benefit analysis. *Journal of environmental management*, *44*(3), pp.285-291.

Brookshire, D.S., Thayer, M.A., Schulze, W.D. and d'Arge, R.C., 1982. Valuing public goods: a comparison of survey and hedonic approaches. *The American Economic Review*, *72*(1), pp.165-177.

Bureau of Census. 1995. Census of Agriculture. Washington D.C.

Burt, O.R. and Brewer, D., 1971. Estimation of net social benefits from outdoor recreation. *Econometrica: Journal of the Econometric Society*, pp.813-827.

Collins, A., Rosenberger, R. and Fletcher, J., 2005. The economic value of stream restoration. *Water resources research*, *41*(2).

Cordell, H.K. and Bergstrom, J.C., 1993. Comparison of recreation use values among alternative reservoir water level management scenarios. *Water Resources Research*, *29*(2), pp.247-258.

Coreil, P.D., 1993. Wetlands functions and values in Louisiana. *Pub.(Louisiana Cooperative Extension Service)(USA)*.

Costanza, R., Farber, S.C. and Maxwell, J., 1989. Valuation and management of wetland ecosystems. *Ecological economics*, *1*(4), pp.335-361.

Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'neill, R.V., Paruelo, J. and Raskin, R.G., 1997. The value of the world's ecosystem services and natural capital. *nature*, *387*(6630), pp.253-260.

Creel, M. and Loomis, J., 1992. Recreation value of water to wetlands in the San Joaquin Valley: Linked multinomial logit and count data trip frequency models. *Water resources research*, *28*(10), pp.2597-2606.

Croke, K., Fabian, R. and Brenninam, G., 1987. Estimating the value of improved water quality in an urban river system. *Journal of Environmental Systems*, *16*(1), pp.13-24.

Curtis, I.A., 2004. Valuing ecosystem goods and services: a new approach using a surrogate market and the combination of a multiple criteria analysis and a Delphi panel to assign weights to the attributes. *Ecological Economics*, *50*(3-4), pp.163-194.

David, J.N., 2002. Compensatory value of urban trees in the United States. *Journal of Arboriculture*, *28*(40), pp.194-199.

De Groot, R.S., Wilson, M.A. and Boumans, R.M., 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological economics*, *41*(3), pp.393-408.

De Groot, R., Brander, L., Van Der Ploeg, S., Costanza, R., Bernard, F., Braat, L., Christie, M., Crossman, N., Ghermandi, A., Hein, L. and Hussain, S., 2012. Global estimates of the value of ecosystems and their services in monetary units. *Ecosystem services*, *1*(1), pp.50-61.

Doss, C.R. and Taff, S.J., 1996. The influence of wetland type and wetland proximity on residential property values. *Journal of agricultural and resource economics*, pp.120-129.

Dugan, P. and Dugan, P.J. eds., 1990. *Wetland conservation: A review of current issues and required action*. IUCN.

Edwards, S.F. and Gable, F.J., 1991. Estimating the value of beach recreation from property values: an exploration with comparisons to nourishment costs. *Ocean and Shoreline Management*, *15*(1), pp.37-55.

Fankhauser, S., 1994. The social costs of greenhouse gas emissions: an expected value approach. *The Energy Journal*, *15*(2).

Farber, S., 1987. The economic value of wetlands systems. *J. Environ. Manage*, *24*, pp.41-51.

Farber, S., 1996. Welfare loss of wetlands disintegration: A Louisiana study. *Contemporary Economic Policy*, *14*(1), pp.92-106.

Gibbons, D.C. and Gibbons, D.C., 1986. *The economic value of water*. Resources for the Future.

Gosselink, J.G., Odum, E.P. and Pope, R.M., 1974. The Value of the Tidal Marsh, Center for Wetland Resources. *Louisiana State University, LSU-SG-74-03*.

Gren, M. and Söderqvist, T., 1994. *Economic valuation of wetlands: a survey* (No. 54). Beijer International Institute of Ecological Economics, The Royal Swedish Academy of Sciences.

Gupta, T.R. and Foster, J.H., 1975. Economic criteria for freshwater wetland policy in Massachusetts. *American Journal of Agricultural Economics*, *57*(1), pp.40-45.

Haener, M.K. and Adamowicz, W.L., 1998. Analysis of “don't know” responses to referendum contingent valuation questions. *Agricultural and Resource Economics Review*, *27*(2), pp.218-230.

Hayes, K.M., Tyrrell, T.J., Tyrell, T.J. and Anderson, G., 1992. Estimating the benefits of water quality improvements in the Upper Narragansett Bay. *Marine Resource Economics*, *7*(1), pp.75-85.

Henry, R., Ley, R. and Welle, P., 1988. The economic value of water resources: the Lake Bemidji survey. *Journal of the Minnesota Academy of Science (USA)*.

Hope, C. and Maul, P., 1996. Valuing the impact of CO2 emissions. *Energy Policy*, *24*(3), pp.211-219.

Hougner, C., Colding, J. and Söderqvist, T., 2006. Economic valuation of a seed dispersal service in the Stockholm National Urban Park, Sweden. *Ecological economics*, *59*(3), pp.364-374.

Hughes, Z. 2006. Ecological and economic assessment of potential eelgrass expansion at Sucia Island, WA.

Ingraham, M.W. and Foster, S.G., 2008. The value of ecosystem services provided by the US National Wildlife Refuge System in the contiguous US. *Ecological Economics*, *67*(4), pp.608-618.

Jenkins, W.A., Murray, B.C., Kramer, R.A. and Faulkner, S.P., 2010. Valuing ecosystem services from wetlands restoration in the Mississippi Alluvial Valley. *Ecological Economics*, *69*(5), pp.1051-1061.

Johnston, R.J., Grigalunas, T.A., Opaluch, J.J., Mazzotta, M. and Diamantedes, J., 2002. Valuing estuarine resource services using economic and ecological models: the Peconic Estuary System study. *Coastal Management*, *30*(1), pp.47-65.

Johnston, R.J., Magnusson, G., Mazzotta, M.J. and Opaluch, J.J., 2002. The economics of wetland ecosystem restoration and mitigation: combining economic and ecological indicators to prioritize salt marsh restoration actions. *American Journal of Agricultural Economics*, *84*, pp.1362-1370.

Kahn, J.R. and Buerger, R.B., 1994. Valuation and the consequences of multiple sources of environmental deterioration: the case of the New York striped bass fishery. *Journal of environmental management*, *40*(3), pp.257-273.

Kenyon, W. and Nevin, C., 2001. The use of economic and participatory approaches to assess forest development: a case study in the Ettrick Valley. *Forest policy and economics*, *3*(1-2), pp.69-80.

Kline, J.D. and Swallow, S.K., 1998. The demand for local access to coastal recreation in southern New England. *Coastal Management*, *26*(3), pp.177-190.

Knoche, S. and Lupi, F., 2007. Valuing deer hunting ecosystem services from farm landscapes. *Ecological economics*, *64*(2), pp.313-320.

Knowler, D.J., MacGregor, B.W., Bradford, M.J. and Peterman, R.M., 2003. Valuing freshwater salmon habitat on the west coast of Canada. *Journal of Environmental Management*, *69*(3), pp.261-273.

Kreutzwiser, R., 1981. The economic significance of the Long Point marsh, Lake Erie, as a recreational resource. *Journal of Great Lakes Research*, *7*(2), pp.105-110.

Lant, C.L. and Roberts, R.S., 1990. Greenbelts in the Cornbelt: riparian wetlands, intrinsic values, and market failure. *Environment and Planning A*, *22*(10), pp.1375-1388.

Leggett, C.G. and Bockstael, N.E., 2000. Evidence of the effects of water quality on residential land prices. *Journal of Environmental Economics and Management*, *39*(2), pp.121-144.

Leschine, T.M., Wellman, K.F. and Green, T.H., 1997. *The economic value of wetlands: wetlands' role in flood protection in Western Washington*. Washington State Department of Ecology.

Liu, Z., 2006. *Water quality simulation and economic valuation of riparian land-use changes* (Doctoral dissertation, University of Cincinnati).

Loomis, J., Kent, P., Strange, L., Fausch, K. and Covich, A., 2000. Measuring the total economic value of restoring ecosystem services in an impaired river Basin: results from a contingent valuation survey. *Ecological economics*, *33*(1), pp.103-117.

Maddison, D., 1995. A cost-benefit analysis of slowing climate change. *Energy policy*, *23*(4-5), pp.337-346.

Mahan, B.L., Polasky, S. and Adams, R.M., 2000. Valuing urban wetlands: a property price approach. *Land economics*, pp.100-113.

Mathews, L.G., Homans, F.R. and Easter, K.W., 2002. Estimating the benefits of phosphorus pollution reductions: an application in the minnesota river 1. *JAWRA Journal of the American Water Resources Association*, *38*(5), pp.1217-1223.

Maxwell, S., 1994. Valuation of rural environmental improvements using contingent valuation methodology: a case study of the Marston vale community forest project. *Journal of Environmental Management*, *41*(4), pp.385-399.

Mazzotta, M.J., 1996. Measuring public values and priorities for natural resources: An application to the Peconic Estuary system.

McPherson, E.G., 1992. Accounting for benefits and costs of urban greenspace. *Landscape and Urban Planning*, *22*(1), pp.41-51.

McPherson, E.G., Scott, K.I. and Simpson, J.R., 1998. Estimating cost effectiveness of residential yard trees for improving air quality in Sacramento, California, using existing models. *Atmospheric Environment*, *32*(1), pp.75-84.

