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State of Washington Office of Financial Management
Olympia, WA

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ECONOMIC ANALYSIS OF WATER INFRASTRUCTURE AND FISHERIES HABITAT RESTORATION NEEDS

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ACRONYMS AND ABBREVIATIONS

ACOE	Army Corps of Engineers
AEP	Annual Exceedance Probability
AR5	Fifth Assessment Report
BCA	Benefit Cost Analysis
CBO	Congressional Budget Office
CIG	Climate Impacts Group
CIP	Capital Improvement Plans
CRB	Columbia River Basin
CRS	Congressional Research Service
CSO	Combined Sewer Overflow
CWNS	Clean Watershed Needs Survey
DWR	Department of Water Resources
EAD	Expected Annual Damages
EDT	Ecosystem Diagnosis and Treatment
EIS	Environmental Impact Statement
ENSO	El Nino Southern Oscillation
EPA	Environmental Protection Agency
ESA	Ecosystem Services Analysis
ESU	Evolutionarily Significant Units
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
gal/d	Gallons per Day
GAO	General Accounting Office
GDP	Gross Domestic Product
GMA	Growth Management Act
GNP	Gross National Product
HGMP	Hatchery and Genetic Management Plan
HUC	Hydrologic Unit Code
IPCC	Intergovernmental Panel on Climate Change
IWM	Integrated Water Management
KPOS	Kootenai – Pend Oreille – Spokane Basin

LCRB	Lower Columbia River Basin
LSRB	Lower Snake River Basin
MCRB	Middle Columbia River Basin
Mgal/d	Million Gallons per Day
MS4s	Municipal Separate Storm Sewer Systems
NAA	No-Action Alternative
NEPA	National Environmental Policy Act
NED	National Economic Development
NEV	Net Economic Value
NFIP	National Flood Insurance Program
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
OFM:	Office of Financial Management
WCB	Washington Coastal Basin
P&G	Ecology and Environment Principles and Guidelines for Water and Related Land Resources Implementation Studies
PR&G	Principles and Requirements for Federal Investments in Water Resources
Pb	Lead
PDO	Pacific Decadal Oscillation
PSB	Puget Sound Basin
RED	Regional Economic Development
RFF	Resources for the Future
RME	Research Monitoring and Evaluation
ROI	Return on Investment
SLR	Sea Level Rise
SWMP	Stormwater Management Program
SWWRC-WSU	State of Washington Water Research Center at Washington State University
TMDL	Total Maximum Daily Load
UCRB	Upper Columbia River Basin
UGA	Urban Growth Areas
USBR	United States Bureau of Reclamation

USDA	United States Department of Agriculture
USFS	United State Forest Service
USGS	United States Geological Survey
WDFW	Washington Department of Fish and Wildlife
WRIA	Watershed Inventory Units
WSU	Washington State University
YBIP	Yakima River Basin Integrated Water Resource Management Plan
YRB	Yakima River Basin
YRBWEP	Yakima River Basin Water Enhancement Project
Zn	Zinc

CAPITAL BUDGET STUDY PROVISO

ENGROSSED SUBSTITUTE HOUSE BILL 2380

CAPITAL BUDGET—SUPPLEMENTAL, EFFECTIVE DATE: 4/18/2016

NEW SECTION. **Sec. 1020.** A new section is added to 2015 3rd sp.8s. c 3 (uncodified) to read as follows:

FOR THE OFFICE OF FINANCIAL MANAGEMENT

Water Infrastructure Investment Analysis (92000016)

The appropriation in this section is subject to the following conditions and limitations:

(1) The legislature finds that population growth, climate change, and other factors are creating increasing stresses on critical water infrastructure, fisheries, and watershed health. To inform policy decisions about the scale and timing of new investments in flood risk reduction, water quality, and water supply both in-stream and out-of- stream, it is the intent of the legislature to direct an analysis of the economic implications related to water infrastructure and fisheries habitat restoration needs across the state.

(2) The appropriation in this section is provided solely for the office of financial management to contract for an analysis of the economic implications relating to water infrastructure and fisheries habitat restoration needs.

(a) The analysis must incorporate existing data and information relating to:

(i) Integrated water supply and management planning that addresses water storage for municipal and agricultural uses, in- stream or out-of-stream water supply needs, or both, as well habitat and passage improvements;

(ii) Multiple benefit approaches that reduce the risk from floods and protect and restore naturally functioning areas; and

(iii) Low-impact development retrofits to reduce toxics and other pollutants in storm water.