Moore, R., Williams, T. and Rodriguez, E., 2011. *Valuing Ecosystem Services from Private Forests* (No. 321-2016-11229).

Morey, E.R., Shaw, W.D. and Rowe, R.D., 1991. A discrete-choice model of recreational participation, site choice, and activity valuation when complete trip data are not available. *Journal of Environmental Economics and Management*, *20*(2), pp.181-201.

Mullen, J.K. and Menz, F.C., 1985. The effect of acidification damages on the economic value of the Adirondack fishery to New York anglers. *American Journal of Agricultural Economics*, *67*(1), pp.112-119.

Murray, B., Jenkins, A., Kramer, R. and Faulkner, S.P., 2009. *Valuing Ecosystem Services from Wetlands: Restoration in the Mississippi Alluvial Valley*. Duke University Nicholas Institute for Environmental Policy Solutions.

Newell, R.G. and Pizer, W.A., 2003. Discounting the distant future: how much do uncertain rates increase valuations?. *Journal of Environmental Economics and Management*, *46*(1), pp.52-71.

Nordhaus, W.D., 1991. To slow or not to slow: the economics of the greenhouse effect. *The economic journal*, *101*(407), pp.920-937.

Nordhaus, W.D. and Yang, Z., 1996. A regional dynamic general-equilibrium model of alternative climate-change strategies. *The American Economic Review*, pp.741-765.

Olewiler, N.D., 2004. *The value of natural capital in settled areas of Canada*. Ducks Unlimited Canada.

Opaluch, J.J., Grigalunas, T., Diamantides, J., Mazzotta, M. and Johnston, R., 1999. Recreational and resource Economic values for the Peconic estuary system. *Washington, DC: US Environmental Protection Agency*.

Parsons, G.R. and Powell, M., 2001. Measuring the cost of beach retreat. *Coastal Management*, *29*(2), pp.91-103.

Pate, J. and Loomis, J., 1997. The effect of distance on willingness to pay values: a case study of wetlands and salmon in California. *Ecological economics*, *20*(3), pp.199-207.

Phillips, S., Silverman, R. and Gore, A., 2007. Greater than zero: toward the total economic value of Alaska's National Forest wildlands. *The Wilderness Society*.

Piper, S., 1997. Regional impacts and benefits of water-based activities: an application in the Black Hills region of South Dakota and Wyoming. *Impact Assessment*, *15*(4), pp.335-359.

Pimentel, D., Wilson, C., McCullum, C., Huang, R., Dwen, P., Flack, J., Tran, Q., Saltman, T. and Cliff, B., 1997. Economic and environmental benefits of biodiversity. *BioScience*, *47*(11), pp.747-757.

Plambeck, E.L. and Hope, C., 1996. PAGE95: An updated valuation of the impacts of global warming. *Energy Policy*, *24*(9), pp.783-793.

Pompe, J.J. and Rinehart, J.R., 1995. Beach quality and the enhancement of recreational property values. *Journal of Leisure Research*, *27*(2), pp.143-154.

Postel, S. and Carpenter, S., 1997. Freshwater ecosystem services. *Nature's services: Societal dependence on natural ecosystems*, *195*.

Qiu, Z., Prato, T. and Boehrn, G., 2006. Economic Valuation of Riparian Buffer and Open Space in a Suburban Watershed1. *JAWRA Journal of the American Water Resources Association*, *42*(6), pp.1583-1596.

Reilly, J.M. and Richards, K.R., 1993. Climate change damage and the trace gas index issue. *Environmental and Resource Economics*, *3*(1), pp.41-61.

Rein, F.A., 1999. An economic analysis of vegetative buffer strip implementation. Case study: Elkhorn Slough, Monterey Bay, California. *Coastal Management*, *27*(4), pp.377-390.

Ribaudo, M.O. and Epp, D.J., 1984. The importance of sample discrimination in using the travel cost method to estimate the benefits of improved water quality. *Land Economics*, *60*(4), pp.397-403.

Robinson, W.S., Nowogrodzki, R. and Morse, R.A., 1989. The value of honey bees as pollinators of US crops. *Am. Bee J.*

Roughgarden, T. and Schneider, S.H., 1999. Climate change policy: quantifying uncertainties for damages and optimal carbon taxes. *Energy Policy*, *27*(7), pp.415-429.

Sala, O.E. and Paruelo, J.M., 1997. Ecosystem services in grasslands. *Nature's services: Societal dependence on natural ecosystems*, pp.237-251.

Schauer, M.J., 1995. Estimation of the greenhouse gas externality with uncertainty. *Environmental and Resource Economics*, *5*(1), pp.71-82.

Shafer, E.L., Carline, R., Guldin, R.W. and Cordell, H.K., 1993. Economic amenity values of wildlife: six case studies in Pennsylvania. *Environmental Management*, *17*(5), pp.669-682.

Silberman, J., Gerlowski, D.A. and Williams, N.A., 1992. Estimating existence value for users and nonusers of New Jersey beaches. *Land Economics*, pp.225-236.

Southwick, E.E. and Southwick Jr, L., 1992. Estimating the economic value of honey bees (Hymenoptera: Apidae) as agricultural pollinators in the United States. *Journal of Economic Entomology*, *85*(3), pp.621-633.

Taylor, L.O. and Smith, V.K., 2000. Environmental amenities as a source of market power. *Land Economics*, pp.550-568.

Thibodeau, F.R., 1981. An economic analysis of wetland protection. *J. Environ. Manage*, *12*, pp.19-30.

Tol, R.S., 1999. The marginal costs of greenhouse gas emissions. *The energy journal*, *20*(1).

Troy, A. and Wilson, M.A., 2006. Mapping ecosystem services: practical challenges and opportunities in linking GIS and value transfer. *Ecological economics*, *60*(2), pp.435-449.

Tyrväinen, L., 2001. Economic valuation of urban forest benefits in Finland. *Journal of environmental management*, *62*(1), pp.75-92.

van Kooten, G.C. and Schmitz, A., 1992. Preserving waterfowl habitat on the Canadian prairies: economic incentives versus moral suasion. *American Journal of Agricultural Economics*, *74*(1), pp.79-89.

Ward, F.A., Roach, B.A. and Henderson, J.E., 1996. The economic value of water in recreation: Evidence from the California drought. *Water Resources Research*, *32*(4), pp.1075-1081.

Whitehead, J.C., Hoban, T.L. and Clifford, W.B., 1997. Economie analysis of an estuarine quality improvement program: The Albemarle-Pamlico system. *Coastal Management*, *25*(1), pp.43-57.

Willis, K.G. and Garrod, G.D., 1991. An individual travel-cost method of evaluating forest recreation. *Journal of agricultural Economics*, *42*(1), pp.33-42.

Wilson, S.J., 2008. *Ontario's wealth, Canada's future: appreciating the value of the Greenbelt's eco-services*. David Suzuki Foundation.

Winfree, R., Gross, B.J. and Kremen, C., 2011. Valuing pollination services to agriculture. *Ecological Economics*, *71*, pp.80-88.

Young, C.E. and Shortle, J.S., 1989. Benefits and costs of agricultural nonpoint-source pollution controls: the case of St. Albans Bay. *Journal of Soil and Water Conservation*, *44*(1), pp.64-67.

Zavaleta, E., 2000. The economic value of controlling an invasive shrub. *AMBIO: a Journal of the Human Environment*, *29*(8), pp.462-467.