(b) The analysis must consider, but not be limited to, fishing and recreation benefits of improved floodplain and riparian habitat, in-stream flows, municipal and agricultural water storage benefits, and fish passage projects.

(c) The analysis must provide a review of other state reports that examine the economic implications to water infrastructure and fisheries habitat restoration needs.

(d) The analysis must address, but not be limited to:

(i) A 20 year forecast of known need for investment for the three categories identified in (a) of this subsection;

(ii) Estimated effects on the Washington economy without new infrastructure investment, including impacts on households, business, and commerce caused by flooding, drought, and degraded water quality from storm water runoff; and

(iii) Estimated economic benefits, including jobs, commerce, and development associated with each billion dollars invested in the categories in (a) of this subsection.

(3) The consultant shall invite representatives of interest groups to provide input in conducting the analysis. The interest groups must include, but are not be limited to, the Washington business roundtable, the Washington state labor council, and the Washington environmental council. The consultant must report its findings to the House of Representatives capital budget committee and the senate ways and means committee by January 15, 2017.

EXECUTIVE SUMMARY

This research is intended to provide an understanding of the economic consequences of water infrastructure in Washington State through a review of literature and interviews with stakeholders. Needs are assessed in regards to stormwater management, flood prevention, water supply, and fisheries restoration in Washington. Failing to invest in these water infrastructure needs suggests that larger future expenditures will be needed to restore further degraded fish habitat, clean up contaminated waters, respond to catastrophic flood disasters, and support water-dependent industries. In addition, failing to invest in water infrastructure suggests human health risks, economic shocks to water-dependent economies, constrained development, legal costs, and a decline in the quality of the natural environment.

General Themes

Several themes emerged in the review of literature on infrastructure investment in Washington. First, there are challenges in managing water resources because it is a public asset, for which there is no clear understanding of the full value. Second, it is difficult to make decisions from the purview of the state since water infrastructure investment needs differ dramatically by river basin. Further complicating this is that decision making processes and water valuations differ by basin.

Stakeholder outreach was conducted in two phases- workshops and individual interviews. Over one hundred individuals were contacted through workshops in Yakima and Lynnwood. Additionally, over twenty interviews were conducted with water infrastructure managers and planners from organizations including the Army Corps of Engineers, the Washington State Department of Ecology, the Department of Health, and the Washington Water Utilities Council. Through these interviews, an understanding was developed of the economic consequences of investing and not investing in water infrastructure and fisheries habitat across the state, as well as an understanding of the plans and needs for water infrastructure over the next twenty years. Similar to the literature review, several trends emerged from the stakeholder outreach process. It was clear that water dependency and needs from water infrastructure varied widely by basin. There is a consistent need across basins for large investments in water infrastructure, although decisions about investments are not made with a uniform methodology. To be effective, however, these investments must consider a realistic interpretation of baseline conditions (in the absence of the project) and then effectively measure the changes from that baseline that are expected to occur as a result of the investment. It is important to include an estimate of all gains and losses associated with the projects including ecosystem services, climate change, fish habitat, and the risk and uncertainty of variable conditions in nature. In addition, consideration of jobs and water dependent sectors will help ensure that projects realize benefits across multiple metrics. These elements are not currently consistently present across all basin analyses.

The appropriate decision making process regarding water infrastructure investment requires education of decision makers and the public about the risks of failing to invest. In the face of changing land use and climate, a probabilistic analysis, and an understanding of how uncertainty affects decision outcomes, is also needed to explore how the chances of floods and droughts going forward may, or may not, support immediate investment in infrastructure to avoid more costly economic consequences in the future. Using the best available science and appropriate tools and techniques to evaluate investments involves close interdisciplinary collaboration and analysis between hydrologists, ecologists, and economists. Some of these considerations are currently incorporated into water infrastructure decisions in Washington, but a greater consideration of ecosystem services is still needed.

Incorporating ecosystem services into investment decisions will allow for more holistic decision-making that will increase the return on investment. By integrating considerations of ecosystem services, hydrology, agriculture, climate change, fish, and regional economic resilience into the decision-making process, multiple benefits can be realized from one investment, increasing the efficacy of funding.

Needs by Basin

A representative forecast of anticipated infrastructure investment requirements in Washington was developed for each of eight basins in the state as a result of the literature review, data collection, and stakeholder outreach. The results are presented in Table ES-1. The analysis suggests that approximately $32.77 billion will be needed in infrastructure for stormwater, water supply support, fisheries habitat restoration, and flood prevention over the next 20 years through 2036.

Table ES-1: Total Washington State Water Infrastructure Investment Needs by Type and Basin ($ in millions)

Investment Type	Yakima	Washington Coastal	Upper Columbia	Puget Sound	Middle Columbia	Lower Columbia	Lower Snake	Kootenai Pend Oreille Spokane	Multi-Basin	Total State
Water Supply	$1,733	$3	$35	$2,315	$766	$179	-	-	$299	$5,330
Stormwater	$8	$19	$8	$18,266	-	$7	$13	$11	$361	$18,694
Flooding	$156	$1,181	-	$22	-	-	-	-	$35	$1,395
Fish Habitat	$502	$598	$844	$1,278	-	$1,252	$201	-	-	$4,675
Multiple	-	-	-	$1,873	$5	-	-	-	$754	$2,632
Total	$2,399	$1,802	$886	$23,754	$771	$1,439	$214	$11	$1,449	$32,765

It is important to note that infrastructure investment needs differ by basin, both in terms of dollars of investment and type of infrastructure. This reflects differences in water systems, population, agriculture, business, and in the valuation of water infrastructure. It is also apparent that all basins need investment in water infrastructure, a theme echoed in the literature. Investing in one of the infrastructure types (stormwater, flood prevention, etc.) also provides opportunities for benefits to be realized in other areas. For example, a well-designed stormwater investment can also provide benefits to fish habitat and urban flood reduction. By incorporating holistic decision making and considering the multiple benefits from one investment across multiple services (ecosystem, hydrology, fish, climate change, agriculture, economic resilience), a more effective (from a cost-benefit perspective) investment is possible. This return on investment is further increased by considering "green" alternatives to existing grey infrastructure.

Table ES-2 shows how the total investment is expected to be needed throughout the 20 year time horizon – from 2017 through 2036.

Table ES-2: Total Washington State Water Infrastructure Investment Identified Needs Projected by Type

	Millions of Dollars								
Investment Type	Total	2017	2018	2019	2020	2025	2030	2035	2036
Water supply	$5,370	$1,381	$276	$257	$236	$191	$221	$174	$174
Stormwater	$18,694	$1,502	$906	$910	$906	$904	$904	$904	$904
Flooding	$1,395	$138	$67	$67	$67	$67	$65	$65	$65
Fish & habitat	$4,675	$284	$234	$234	$234	$234	$229	$229	$229
Multiple	$2,632	$1,527	$78	$83	$82	$65	$44	$44	$44
Total	$32,765	$4,832	$1,560	$1,551	$1,524	$1,462	$1,462	$1,416	$1,416

Note that Tables ES-1 and ES-2 do not include the roughly $2 billion needed to repair culverts and protect fish habitat. According to the Washington State Department of Transportation (WSDOT), 996 WSDOT culverts are subject to a recent federal court injunction (March 2013) that requires the State to remove state-owned culverts blocking salmon and steelhead habitat by 2030.[1] At the most recent estimate, an estimated 825 of the WSDOT culverts affect significant habitat (more than 200 meters upstream). As of December 2016, the Department of Transportation estimates that repairing the 825 culverts required under the injunction will cost $2.4 billion by 2030[2], though a report in the Seattle Times lists this number as $1.9 billion.[3]

Regional Economic Impact

In addition to gains and losses as a result of projects, there is the regional economy to consider in different basins. The regional economy is collective economic system within an area and addresses the idea that when one sector of the economy declines or grows, there is a 'ripple effect' in the other sectors of the economy. To aid in the understanding of this for the purpose of water infrastructure investment, basin-wide economies were analyzed for the

[1] WSDOT. Federal Court Injunction Related to Fish Passage. Accessible at https://www.wsdot.wa.gov/Projects/FishPassage/CourtInjunction.htm

[2] WSDOT. WSDOT Fish Barrier Correction. December 2016. Accessible at https://www.wsdot.wa.gov/NR/rdonlyres/878FC8F2-B15D-49ED-BE85-229D4989C0E9/0/FishPassageFolioforWeb.pdf