APPENDIX D. VALUE TRANSFER STUDIES BY LAND COVER

Table D-1. Summary of Estuary Ecosystem Service Values by Study and Type

Land Cover	Author/Publication Year	Value Year	Primary Ecosystem Service	Values ($2019) Min	Max
ESTUARY	Anderson, G.D. and Edwards, S.F. 1986	2013	Aesthetic / Amenity	$612.90	$672.04
	Armstrong, D.A., Rooper, C. and Gunderson, D. 2003	2013	Aesthetic / Amenity	$2,829.30	$2,829.29
	Azar, C. and Sterner, T. 1996	2004	Aesthetic / Amenity	$1,938.99	$1,938.99
	Azar, C. and Sterner, T. 1996	2004	Aesthetic / Amenity	$196.29	$196.29
	Azar, C. and Sterner, T. 1996	2004	Aesthetic / Amenity	$383.29	$383.29
	Azar, C. and Sterner, T. 1996	2004	Aesthetic / Amenity	$441.64	$441.64
	Barrow, C.J. 1991	2004	Aesthetic / Amenity	$209.55	$209.55
	Batie, S. S. and Wilson, J. R. 1978	2004	Aesthetic / Amenity	$290.45	$290.45
	Johnston, R.J. et al. 2002	2004	Aesthetic / Amenity	$249.41	$2,463.78
	Whitehead, J.C., Hoban, T.L., and Clifford, W.B.	2004	Aesthetic / Amenity	$1.33	$103.98
	Costanza, R., et al. 1997	2004	Biological Control	$65.72	$65.72
	Hayes, K. M., Tyrrell, T.J. & Anderson, G. 1992	2004	Biological Control	$51.72	$51.72
	Costanza, R., et al. 1997	2004	Natural Hazards Mitigation	$481.97	$481.97
	Hughes, Z. 2006	2006	Natural Hazards Mitigation	$379.31	$379.31
	Armstrong, D.A., Rooper, C. and Gunderson, D. 2003	2013	Food	$28.79	$158.36
	Hayes, K. M., Tyrrell, T.J. & Anderson, G. 1992	2012	Food	$1,186.23	$2,267.63
	Johnston, R.J. et al. 2002	2016	Food	$1,135.22	$2,170.12
	Kahn, J.R. and Buerger, R.B. 1994	2005	Food	$889.39	$889.40
	Creel, M. and Loomis, J.	2013	Habitat & Nursery	$631.21	$692.11
	Farber, S. and Costanza, R.	2004	Habitat & Nursery	$18.54	$25.28
	Johnston, R.J. et al. 2002	2006	Habitat & Nursery	$608.53	$1,917.17
	Nordhaus, W.D. & Yang, Z.L. 1996	2013	Habitat & Nursery	$408.60	$408.60
	Nowak, D.J. et al. 2002	2006	Habitat & Nursery	$14.59	$14.59
	Olewiler, N. 2004	2006	Habitat & Nursery	$19.89	$19.89
	Olewiler, N. 2004	2006	Habitat & Nursery	$20.00	$511.17
	Opaluch, J. et al. 1999	2006	Habitat & Nursery	$1,610.42	$1,610.42
	Bell, F.W. 1997	2004	Recreation / Tourism	$90.19	$90.19
	Bennett, R., et. al. 1995	2005	Recreation / Tourism	$1.33	$6.63
	Costanza, R., et al.	2013	Soil Formation	$219.26	$13,765.88
	Ribaudo, M. and Epp, D.J. 1984	2013	Soil Formation	$84.00	$13,366.67
	Bockstael, N.E., McConnell, K.E. and Strand, I.E.	2006	Water Supply	$106.39	$188.82
	Leggett, C. G. & Bockstael, N. E.	2013	Water Supply	$47.79	$47.79
	Thibodeau, F.R. and Ostro, B.D. 1981	2006	Water Supply	$89.37	$158.61
	Thibodeau, F.R. and Ostro, B.D. 1981	2013	Water Supply	$46.41	$46.41
	Thibodeau, F.R. and Ostro, B.D. 1981	2006	Water Supply	$7.44	$26.05
	Costanza, R., et al. 1997	2004	Water Treatment/Quality	$17,960.96	$17,960.96
	Piper, S. 1995	2004	Water Treatment/Quality	$14,135.28	$14,135.28
	Sala, O.E. and Paruelo, F.M. 1999	2013	Water Treatment/Quality	$167.74	$21,874.19

Table D-2. Summary of Wetlands Ecosystem Service Values by Study and Type

Land Cover	Author/Publication Year	Value Year	Primary Ecosystem Service	Values ($2019) Min	Max
WETLANDS	Murray, B., Jenkins, A., Kramer, R., Faulkner, S. P. 2009	2008	Aesthetic / Amenity	$7.06	$7.53
	Amacher, G.S., Brazee, R.J., Bulkley, J.W. and Moll, R.A. 1989	2007	Aesthetic / Amenity	$40.72	$40.72
	Gibbons, D.C. 1986	2004	Aesthetic / Amenity	$1,608.54	$3,074.39
	Gren, I.M. and Soderqvist, T. 1994	2004	Aesthetic / Amenity	$419.18	$419.19
	Thibodeau, F.R. and Ostro, B.D. 1981	1981	Aesthetic / Amenity	$873.11	$873.11
	Gren, I.M. and Soderqvist, T. 1994	1993	Biodiversity	$77.30	$77.30
	Bell, F.W. 1989	1994	Food	$974.97	$974.97
	Costanza, R., Farber, S. C., and Maxwell, J. 1989	1983	Food	$63.88	$63.88
	Farber, S. and Costanza, R. 1987	1983	Food	$104.53	$104.53
	Gosselink, J.G., Odum, E.P. and Pope, R.M. 1974	1968	Food	$165.47	$165.47
	Gosselink, J.G., Odum, E.P. and Pope, R.M. 1974	1970	Food	$309.68	$309.68
	Gosselink, J.G., Odum, E.P. and Pope, R.M. 1974	1970	Food	$483.88	$483.88
	Murray, B., Jenkins, A., Kramer, R., Faulkner, S. P. 2009	2008	Gas & Climate Regulation	$76.23	$100.23
	Murray, B., Jenkins, A., Kramer, R., Faulkner, S. P. 2009	2008	Gas & Climate Regulation	$596.68	$596.68
	Murray, B., Jenkins, A., Kramer, R., Faulkner, S. P. 2009	2008	Gas & Climate Regulation	$27.76	$27.76
	Wilson, S.J. 2008	2005	Gas & Climate Regulation	$5.10	$211.32
	Bell, F.W. 1989	1996	Habitat & Nursery	$76.68	$76.68
	Coreil, P.D. 1993	2007	Habitat & Nursery	$50.08	$50.08
	Gupta, T.R. and Foster. J.H. 1975	1996	Habitat & Nursery	$404.15	$404.15
	Johnston, R.J., et al. 2002	2007	Habitat & Nursery	$1,097.85	$1,097.85
	Pimentel et al. 1995	2006	Habitat & Nursery	$6,386.10	$15,554.76
	Pimentel et al. 1995	1969	Habitat & Nursery	$40.82	$5,000.00
	Pimentel et al. 1995	2004	Habitat & Nursery	$190.98	$1,263.93
	Pimentel et al. 1995	2006	Habitat & Nursery	$73.06	$334.88
	Pimentel et al. 1995	2006	Habitat & Nursery	$1,836.03	$1,836.03
	Wilson, S.J. 2008	2006	Habitat & Nursery	$2,283.45	$2,283.45
	Costanza, R., Farber, S. C., and Maxwell, J. 1989	1983	Natural Hazard Mitigation	$323.17	$323.17
	Costanza, R., et al. 1997	1994	Natural Hazard Mitigation	$2,284.14	$2,284.14
	Dugan, P.J. (ed) 1990	1994	Natural Hazard Mitigation	$5,015.36	$5,015.36
	Farber, S. and Costanza, R. 1987	1983	Natural Hazard Mitigation	$18.84	$18.84
	Gupta, T.R. and Foster, J.H. 1975	1972	Natural Hazard Mitigation	$8,910.19	$8,910.37
	Johnston, R.J., et al. 2002	1994	Natural Hazard Mitigation	$2,284.14	$2,284.14
	Johnston, R.J., Magnusson, G., Mazzotta, M., Opaluch, J. 2002	2004	Natural Hazard Mitigation	$44,258.26	$44,258.26
	Johnston, R.J., et al. 2002	2013	Natural Hazard Mitigation	$1,852.69	$8,459.14
	Costanza, R., Farber, S. C., and Maxwell, J. 1989	1983	Recreation / Tourism	$11.04	$11.04
	Gosselink, J.G., Odum, E.P. and Pope, R.M. 1974	1968	Recreation / Tourism	$75.60	$75.60
	Qiu et al. 2006	1968	Recreation / Tourism	$410.08	$410.08
	Bell, F.W. 1989	1994	Recreation / Tourism	$1,030.17	$1,030.17
	Farber, S. and Costanza, R. 1987	1985	Recreation / Tourism	$15.11	$15.11
	Bergstrom, J.C., Stoll, J.R., Titre, J.P. and Wright, V.L. 1990	2006	Recreation / Tourism	$55.45	$55.45
	Farber, S. 1996	2007	Recreation / Tourism	$19.26	$19.26
	Gibbons, D.C. 1986	2004	Recreation / Tourism	$4,732.10	$5,228.12
	Gren, I.M. and Soderqvist, T. 1994	1993	Recreation / Tourism	$545.64	$545.66
	Gren, I.M. and Soderqvist, T. 1994	1993	Recreation / Tourism	$3,410.28	$3,410.35
	Gren, I.M. and Soderqvist, T. 1994	1993	Recreation / Tourism	$301.97	$301.97
	Gren, I.M. and Soderqvist, T. 1994	1993	Recreation / Tourism	$331.93	$331.94
	Gren, I.M. and Soderqvist, T. 1994	1993	Recreation / Tourism	$9,171.37	$9,171.56
	Gupta, T.R. and Foster, J.H. 1975	1972	Recreation / Tourism	$419.16	$419.17
	Lant, C.L. and Roberts, R.S. 1990	1994	Recreation / Tourism	$221.55	$221.55
	Wilson, S.J. 2008	2005	Recreation / Tourism	$131.19	$131.19
	Gosselink, J.G., Odum, E.P. and Pope, R.M. 1974	1966	Waste Treatment	$2,030.81	$2,030.81
	Lant, C.L. and Roberts, R.S. 1990	1994	Waste Treatment	$221.55	$221.55
	Shafer, E.L. et al. 1993	2004	Waste Treatment	$1,665.78	$2,575.60
	Shafer, E.L. et al. 1993	2004	Waste Treatment	$136.60	$153.85
	Shafer, E.L. et al. 1993	2004	Waste Treatment	$21,962.86	$21,962.86
	Thibodeau, F.R. and Ostro, B.D. 1981	1981	Waste Treatment	$46,851.85	$46,851.85
	Wilson, S.J. 2008	2005	Waste Treatment	$1,181.50	$1,181.50
	Thibodeau, F.R. and Ostro, B.D. 1981	2006	Water Regulation	$7,887.98	$7,887.98
	Leschine, T.M., Wellman, K.F. and Green, T.H. 1997	2007	Water Supply	$4,151.47	$4,151.47
	Ward, F.A., Roach, B.A., Henderson, J.E. 1993	2004	Water Supply	$612.73	$612.73
	Whitehead, J.C., Hoban, T.L., and Clifford, W.B. 1997	2004	Water Supply	$4,066.31	$4,066.31
	Gren, I.M. and Soderqvist, T. 1994	1993	Water Treatment & Quality	$583.11	$583.12
	Wilson, S.J. 2008	2005	Water Treatment & Quality	$185.62	$185.62