[3] The Seattle Times. "Washington must fix culverts that block salmon from habitat, court rules". June 27, 2016. Accessible at http://www.seattletimes.com/seattle-news/environment/washington-must-fix-salmon-blocking-culverts-court-says/

level of water dependency in each. The multipliers shown below were developed from IMPLAN software input-output model, and each shows the degree to which a job in the water-dependent sector, and a dollar spent in the water-dependent sector is multiplied within that basin (see Table ES-3). The percent of jobs and output in water-dependent sectors is also shown. The results of this analysis show that securing water supplies in basins such as the Upper Columbia, Yakima, and Middle Columbia, which have 40 percent or more of all jobs in water dependent sectors, may bring greater strength to the local economies than in other basins where a smaller share of jobs and output are in water-dependent sectors.

Table ES-3: Basin Comparison of Water Dependent Multipliers and Industry Details

	Water Dependent Employment Multipliers			Water Dependent Output Multipliers			Water Dependent Industry Detail	
Basin	**Ag and Mining**	**Manu-facturing**	**Commercial**	**Ag and Mining**	**Manu-facturing**	**Commercial**	**Employment (Share of total)**	**Output ($Million) (Share of total)**
Washington Coastal	1.34	2.05	1.29	1.36	1.40	1.45	25,444 (36.2%)	$3,984 (39.6%)
Lower Columbia	1.31	2.03	1.34	1.39	1.26	1.47	72,876 (29.8%)	$16,566 (39.3%)
Middle Columbia	1.29	2.01	1.30	1.36	1.31	1.45	21,458 (42.2%)	$4,079 (50.4%)
Upper Columbia	1.41	2.33	1.31	1.42	1.43	1.46	89,303 (42.6%)	$ 13,938 (46.7%)
Puget Sound	1.54	2.75	1.47	1.63	1.53	1.85	780,141 (26.7%)	$199,962 (33.6%)
Lower Snake	1.32	1.49	1.16	1.27	1.23	1.29	11,088 (29.1%)	$1,987 (28.4%)
Kootenai-Pend Oreille-Spokane	1.33	2.37	1.56	1.47	1.53	1.82	78,662 (28.8%)	$11,740 (30.6%)
Yakima	1.41	2.33	1.31	1.43	1.44	1.56	96,645 (39.5%)	$13,099 (37.4%)
Total	N/A	N/A	N/A	N/A	N/A	N/A	1,175,617 (29.0%)	$ 265,355 (34.6%)

Additional analyses of basin level investment following the forecast shown in Table ES-1 deals with the fact that the expenditures needed for investment also result in a stimulus to the regional economies. This stimulus is expected to play out primarily in the construction industry in each basin. Just as water-dependent sectors have a multiplier effect for water supply infrastructure, construction has a similar effect for in the economy. Table ES-4 shows how the total infrastructure investment expenditures would ultimately stimulate the economy in terms of jobs and output growth using the IMPLAN results. The totals suggest that the expenditure of over $32 billion over 20 years would result in a stimulus effect totaling over $50 billion in the statewide economy and support over 16,000 jobs annually.

Table ES-4: Employment, and Output increases Associated with Identified Infrastructure Investment Projects

Basin	Total Infrastructure needs ($Million)	Average Annual Investment Needs ($Million)	Increased Average Annual Employment	Increased Annual Final Demand or Output ($Million)	Total 20-year Increased Final Demand or Output ($Million)
Washington Coastal	$1,802	$90	953	$132	$2,638
Lower Columbia	$1,439	$72	650	$101	$2,017
Middle Columbia	$771	$39	383	$54	$1,083
Upper Columbia	$886	$44	457	$66	$1,310
Puget Sound	$23,754	$1,188	12,293	$2,150	$42,995
Lower Snake	$214	$11	96	$14	$283
Kootenai-Pend Oreille-Spokane	$11	$0.6	7	$1	$20
Yakima	$2,439	$122	1,238	$187	$3,734
Total State	**$31,316**	**$1,566**	**$16,077**	**$2,704**	**$54,079**

Extent of the Study

Note that this study does not complete a formal review of all proposed projects or endorse particular projects for funding, both of which are beyond the scope of this project. Conclusions regarding the merit of individual projects also lie beyond the scope of this work. General recommendations that can reasonably extracted from this work, mainly that water infrastructure investment is needed statewide, and that particular needs (type and cost) vary substantially by Basin. All Basins can benefit from considering investments that trigger returns on investment in multiple metrics.

Data used to estimate the infrastructure needs were gathered through data collection, interviews, and literature reviews, and demonstrate the best effort at totaling anticipated investment. No attempt was made to determine whether funding for these projects has been secured or identified. In most cases funding is being pursued, but has not been secured, and comes from a variety of sources. Also, the research team is certain that there are significant water and fisheries habitat investment needs that are not included in the comprehensive data base developed either because we were not aware of existing projects and needs, or because the needs have not yet been addressed or quantified.

1. INTRODUCTION

Droughts, water supply shortages, flooding, and water quality declines are increasingly affecting the Washington state economy. These threats to water availability, water quality, fisheries, and overall watershed health are managed and mitigated through water infrastructure investments supported by the state legislature. The purpose of this report is to categorize, quantify and evaluate the economic impacts (on households, businesses and commerce) of proposed infrastructure investments in Washington State. Ramboll Environ was retained by the Office of Financial Management (OFM) on behalf of the state legislature to conduct the analysis.

Washington state's watersheds and water infrastructure are facing ongoing pressures to provide the state with needed water for domestic and commercial use, agriculture and industrial uses, and for instream flows for fish and ecosystem maintenance. Some of the main drivers of this pressure are population growth, economic growth, urbanization, a changing climate, and the cumulative impacts associated with aging infrastructure and long-term ecological degradation. The availability of water is a key element in preserving and sustaining the ongoing economic health of the state. For example, the Anderson Economic Group reported that Washington state rates 10th in the nation in terms of the share of employment that is water-related.[4] In their analysis, fully 20 percent of employment in the state is water related which is substantially higher than the national average of 12.6 percent of employment. . The Anderson Group study did not include the 'downstream' economic importance of water related industries like fishing and tourism.

Because water infrastructure investment can be costly and have long term impacts to the state, it is critical to forecast conditions in the state for the future. Forecasting this investment is challenging given the uncertainty of changing climate and other conditions. As the legislature considers the scale and timing of new investments in flood risk reduction, water quality, and water supply for all of the above purposes, an economic analysis can provide important information to support policy decisions on this topic.

Benefit cost analyses uses the information described above to evaluate the measures of loss that will occur in the absence of any investment in water infrastructure. The conditions that will be expected with investment in a particular project or set of projects will be evaluated and the reduced losses will be estimated, which will then count as benefits of the project. The benefits (added up over the number of years of the project) will be compared with the costs (also added over the number of years of the project) to evaluate whether the benefits of the project exceed the costs. If the (present value of) the benefits exceeds the (present value of) all costs, then the project is considered 'feasible.' That is, a feasible project is one with benefits that exceed costs. Other metrics are used to compare between alternative projects. For example, the most common is the metric termed 'net benefits', which is simply are the present value of benefits minus the present value of costs. When alternative projects include several feasible projects, the one with the greatest net benefits might be selected among them. It is important to remember that these benefits and costs include gains and

4 Rosaen, Alex L., 2014, Innovating for the Blue Economy: Water Research at the URC, Report commissioned by the University Research Corridor, University of Michigan, Michigan State University, Wayne State University, available at: http://urcmich.org/wp-content/uploads/2015/03/URC_Water-Industry-Sector.pdf

losses to ecosystem services including recreation and fisheries. If the costs exceed the benefits (damages or losses avoided) through time, then the project(s) under evaluation would be considered infeasible.

The benefit cost analysis dynamics described above provide a basis for formal economic data used in decision making, but other factors also play a role in determining the best investment(s) for a state or community. For example, impacts to the overall regional economy are often important. In formal Benefit Cost Analysis (BCA), regional economic impacts such as jobs, income, Gross Domestic Product (GDP) and tax impacts are assumed to occur somewhere else if they are not spent within a particular geography, and consequently are not counted as a net gain. These impacts can be significant to a state or local jurisdiction that risks losing out on revenue and economic activity to a nearby competitor. Such impacts include business interruptions, reduced payroll, and tourism impacts. The reductions or impacts can also trigger additional economic slowdowns in industrial sectors that are linked to the sectors affected. Understanding these ripple effects is critical to members of legislative bodies who are tasked to protect and enhance the overall economic and ecological health of the entire state.

With climate change, there is increasing uncertainty about the magnitude of potential future impacts to water supplies and watersheds as a result of droughts and flooding. For the best decision making, these uncertainties need to be defined and incorporated into the overall presentation of the economic effects of changing water services.