Table D-3. Summary of Rivers & Lakes Ecosystem Service Values by Study and Type

Land Cover	Author/Publication Year	Value Year	Primary Ecosystem Service	Values ($2019) Min	Values ($2019) Max
RIVERS & LAKES	Breaux, A., Farber, S. & Day, J. 1995	1995	Aesthetic / Amenity	$5,470.97	$13,149.46
	Breaux, A., Farber, S. & Day, J. 1995	1995	Aesthetic / Amenity	$521.22	$521.22
	Breaux, A., Farber, S. & Day, J. 1995	1995	Aesthetic / Amenity	$152.52	$320.95
	Collins, A., Rosenberger, R., and Fletcher, J. 2005	2005	Aesthetic / Amenity	$31.22	$98.37
	Costanza, R., et al. 1997	1997	Aesthetic / Amenity	$258.45	$370.77
	Costanza, R., et al. 1997	1997	Aesthetic / Amenity	$5,612.87	$5,612.87
	Costanza, R., et al. 1997	1997	Aesthetic / Amenity	$271.88	$271.88
	Costanza, R., et al. 1997	1997	Aesthetic / Amenity	$157.23	$157.23
	Costanza, R., et al. 1997	1997	Aesthetic / Amenity	$623.34	$623.34
	Costanza, R., et al. 1997	1997	Aesthetic / Amenity	$1,244.03	$1,244.03
	Costanza, R., et al. 1997	1997	Aesthetic / Amenity	$90.51	$90.51
	Costanza, R., et al. 1997	1997	Aesthetic / Amenity	$22.55	$2,168.44
	Costanza, R., et al. 1997	1997	Aesthetic / Amenity	$92.84	$92.84
	Collins, A., Rosenberger, R., and Fletcher, J. 2005	2005	Habitat & Nursery	$47.09	$129.97
	Phillips, S., Silverman, R. and Gore, A. 2008	2006	Habitat & Nursery	$152.69	$3,312.90
	Brookshire, D., Thayer, M., Schulze, W. and D'Arge, R. 1982	1982	Recreation / Tourism	$319.63	$904.51
	Burt, O. R. and Brewer, D. 1971	1971	Recreation / Tourism	$432.36	$1,604.77
	Collins, A., Rosenberger, R., and Fletcher, J. 2005	2005	Recreation / Tourism	$22.33	$101.51
	Cordell, H. K. & Bergstrom, J. C. 1993	1993	Recreation / Tourism	$174.19	$730.11
	Cordell, H. K. & Bergstrom, J. C. 1993	1993	Recreation / Tourism	$204.24	$204.24
	Postel, S. and Carpenter, S. 1997	1994	Recreation / Tourism	$157.23	$157.23
	Rein, F. A. 1999	1999	Erosion Control	$2.79	$2.79
	Costanza, R., et al. 1997	2007	Waste Treatment	$449.08	$449.08
	Schauer, M.J. 1995	1995	Waste Treatment	$11.00	$2,605.38
	Costanza, R., et al. 1997	2007	Water Regulation	$3,677.04	$3,677.04
	Costanza, R., et al. 1997	2007	Water Supply	$884.75	$884.73
	Croke, K., Fabian, R. and Brenniman, G.	1986	Water Supply	$702.12	$702.12
	Gibbons, D.C. 1986	2007	Water Supply	$586.47	$586.47
	Gibbons, D.C. 1986	1980	Water Supply	$625.01	$625.01
	Ribaudo, M. and Epp, D. J.	2006	Water Supply	$1,035.29	$1,035.29
	Tol, R.S.J. 1999	1999	Water Supply	$697.61	$697.61
	Tol, R.S.J. 1999	1999	Water Supply	$639.26	$639.26
	Tyrvainen, L. 2001	2001	Water Supply	$1,478.66	$1,478.66
	Tyrvainen, L. 2001	2001	Water Supply	$1,493.90	$1,493.90
	US Department of Commerce 1995	1994	Water Supply	$420.73	$420.73
	Young, C.E. & Shortle, J.S. 1989	1989	Water Supply	$793.55	$3,064.52
	Zavaleta, E. 2000	2000	Water Supply	$2,843.01	$2,843.01
	Willis, K.G. 1991	1991	Water Treatment & Quality	$751.99	$953.58
	Young, C.E.and& Shortle, J.S. 1989	1989	Water Treatment & Quality	$16,107.53	$16,107.53
	Zhongwei, L. 2006	2006	Water Treatment & Quality	$5,110.75	$5,110.75

Table D-4. Summary of Forests Ecosystem Service Values by Study and Type

Land Cover	Author/Publication Year	Value Year	Primary Ecosystem Service	Values ($2019) Min	Max
FORESTS	Bishop, K. 1992	2006	Aesthetic / Amenity	$675.47	$675.47
	Bockstael, N.E., McConnell, K.E. and Strand, I.E. 1989	2012	Aesthetic / Amenity	$608.75	$608.75
	Bouwes, N.W. and Schneider, R. 1979	2004	Aesthetic / Amenity	$118.04	$214.85
	Shafer, E.L. et al. 1993	2012	Aesthetic / Amenity	$501.17	$501.17
	Willis, K.G. 1991	2011	Aesthetic / Amenity	$27.65	$47.40
	Willis, K.G. and Garrod, G.D. 1991	2011	Aesthetic / Amenity	$19.98	$21.39
	Anielski, M. and Wilson, S.	2008	Biological Control	$20.63	$22.44
	Krieger, D.	1998	Biological Control	$10.75	$11.27
	Wilson, S.J. 2008	2005	Biological Control	$10.17	$10.17
	Gren, I.M. and Soderqvist, T. 1994	2000	Biodiversity	$2,588.11	$2,588.11
	Hayes, K. M., Tyrrell, T.J. and Anderson, G. 1992	2006	Biodiversity	$46.68	$46.68
	Anielski, M. and Wilson, S.	2008	Food	$0.29	$0.34
	Curtis, I. A.	2008	Food	$1.65	$2.05
	Azar, C. and Sterner, T. 1996	2004	Gas & Climate Regulation	$13.28	$268.20
	Hope, C. and Maul, P. 1996	2013	Gas & Climate Regulation	$14.61	$57.09
	Ingraham, M. W. and Gilliland Foster, S.	2008	Gas & Climate Regulation	$1,773.26	$1,925.58
	Kenyon, W. and Nevin, C. 2001	2006	Gas & Climate Regulation	$87.53	$87.53
	Knowler, D.J. et al.	2004	Gas & Climate Regulation	$267.90	$267.90
	Kreutzwiser, R. 1981	2004	Gas & Climate Regulation	$39.79	$39.79
	Lant, C. L. and Tobin, G. 1989	2004	Gas & Climate Regulation	$30.50	$87.53
	Lant, C. L. and Tobin, G. 1989	2004	Gas & Climate Regulation	$6.63	$49.07
	Lant, C. L. and Tobin, G. 1989	2004	Gas & Climate Regulation	$7.96	$57.03
	Leggett, C. G. and Bockstael, N. E. 2000	2004	Gas & Climate Regulation	$9.28	$30.50
	Leschine, T.M. et al. 1997	2004	Gas & Climate Regulation	$13.26	$45.09
	Loomis, J., Kent, P., Strange, L., Fausch, K. and Covich, A. 2000	2004	Gas & Climate Regulation	$10.61	$87.53
	Maddison, D. 1995	2004	Gas & Climate Regulation	$492.04	$1,237.40
	Mahan, B.L., Polasky, S. and Adams, R.M. 1995	2004	Gas & Climate Regulation	$13.26	$61.01
	Mathews, L.G. et al. 2002	2006	Gas & Climate Regulation	$64.99	$64.99
	Maxwell, S.	2004	Gas & Climate Regulation	$55.70	$55.70
	Mazzotta, M. 1996	2006	Gas & Climate Regulation	$26.53	$26.53
	McPherson, E.G. 1992	2004	Gas & Climate Regulation	$51.72	$422.00
	McPherson, E.G., Scott, K., and Simpson, J.R. 1998	2004	Gas & Climate Regulation	$30.50	$30.50
	Morey, E.R., Shaw, W.D. and Rowe 1991	2004	Gas & Climate Regulation	$75.60	$75.60
	Mullen, J.K. and Menz, F.C. 1985	2004	Gas & Climate Regulation	$400.53	$400.53
	Newell, R.G. & Pizer, W.A. 2003	2004	Gas & Climate Regulation	$9.29	$45.14
	Pimental, D.C., et al. 1997	2004	Gas & Climate Regulation	$17.26	$17.26
	Reilly, J.M. and Richards, K.R. 1993	2004	Gas & Climate Regulation	$18.59	$65.06
	Roughgarden, T. & Shneider, S.H. 1999	2004	Gas & Climate Regulation	$51.78	$51.78
	Schauer, M.J. 1995	2004	Gas & Climate Regulation	$30.54	$422.22
	Tol, R.S.J. 1999	2004	Gas & Climate Regulation	$75.68	$400.98
	Wilson, S.J. 2008	2005	Gas & Climate Regulation	$15.32	$359.91
	Curtis, I. A.	2008	Habitat & Nursery	$6.34	$7.35
	Ingraham, M. W. and Gilliland Foster, S.	2008	Habitat & Nursery	$255.81	$277.91
	Moore, R., Williams, T., Rodriguez, E. 2011	2009	Habitat & Nursery	$260.51	$293.22
	Pate, J. and Loomis, J. 1997	2004	Habitat & Nursery	$564.99	$564.99
	Troy, A. and Wilson. M.	2008	Habitat & Nursery	$5.06	$5.49
	de Groot, et al.	2012	Natural Hazards Mitigation	$52.34	$52.34
	Jenkins, W.A. et al.	2013	Natural Hazards Mitigation	$138.71	$732.26
	Plambeck, E.L. and Hope, C. 1996	2004	Pollination	$75.24	$340.65
	Moore, R., Williams, T., Rodriguez, E. 2011	2009	Pollination	$214.95	$214.95
	Wilson, S.J. 2008	2004	Pollination	$210.31	$434.32
	Bennett, R., et. al. 1995	2006	Recreation / Tourism	$209.84	$209.84
	Troy, A. and Wilson. M.	2008	Recreation / Tourism	$243.02	$263.95
	Willis, K. G. 1991	2011	Recreation / Tourism	$30.82	$52.84
	Willis, K. G. 1991	2011	Recreation / Tourism	$134.87	$212.55
	Wilson, S.J. 2008	2005	Recreation / Tourism	$131.09	$131.09
	Costanza, et al. 1997	2006	Soil Formation	$16.93	$16.93
	Wilson, S.J. 2008	2005	Soil Formation	$6.66	$6.66
	Wilson, S.J. 2008	2005	Waste Treatment	$22.71	$22.71
	Moore, R., Williams, T., Rodriguez, E. 2011	2009	Water Regulation	$2,018.69	$5,414.72
	Wilson, S.J. 2008	2005	Water Regulation	$596.46	$596.46
	Curtis, I. A.	2008	Water Supply	$5.78	$7.80
	Thibodeau, F.R. and Ostro, B.D.	2013	Water Supply	$18.28	$625.81
	Ingraham, M. W. and Gilliland Foster, S.	2008	Water Treatment & Quality	$2,844.19	$3,087.21
	Troy, A. and Wilson. M.	2008	Water Treatment & Quality	$703.49	$763.95
	Wilson, S.J. 2008	2005	Water Treatment & Quality	$185.63	$185.63