In summary, the Ramboll Environ approach is to evaluate changes in value to various statewide 'asset classes' including buildings and infrastructure, ecosystem services, and agriculture over the next 20 years, through the year 2036, absent any additional water investment infrastructure. These estimates will be used to benchmark conditions absent investment so that investments in water infrastructure may be explored throughout the state in terms of the benefits these projects will generate. Water infrastructure investment benefits will then be evaluated using BCA, and evaluated again in terms of the regional economic impact potential each possesses (jobs, related industries, statewide GDP). This effort will be supported and informed by reaching out to stakeholders throughout Washington including local governments, interested parties, and other state organizations.

1.1 Goals and Objectives

Two specific goals which are to be addressed through the analysis:

A. Assessing the impact on the Washington state economy (households, businesses, and commerce) of predicted floods, droughts, and storm water runoff; and

B. Developing estimates of the economic benefits (jobs, commerce and development) of flood, drought, and storm water infrastructure investment incrementally by $1 billion - $10 billion.

These goals are consistent with the recognized sequence of analysis for benefit cost analysis. The **first** provides an understanding of the economic impacts to water supplies in the absence of additional infrastructure investment, and the **second** will support the analysis of the impacts of the investments themselves. The benefits, costs, and impacts of any investment must be measured by comparing the proposed investment to what would occur in the absence of action.

The second broad goal of the project will be to estimate the economic impacts of proposed infrastructure investments to the state economy. This second goal will require estimates of all benefits and costs of proposed and needed infrastructure investments and the regional economic impacts of the proposed investment. Impacts are different from benefits and costs because impacts are the stimulative effect of spending, or the way that investment can 'ripple through' a regional economy. In a pure theoretical economic sense, understanding these impacts are a bonus to the investment decision and should not be included in the baseline calculus about whether or not to invest. Impacts always increase with spending (to greater and lesser degrees depending on the case), while an investment decision is based on the outcomes (benefits) that are achieved with public expenditures. However, as mentioned in a previous section, understanding these impacts is a factor to consider – especially with public investment.

To accomplish the goals articulated in "a" and "b" above, several specific objectives are requested by the proviso language. These include the following.

1. Completing a scientific and technical review of water supply, floods and drought, storm water, planned infrastructure investment projects, and the benefits of those projects to the Washington state economy. This review will incorporate the existing data and reports relating to economic implications to the state.
2. Developing at least a 20-year forecast of infrastructure investment needs.
3. Conducting an economic analysis of the impacts of drought and water supply, floods, and storm water runoff.
4. Working with multiple stakeholders, including the public, Washington Business Roundtable, the Washington State Labor Council, the Washington Environmental Council, and local governments.

Our overall approach was to employ a multi-disciplinary group of economists, water engineers and flood protection specialists, ecologists and environmental experts, and communications professionals to gather and interpret existing information, then identify gaps and develop assumptions about the water infrastructure investment that may be needed statewide. This data collection and project initiation will prepare the researchers to conduct an economic analysis, and then develop a report to meet the needs of the legislature.

1.2 Definition of Water Infrastructure Investment and Fisheries and Habitat Restoration

Water infrastructure is the system of built infrastructure that supplies and manages water for agriculture, drinking, energy, stormwater management, and ecosystem protection, among many other purposes. A recent dialogue at the Aspen Institute[5] argued that the traditional definition of water infrastructure ("grey infrastructure", or the constructed components)

[5] Bolger, R., D. Monsma, R. Nelson. Sustainable Water Systems: Step One - Redefining the Nation's Infrastructure Challenge. A report of the Aspen Institute's Dialogue on Sustainable Water Infrastructure in the U.S. May, 2009.

Accessible at https://dorutodpt4twd.cloudfront.net/content/uploads/files/content/docs/pubs/water_infra_final.pdf must evolve to include a more sustainable frame for water infrastructure, considering both the traditional "grey" and the natural ("green") infrastructure. Green infrastructure should integrate the traditional components of grey water infrastructure (the physical components for supply, distribution, and disposal) with the need to protect and restore ecosystems, conserve and use efficiently, reuse and reclaim, and pursue low impact development "to ensure the reliability and resilience of water infrastructure".

From a report by The Johnson Foundation,

> Water management agencies have focused for over 100 years on the hardware of water and wastewater management: the pipes, pumps and reservoirs needed to move the drinking water, waste and stormwater through the system or store it until needed. These rigid systems were designed and operated based on the assumption of stationarity in our natural systems. Those assumptions are now seen as short-sighted and no longer match our understanding of nature. We need to transition from systems built around managing water under historical conditions of 'certainty' to those built around flexibility to respond to unpredictable or rapidly changing conditions.[6]

Incorporating green infrastructure into the traditional definition of grey water infrastructure allows for multiple benefits to be realized across investments, increasing their value and providing for more adaptable infrastructure that is able to mitigate unforeseen impacts and manage rapidly changing supply and demand.

For the purpose of this report, which is designed to explore water infrastructure and fisheries and habitat restoration investments, the term "infrastructure" will be considered as inclusive of both engineered, and hard infrastructure as well as natural or green infrastructure.

1.2.1 Types of Investment

There were three main infrastructure types considered at the outset of this analysis. These three were Water Supply and Management (inclusive of agricultural and municipal water storage, fisheries habitat and passage improvements, instream or out of stream needs, drought mitigation), Flood Risk Reduction (inclusive of flood protection, restoration and protection of naturally functioning areas), and Water Quality and Storm Water Runoff (inclusive of retrofits, point or nonpoint source pollution control, green/low impact infrastructure, and combined sewer overflows). Because fisheries habitat restoration investment overlaps with each of the other three types of investment, we ultimately conducted the analysis considering four types investment: Water Supply and Management, Flood Risk Reduction, Water Quality and Stormwater, and Fisheries and Habitat Restoration.

1.2.2 Basins

There are eight Hydrologic Unit Code (HUC) level 4 regions in the State of Washington, delineating the large river basins. These include the Puget Sound, the Upper Columbia, the

[6] Financing Sustainable Water Infrastructure: Convening Report, Meeting Convened by American Rivers Cere The Johnson Foundation at Wingspread July – August, 2011. Accessible at http://www.johnsonfdn.org/sites/default/files/reports_publications/WaterInfrastructure.pdf

Yakima, the Middle Columbia, the Lower Columbia, the Lower Snake, the Kootenai-Pend Oreille-Spokane, and the Washington Coastal river basin. Most economic data is provided at the County level, and the Counties do not often overlap with HUC 4 boundaries (see Figure 1-1), so County economic data is assigned to the HUC most relevant to the county population.

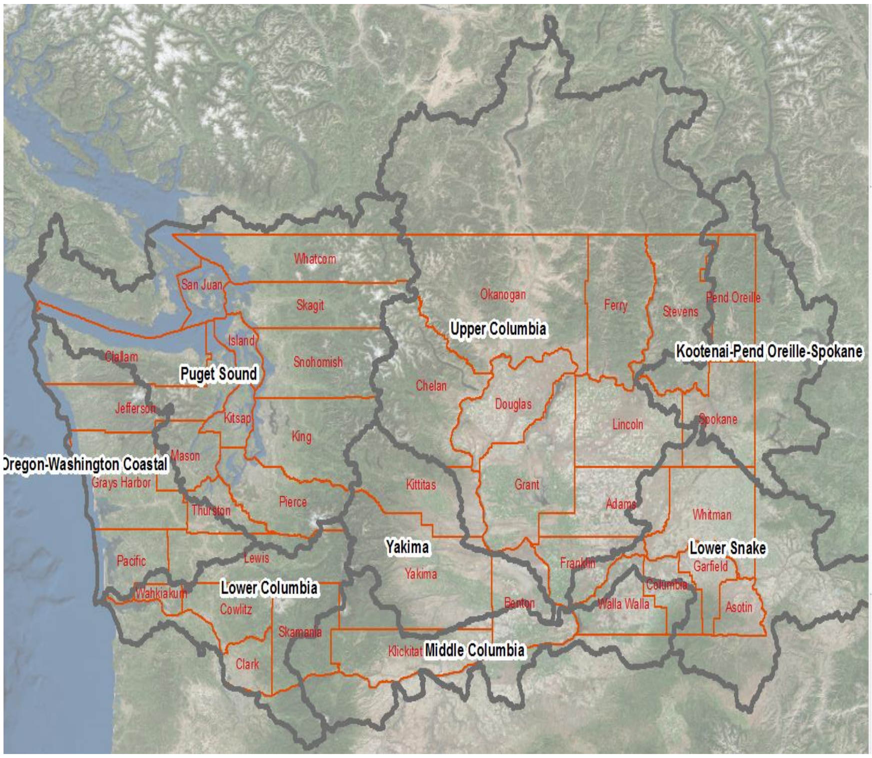

Figure 1-1: The HUC 4 and county boundaries in Washington State. Scale 1:4,240,071.