Table D-5. Summary of Grassland Ecosystem Service Values by Study and Type

Land Cover	Author/Publication Year	Value Year	Primary Ecosystem Service	Values ($2019) Min	Max
GRASSLAND	Brookshire, D., Thayer, M., Schulze, W. and D'Arge, R. 1982	2007	Aesthetic / Amenity	$99.04	$99.04
	Gosselink, J.G., E.P. Odum and R.M. Pope 1974	1982	Aesthetic / Amenity	$212.73	$212.73
	De Groot, R.S., Wilson, M.A. and Boumans. R.M.J. 2002	2008	Biodiversity	$3.62	$91.22
	Hayes, K. M., Tyrrell, T.J. & Anderson, G. 1992	2006	Biological Control	$15.71	$15.71
	De Groot, R.S., Wilson, M.A. and Boumans. R.M.J. 2002	2008	Biological Control	$1.21	$63.52
	Wilson, S.J. 2008	2005	Biological Control	$15.59	$15.59
	Newell, R.G. & Pizer, W.A. 2003	2004	Gas & Climate Regulation	$5.11	$6.45
	Newell, R.G. & Pizer, W.A. 2003	2004	Gas & Climate Regulation	$6.45	$6.45
	Nordhaus, W.D. 1991	1997	Gas & Climate Regulation	$44.88	$44.88
	Troy, A. and Wilson. M. 2006	2008	Gas & Climate Regulation	$4.35	$4.74
	Wilson, S.J. 2008	2005	Gas & Climate Regulation	$15.07	$82.99
	De Groot, R.S., Wilson, M.A. and Boumans. R.M.J. 2002	2008	Habitat & Nursery	$1.80	$1,240.37
	Plambeck, E.L. & Hope, C. 1996	2006	Pollination	$17.08	$17.08
	De Groot, R.S., Wilson, M.A. and Boumans. R.M.J. 2002	2008	Pollination	$8.44	$20.36
	Reilly, J.M. & Richards, K.R. 1993	2006	Erosion Control	$19.81	$19.81
	De Groot, R.S., Wilson, M.A. and Boumans. R.M.J. 2002	2008	Erosion Control	$17.48	$199.53
	Sala, O.E. and J.M. Paruelo 1997	2007	Erosion Control	$72.14	$72.14
	Troy, A. and Wilson. M. 2006	2008	Erosion Control	$0.63	$0.67
	Wilson, S.J. 2008	2005	Erosion Control	$19.48	$19.48
	Costanza, et al. 1997	2006	Soil Formation	$21.45	$21.45
	Gorlach, et al. 2004	2006	Soil Formation	$11.27	$111.64
	Roughgarden, T. & Shneider, S.H. 1999	2006	Soil Formation	$0.67	$0.67
	Wilson, S.J. 2008	2005	Soil Formation	$3.90	$3.90
	Troy, A. and Wilson. M. 2006	2008	Waste Treatment	$53.83	$58.42
	Wilson, S.J. 2008	2005	Waste Treatment	$56.89	$56.89
	Taylor, L.O. & Smith, V.K. 2000	2006	Water Regulation	$2.05	$2.05
	Wilson, S.J. 2008	2005	Water Regulation	$2.73	$2.73
	De Groot, R.S., Wilson, M.A. and Boumans. R.M.J. 2002	2008	Water Supply	$69.77	$69.77
	Troy, A. and Wilson. M. 2006	2008	Water Treatment & Quality	$1.86	$2.02

Table D-6. Summary of Cropland Ecosystem Service Values by Study and Type

Land Cover	Author/Publication Year	Value Year	Primary Ecosystem Service	Values ($2019) Min	Max
CROPLAND	Bergstrom, J., Dillman, B. L. and Stoll, J. R. 1985	2006	Aesthetic / Amenity	$90.69	$90.69
	Costanza, et al. 1997	2007	Biological Control	$39.90	$39.90
	Costanza, et al. 1997	2007	Food	$90.69	$90.69
	Costanza, et al. 1997	2007	Gas & Climate Regulation	$496.98	$496.98
	van Kooten, G. C. and Schmitz, A. 1992	2001	Habitat & Nursery	$8.27	$56.81
	Willis, K. G. and Benson, J. F. 2004	2001	Habitat & Nursery	$31.76	$43.39
	Olewiler, N.		Natural Hazards Mitigation	$0.87	$4.77
	Costanza, et al. 1997	2007	Pollination	$22.97	$22.97
	Robinson, W. S., Nowogrodzki, R. and Morse, R. A. 1989	2006	Pollination	$15.01	$15.01
	Southwick, E.E., Southwick, L. 1992	2006	Pollination	$2.98	$2.98
	Wilson. S.J. 2008	2005	Pollination	$432.10	$432.10
	Winfree, R., Gross, B., Kremen, C. 2011	2014	Pollination	$49.77	$2,065.08
	Knoche, S. and Lupi, F. 2007	2011	Recreation / Tourism	$4.40	$18.10
	Olewiler, N.	2011	Recreation / Tourism	$4.40	$18.10
	Olewiler, N.	2011	Recreation / Tourism	$0.87	$4.77
	Pimentel, D., et al. 1995	1992	Soil Erosion Control	$76.65	$76.65
	Pimentel, D., et al. 1995	1992	Soil Erosion Control	$28.86	$28.86
	Pimentel, D., et al. 1995	1992	Soil Formation	$121.73	$121.73

Table D-7. Summary of Beaches Ecosystem Service Values by Study and Type

Land Cover	Author/Publication Year	Value Year	Primary Ecosystem Service	Values ($2019) Min	Max
BEACHES	Alvarez-Farizo, B., et al. 1999	2006	Aesthetic / Amenity	$22,070.00	$22,070.00
	Amacher, G.S., Brazee, R.J., Bulkley, J.W. and Moll, R.A. 1989	2004	Aesthetic / Amenity	$519.89	$1,403.18
	Amacher, G.S., R.J. Brazee, J.W. Bulkley and R.A. Moll	2006	Aesthetic / Amenity	$519.89	$1,403.18
	Pompe, J.J. and Rinehart, J.R. 1995	2011	Aesthetic / Amenity	$44,174.02	$55,009.38
	Rein, F. A. 1999	2006	Aesthetic / Amenity	$26.90	$30,025.39
	Taylor, L.O. and Smith, V.K. 2000	2011	Aesthetic / Amenity	$3,876.31	$23,692.33
	Taylor, L.O. and Smith, V.K. 2000	2011	Aesthetic / Amenity	$23,796.04	$23,796.04
	Henry, R., Ley, R., and Welle, P. 1998	2006	Cultural / Spiritual	$31.17	$31.17
	Taylor, L.O. and Smith, V.K. 2000	2006	Cultural / Spiritual	$36.61	$36.61
	Hougner, C. 2006	2006	Natural Hazard Mitigation	$27,559.69	$27,559.69
	Hughes, Z. 2006	2006	Natural Hazard Mitigation	$44,673.35	$44,673.35
	Parsons, G.R. and Powell, M. 2001	2006	Natural Hazard Mitigation	$2,020.82	$4,072.64
	Pompe, J.J. and Rinehart, J.R. 1995	2011	Natural Hazard Mitigation	$44,791.16	$44,791.16
	Hughes, Z. 2006	2006	Food	$859.58	$859.58
	Allen, J., Cunningham, M., and Rosenthal, L. 1992	2006	Recreation / Tourism	$43,763.64	$56,478.03
	Silberman, J., Gerlowski, D.A., and Williams, N.A. 1992	2006	Recreation / Tourism	$27,454.35	$27,454.89
	Kline, J. D. and Swallow, S. K. 1998	2011	Recreation / Tourism	$859.58	$859.58

Table D-8. Summary of Pasture Ecosystem Service Values by Study and Type

Land Cover	Author/Publication Year	Value Year	Primary Ecosystem Service	Values ($2019) Min	Max
PASTURE	Costanza, R., et al. 1997	2004	Aesthetic / Amenity	$5,110.75	$5,110.75
	Creel, M. and Loomis, J. 1992	2004	Aesthetic / Amenity	$41.27	$41.27
	Costanza, R., et al. 1997	2004	Biological Control	$0.04	$0.04
	Pompe, J.J. and Rinehart, J.R. 1995	2013	Pollination	$7.72	$7.72
	Wilson, S. J. 2008	2012	Pollination	$458.06	$458.06
	Costanza, R., et al. 1997	2013	Recreation / Tourism	$1.33	$1.33
	Sala, O.E. and Paruelo, F.M. 1997	2004	Soil Formation	$7.96	$7.96
	Costanza, R., et al. 1998	2004	Water Regulation	$2.98	$34.17

Table D-9. Summary of Shrub/Scrub Ecosystem Service Values by Study and Type

Land Cover	Author/Publication Year	Value Year	Primary Ecosystem Service	Values ($2019) Min	Max
SHRUB/SCRUB	Boxall, P. C., McFarlane, B. L. and Gartrell, M.	1996	Aesthetic / Amenity	$3.70	$3.70
	Doss, C. R. and Taff, S. J. 1996	2013	Aesthetic / Amenity	$1.08	$1,448.39
	Doss, C. R. and Taff, S. J. 1996	2013	Aesthetic / Amenity	$0.25	$117.87
	Maxwell, S.	1989	Aesthetic / Amenity	$3.70	$3.70
	Willis, K. G. and Garrod, G. D. 1991	2013	Aesthetic / Amenity	$620.65	$620.65
	Birdsey (2007)	2007	Gas & Climate Regulation	$209.84	$209.84
	Birdsey (2007)	2007	Gas & Climate Regulation	$7.50	$7.50
	Haener, M. K. and Adamowicz, W. L. 1998	2006	Habitat & Nursery	$1.49	$1,447.90
	Kenyon, W. and Nevin, C. 2001	2006	Habitat & Nursery	$0.22	$0.22
	Shafer, E. L., R. Carline, R. W. Guldin, and H. K. Cordell	1993	Habitat & Nursery	$75.33	$75.33
	Bennep, R., et. al.	1995	Recreation / Tourism	$0.11	$395.67
	Costanza, et al. 1997	2013	Recreation / Tourism	$619.35	$619.35
	Edwards, S.F. and Gable, F. J. 1991	2013	Recreation / Tourism	$11.83	$235.48

Table D-10. Summary of Urban Greenscape Ecosystem Service Values by Study and Type

Land Cover	Author/Publication Year	Value Year	Primary Ecosystem Service	Values ($2019) Min	Max
URBAN GREENSPACE	Fankhauser, S. 1994	2004	Aesthetic / Amenity	$ 5.10	$ 5.10
	Fankhauser, S. 1995	2004	Aesthetic / Amenity	$ 2,314.32	$ 2,314.32
	Fankhauser, S. 1994	2004	Aesthetic / Amenity	$ 1,567.64	$ 1,567.64
	McPherson, E. G. 1992	2006	Gas & Climate Regulation	$ 217.58	$ 1,085.35
	Nordhaus, W.D. 1991	2006	Gas & Climate Regulation	$ 217.58	$ 33.26
	Nordhaus, W.D. and Yang, Z.L. 1996	2006	Gas & Climate Regulation	$ 217.51	$ 217.51
	Tyrvainen, L.	2006	Recreation / Tourism	$ 33.26	$ 33.26
	Thibodeau, F.R. and Ostro, B.D. 1981	2006	Water Regulation	$ 7.10	$ 7.10
	McPherson, E. G.	2006	Water Regulation	$ 7.96	$ 7.96

[page intentionally left blank]

APPENDIX E. ESV MODEL FACTORS

Table E-1. Chehalis Basin - (Low) Fitted Coefficients by Land Cover

Variable Name	Beach	Estuary	Riv_Lake	Wetlands	Cropland	Forest	Grassland	Pasture	Shrub	UGS
Food	0.189976	0.713341		0.59812	0.27378	0.23876				
Water Supply		0.449986	0.41319	0.4971		0.601103	0.792	0.1899936		
Biological Control		0.461003			0.423	0.46304	0.265072			
Erosion Control			0.41113		0.2833		0.208			
Gas & Climate Regulation				0.476075	0.18643	0.48137	0.208		1.0596845	0.639421
Natural Hazards Mitigation	0.27906	0.62891		0.462963		0.48137				
Pollination					0.2528	0.810009	0.208	0.1899936		
Soil Formation		0.559887			0.433	0.410799	-0.0159	0.2999453		
Waste Treatment			0.379156	0.462963			-0.0159			
Water Treatment & Quality		0.559887	0.379156	0.4199		0.500194	-0.03321			
Water Regulation			0.379156	0.462963		0.510079	-0.03321			0.360579
Aesthetic/Amenity	0.187993	0.80126	0.169603	0.689128	0.2528	0.790001	-0.01439	0.2999453	-0.2078392	0.269005
Recreation/Tourism	0.187993	0.780126	0.849787	0.689128	0.467	0.790001			-0.2078392	0.325611
Habitat and Nursery		0.27036	0.274006	0.399891	0.2633	0.391106	-0.037948		0.297113	
Biodiversity/Genetic Resources				0.399891		0.391106	-0.037948			

Table E-2. Chehalis Basin - (High) Fitted Coefficients by Land Cover

Variable Name	Beach	Estuary	Riv_Lake	Wetlands	Cropland	Forest	Grassland	Pasture	Shrub	UGS
Food	0.1880	0.7394		0.5981	0.2738	0.2259				
Water Supply		0.4784	0.4040	0.5161		0.6007	0.7920	0.18994		
Biological Control		0.4600			0.4230	0.4710	0.2651			
Erosion Control			0.4011		0.2833		0.2080			
Gas & Climate Regulation				0.4811	0.1864	0.4900	0.2080		1.0597	0.6394
Natural Hazards Mitigation	0.2891	0.5799		0.4896		0.4979				
Pollination					0.2528	0.8211	0.2080	0.18799		
Soil Formation		0.5599			0.4999	0.3808	-0.0159	0.29995		
Waste Treatment			0.3800	0.4796			-0.0159			
Water Treatment & Quality		0.5883	0.3806	0.4298		0.5099	-0.0337			
Water Regulation			0.3807	0.4730		0.5116	-0.0337			0.36058
Aesthetic/Amenity	0.8221	0.8093	0.8344	0.7090	0.2289	0.8209	-0.0131	0.29992	-0.20784	0.26901
Recreation/Tourism	0.8223	0.8093	0.8498	0.6891	0.4670	0.8209			-0.20784	0.32561
Habitat and Nursery		0.3404	0.2740	0.4099	0.2599	0.3991	-0.0380		0.29711	
Biodiversity/Genetic Resources				0.4099		0.3991	-0.0379			

APPENDIX F. LAND COVER MAPS

Figure F-1. Chehalis Basin Barren Distribution and Intensity

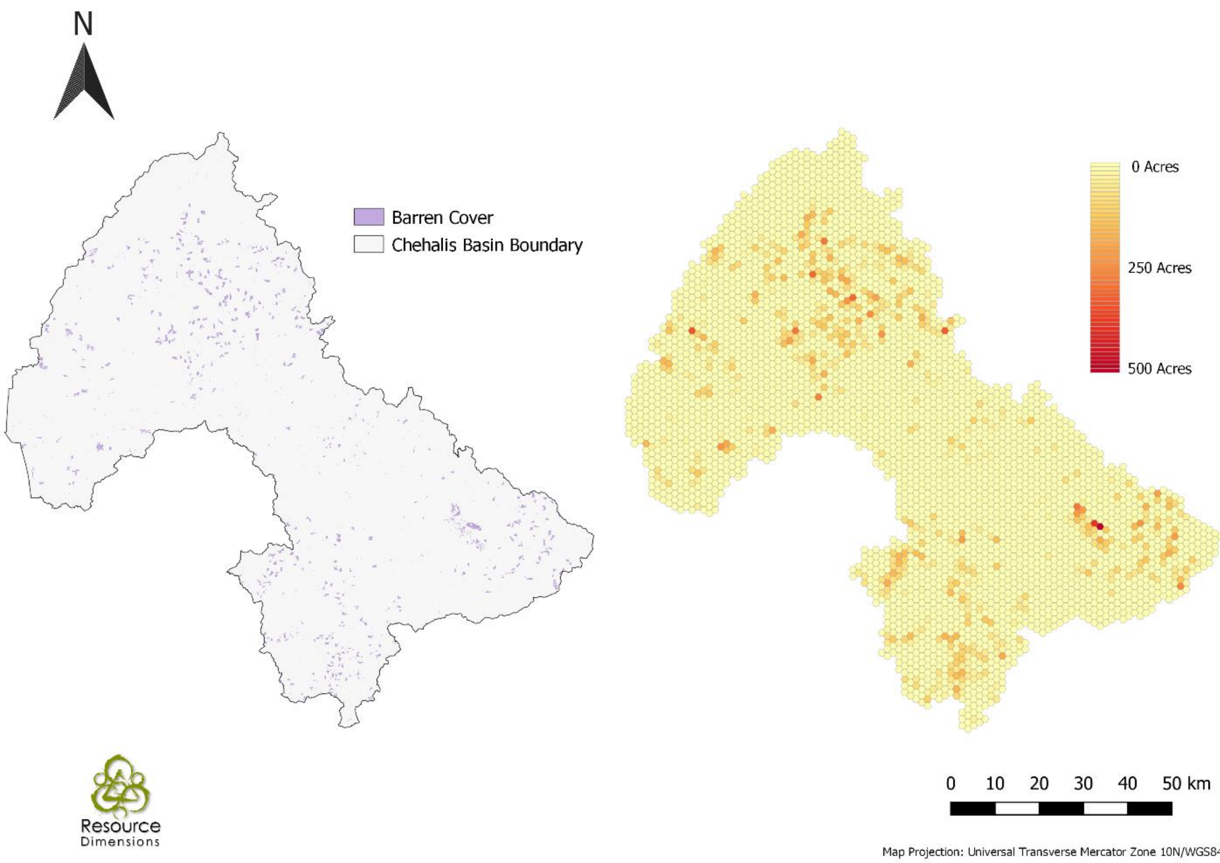


Figure F-2. Chehalis Basin Developed Distribution and Intensity

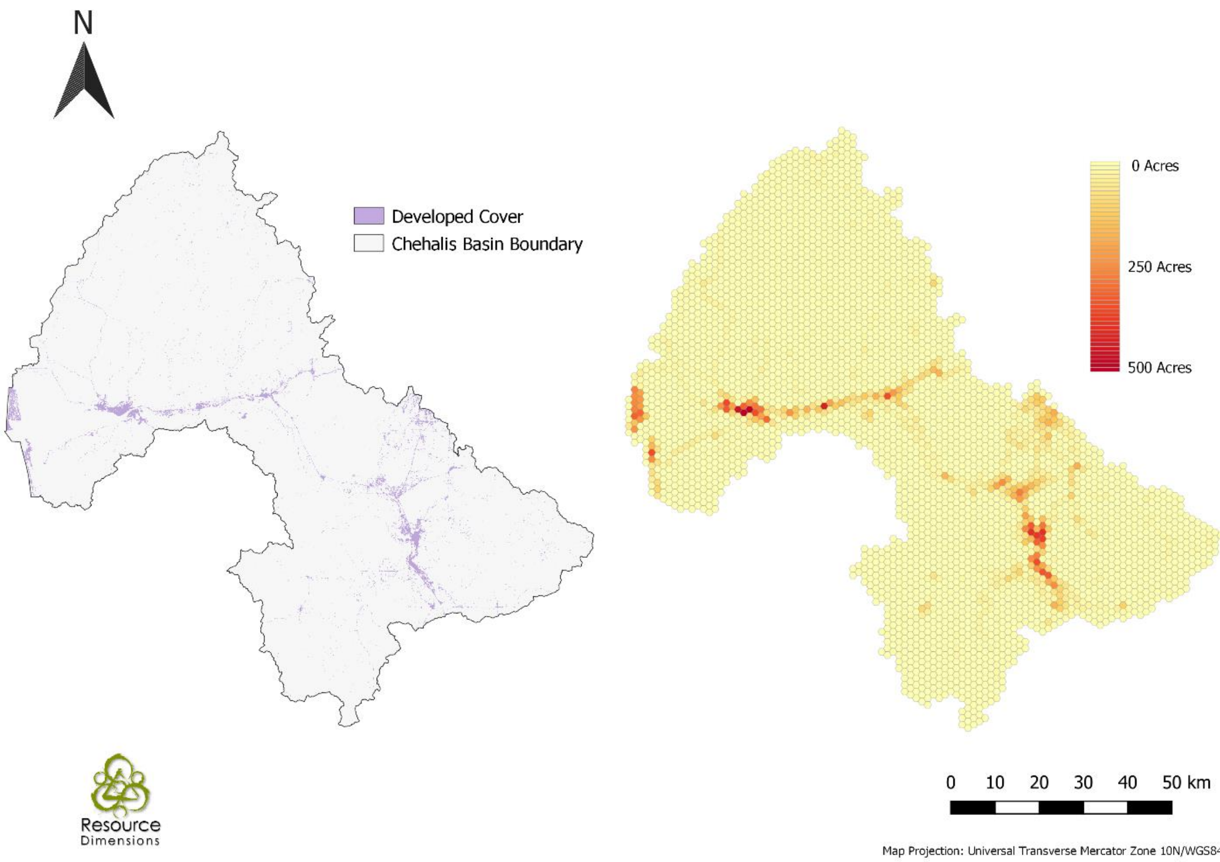
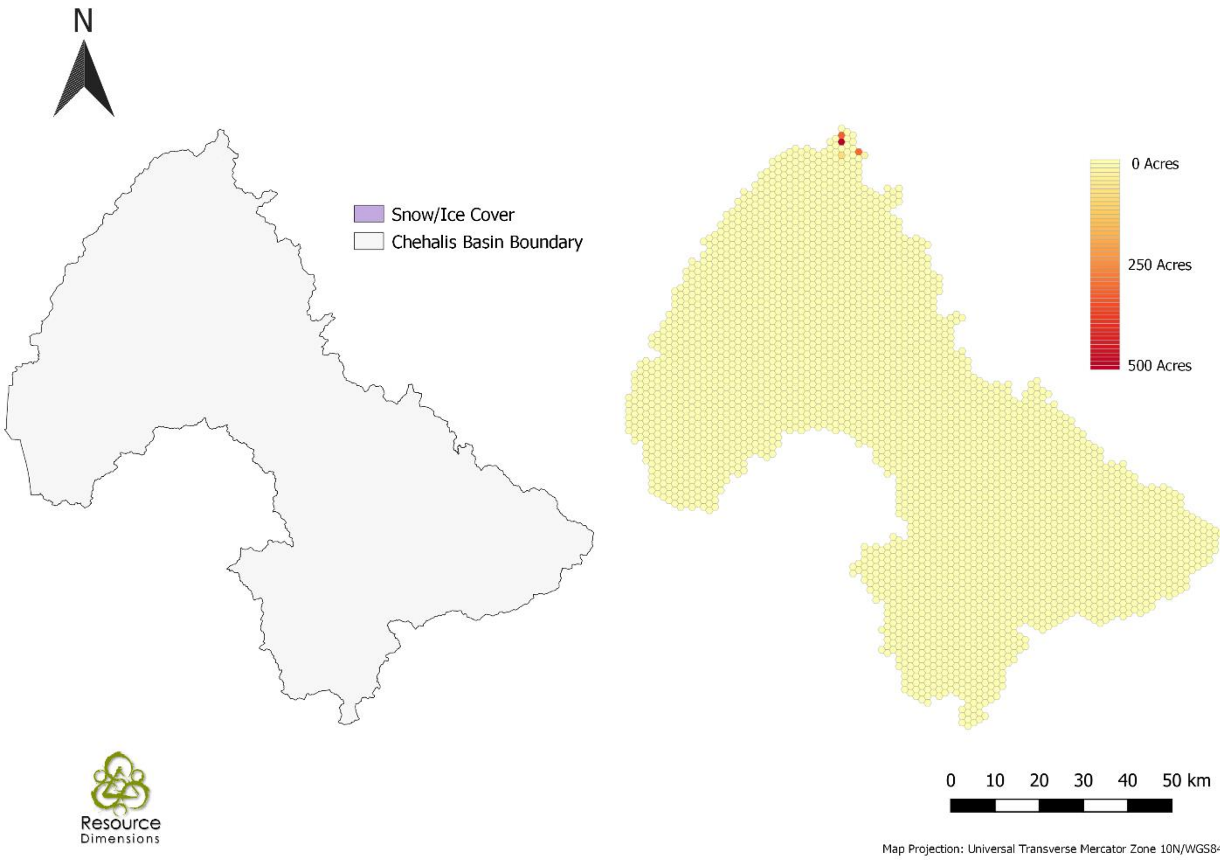


Figure F-3. Chehalis Basin Snow Distribution and Intensity



[page intentionally left blank]

APPENDIX G. CULTURAL ASSESSMENT DB

Table G-1. Cultural Narrative Research Database

#	TITLE	TYPE	TRIBE	LINK
1	People of the Quinault	Website	Quinault	http://www.quinaultindiannation.com/
2	Quinault Division of Natural Resources	Website	Quinault	http://qlandandwater.org/
3	Quinault Traditional Ecological Knowledge	Website	Quinault	http://qlandandwater.org/culture/traditional-ecological-knowledge/
4	Quinault Fisheries Department	Website	Quinault	http://qlandandwater.org/departments/fisheries/
5	Quinault Water Protection Program	Website	Quinault	http://qlandandwater.org/departments/environmental-protection/water/
6	Where Fish Live - The Quinault River	Video	Quinault	https://www.youtube.com/watch?time_continue=6&v=CK-3zhuIFyk&feature=emb_title
7	Measuring Soci-Cultural Values Associated	Publication	Quinault	https://www.eopugetsound.org/sites/default/files/Quinault_Salmon-Cultural-Values.pdf
8	Stories from the Blue: Quinault Indian Nation	Video	Quinault	https://www.youtube.com/watch?v=DKUNmJSXaMw
9	Stand.Earth	Video	Quinault	https://www.facebook.com/standearth/videos/10155631418999221/?v=10155631418999221
10	Sovereignty in Action: Fawn Sharp	Video	Quinault	https://www.youtube.com/watch?v=UepWmWVEHB4
11	Quinault Indian Nation: Standing Up To Oil	Video	Quinault	https://www.youtube.com/watch?v=DJpSNHb7aJA
12	People of the Sands	Website	Chehalis	https://www.chehalistribe.org/our-story/people-of-the-sands/
13	Chehalis Tribal Newsletter - July 2019	Publication	Chehalis	https://www.chehalistribe.org/newsletter/pdf/2019-07.pdf
14	Chehalis Tribal Arts & Cultural Preservation	Website	Chehalis	https://www.chehalistribe.org/home-page/tribal-art-cultural-preservation/
15	The Story of the Flood	Website	Chehalis	http://www.bigorrin.org/archive34.htm
16	If the fish go, surviving symbol of Chehalis Indians' culture will be lost	News Article	Chehalis	https://lmtribune.com/if-the-fish-go-surviving-symbol-of-chehalis-indians-culture/article_d31d6f40-2a78-583c-a5cf-de1c98241d83.html
17	Tribe voices concerns about fish	Publication	Chehalis	https://www.chehalistribe.org/newsletter/pdf/2016-03.pdf
18	'Extinction is not an option'	News Article	Quinault	http://www.thedailyworld.com/news/extinction-is-not-an-option-quinault-worry-for-salmon-beset-by-sea-lions-climate-change-and-dams/
19	Respecting the Chehalis	Publication	Chehalis	https://www.wildsalmoncenter.org/2019/10/15/respecting-the-chehalis/
20	Confederated tribes of the Chehalis Reservation, human and natural resources	Article	Chehalis	https://hdl.handle.net/2027/mdp.39015034099039
21	Chehalis Tribe Plans Showcase for Native Carvers	Article	Chehalis	http://www.chronline.com/news/chehalis-tribe-plans-showcase-for-native-carvers/article_b8e9deac-5811-11e9-ada1-e32834e6c538.html
22	Chehalis Tribe of Washington	Website	Chehalis	https://www.legendsofamerica.com/chehalis-tribe/
23	Salishan People of the Pacific Northwest	Website	Salish	https://www.legendsofamerica.com/salishan-people/

#	TITLE	TYPE	TRIBE	LINK
24	Native American Tribes & the Indian History in Chehalis, Washington	Website	Chehalis	https://www.americanindiancoc.org/native-american-tribes-the-indian-history-in-chehalis-washington/
25	10 Things You Should Know About the Quinault Nation	Website	Quinault	https://newsmaven.io/indiancountrytoday/archive/10-things-you-should-know-about-the-quinault-nation-VIFBEk-q0ESJ_sShq8dQIQ/
26	Quinault Indian Nation	Article	Quinault	https://www.bia.gov/sites/bia.gov/files/assets/as-ia/ieed/ieed/pdf/Quinault%20Aggregate_508.pdf
27	What it was like being adopted into the Quinault Indian Nation	Article	Quinault	https://www.statepress.com/article/2018/04/spartcult-what-it-was-like-being-adopted-into-the-quinault-indian-nation
28	Tribes Seek to Govern Non-Members : Indians' New Powers Bring Gains, Conflicts	Article	Quinault	https://www.latimes.com/archives/la-xpm-1986-05-27-mn-7365-story.html
29	Tribes forced to adapt ways of life due to climate change	Article	Quinault	https://www.indianz.com/News/2019/04/01/yes-magazine-tribes-forced-to-adapt-ways.asp
30	Facing Rising Waters, A Native Tribe Takes Its Plea To Paris Climate Talks	NPR	Quinault	https://www.npr.org/2015/12/01/455745765/facing-rising-waters-a-native-tribe-takes-its-plea-to-paris-climate-talks
31	A Washington Tribe Confronts Climate Change, Sea Level Rise	OPR	Quinault	https://www.opb.org/news/article/a-washington-tribe-confronts-climate-change-sea-level-rise/
32	Anglers Quest 2015 – Quinault Indian Nation	Article	Quinault	https://www.soulriverinc.org/blog/post/anglers-quest-2015--quinault-indian-nation
33	Turtle Island Storyteller Harvest Moon	Blog?	Quinault	http://www.wisdomoftheelders.org/turtle-island-storyteller-harvest-moon/
34	Moving Taholah Village Before It's Swallowed by the Sea	Article	Quinault	https://psmag.com/news/moving-taholah-village-before-its-swallowed-by-the-sea
35	Where Eagles Fly	Video	Quinault	https://vimeo.com/118748588
36	Bringing Back the Blueback	Article	Quinault	https://www.wildsalmoncenter.org/2010/09/05/bringing-back-blueback/
37	For American Indians, Coping with Climate Change Is Ancient History	Article	Quinault	https://www.scientificamerican.com/article/for-american-indians-coping-climate-change-ancient-history/
38	Making history by saving it: UW groups keep indigenous languages alive	Article	Quinault	https://www.peninsuladailynews.com/news/making-history-by-saving-it-uw-groups-keep-indigenous-languages-alive/
39	Tribes commit to uphold Paris climate agreement	Article	Both	https://www.hcn.org/issues/49.16/tribes-commit-to-paris-climate-agreement
40	The paddle to Quinault Journey	Blog	Quinault	https://blog.pendleton-usa.com/2013/08/30/the-paddle-to-quinault-journey/
41	Museum Curator & Artist Leilani Jones-Chubby Preserves QIN Cultural Heritage	Article	Quinault	http://www.graysharbortalk.com/2017/06/16/quinault-tribal-muesum-leilani-jones-chubby/
42	Northwest's first citizens develop tribal tourism	Article	Both	https://www.seattletimes.com/life/travel/northwests-first-citizens-develop-tribal-tourism/
43	Quinault Spiritual Pole	Blog	Quinault	http://www.wilkersonart.com/wordpress/?p=65

APPENDIX H. KEY TERMS

Beneficiaries: The interests of an individual (i.e., person and/or group) that drive active or passive consumption and/or appreciation of ecosystem services resulting in an impact (positive or negative) on their welfare.

Benefits: an impact, positive or negative, on human welfare.

Benefit transfer: Economic valuation approach in which estimates obtained in primary studies are used to estimate values in context for other studies. This approach is widely used given relative low cost though must be carefully used given values are context specific. Care must be taken to assess values for transferability.

Biodiversity: The variability among living organisms from all sources including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within and among species and diversity within and among ecosystems. Biodiversity itself is not an ecosystem service but provides the major foundation for all ecosystem services.

Built Capital: Includes all human constructed infrastructure such as sewers, water systems, machinery, roads, electronic communication, technologies, buildings, and housing.

Capital Asset Value (of an ecosystem): The present value of the stream of future benefits that an ecosystem will generate under a particular management regime. Present values are derived by discounting future benefits and costs; discount rates applied are often set arbitrarily.

Classification system: An organized structure for identifying and organizing ecosystem services into a coherent scheme.

Discount rate: The rate at which people value consumption or income now, compared with consumption or income in the future, This may due to uncertainty, productivity, or time preference for the present.

Cultural Services: The non-material benefits people obtain from ecosystems including aesthetic inspiration, cultural identity, sense of home/place, and spiritual experience related to the natural environment.

Ecosystem Functions: (sometimes referred to as ecosystem or ecological processes) result from the interaction of an ecosystem's structural components (e.g., trees, forests, slopes, streams) and its dynamic processes (e.g., hydrological cycle, Earth's rotation). Ecosystem functions are an integral part of biodiversity, and can thus be broadly defined as the biological, geochemical and physical processes that take place or occur within an ecosystem.

Externalities: A side effect or consequence of an industrial or commercial activity that affects other parties without this being reflected in the cost of the goods or services involved.

Ecosystem Goods: The tangible products of the processes and interactions of natural systems that benefit humans.

Ecosystem Services: Ecosystem services are the direct and indirect contributions of ecosystems to human well-being. They support directly or indirectly our survival and quality of life.

Ecosystem Service Valuation (ESV): an economic process that assigns a value, typically monetary, to an ecosystem and/or its services. This allows for proposed projects or management policies to be assessed in terms of their ability to improve ecological processes that produce the full diversity of ecosystem goods and services.

Framework: a structure that includes the relationships among a set of assumptions, concepts, and practices that establish an approach for accomplishing a stated objective or objectives.

Human Capital: The economic value of abilities or qualities of labor that influence productivity (e.g., education is an investment in human capital that pays off in terms of higher productivity).

Natural Capital: includes all natural aspects of community. Assets of clean water, clean air, wildlife, parks, lakes, good soil, landscape – all are examples of natural capital.

River Basin: The area of land that is drained by a river and its tributaries. This includes all streams and creeks that flow downhill into the river.

Social Capital: Is the area of investment that impacts how people, groups, and organizations in community get along. Without a functioning society in which people respect each other and have some concern for the well-being of others, most economic activity would be impossible. Examples include leadership, working together, mutual trust, and sense of a shared future.

Value: The contribution of an action or object to user-specified goals, objectives, or conditions.

Valuation: The process of expressing a value for a particular good or service in a certain context (e.g., decision-making), usually in terms of something that can be counted, often money, but also through methods and measures from other disciplines (e.g., sociology, ecology)

Watershed: The area of land where all of the water that is under it or drains off of it goes into the same place. A good example of a watershed is a river valley that drains into the ocean.

Resource Dimensions

Economics | Community Solutions | Land Use | Natural Resources | Regulatory Support

Gig Harbor, Washington | www.ecologicalecon.com