Data layers: Washington State Department of Ecology GIS Data: HUC 4 boundaries; Washington State Office of Financial Management: County boundaries. Generated by Ramboll-Environ, August 11, 2016. Using: ArcGIS for Desktop Advanced [GIS]. Version 10.3, Redlands, CA: ESRI, 2014.

The majority of the geospatial data collected is from the Washington State Department of Transportation Geodata Distribution Catalogue,[7] which details political and administrative features, environmental features, and general geographic reference data, and the Washington State Department of Ecology GIS Database,[8] which has GIS layers describing statewide air and water quality monitoring information, drought areas, water quality assessments, well logs, WRIAs, other political boundaries, and a variety of additional data. Geospatial data on hydrography and watershed boundaries is from the USGS National Hydrography Dataset.[9] The Washington State Office of Financial Management[10] provides census and county geospatial information.

[7] http://www.wsdot.wa.gov/mapsdata/geodatacatalog

[8] http://www.ecy.wa.gov/services/gis/data/data.htm

[9] nhdftp.usgs.gov

[10] http://www.ofm.wa.gov/pop/geographic/tiger.asp

1.3 Organization of Report

The report is organized into five chapters following this introduction. Chapter 2 reviews literature related to the economic value of water infrastructure investment, provides an overview of current water use and Washington resources, and covers several key topics germane to the discussion of water investment planning decisions. Chapter 3 is a short statement of the approach and methodology used in the study. Chapter 4 provides a basin by basin analysis of water infrastructure projects and needs, and for each basin provides an overview of basin-wide hydrology, aquatic ecology, and basin economics. Chapter 5 reviews the potential benefits of slated infrastructure investments. Chapter 6 is an analysis of the regional economic impacts associated with water infrastructure investment in Washington.

2. BACKGROUND INFORMATION: WATER INFRASTRUCTURE INVESTMENT AND THE ECONOMY

This chapter provides an overview of the importance of water infrastructure investment decisions, and is intended to briefly present some of the basic economic information that is critical to improved decision-making in infrastructure investment.

The first subsection provides an overview of the fundamental relationship between any infrastructure investment and the underlying economic principles. The next subsection covers some of the background literature on measuring the economic benefits of water infrastructure. Subsection 2.3 discusses ecosystem services and Subsection 2.4 provides an overview of the most critical concepts that complicate decision making about water resources: risk and uncertainty. These topics are increasingly critical as the State recognizes that these are essential parts of the decision making process that must be evaluated with all of the other considerations.

2.1 Infrastructure Investment and the Economy

According to the United States General Accounting Office (GAO), government spending on infrastructure has a beneficial impact on the nation's economy, but there are mixed results as to whether infrastructure spending leads to economic growth.[11] It is important to note, however, that the goal of infrastructure improvements is not always to help the economy, but sometimes to improve public safety. As a result of this, the GAO reports that the federal government does not consistently analyze the benefits and costs of infrastructure projects. According to the Congressional Research Service (CRS), "In many cases, funding goes to projects that are presumed to be the most important, without a rigorous study of the costs and the benefits".[12] According to the GAO, "[The] federal budget structure does not prompt explicit debate about infrastructure spending that is intended to have long-term benefits".[13] Because of public safety needs, the GAO cautions that it is unclear whether cost-benefit analysis is useful in prioritizing infrastructure projects. Echoing this sentiment, the Congressional Budget Office (CBO) states, "Many federal investments are motivated primarily by noneconomic policy goals (such as equality of opportunity, national security, and the advance of scientific knowledge). Others are influenced by political considerations. For those reasons, one cannot expect that federal funds will always be directed to the most cost-beneficial use, even within those classes of projects that have an economic rationale".[14]

The GAO recommends that to maximize the benefits of infrastructure investment and improve the return on investment (ROI), the decision-making process about how and what to fund needs to improve. Specifically, for each infrastructure investment consideration, the

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[11] United States General Accounting Office. Report to the Congress: *U.S. Infrastructure: Funding Trends and Opportunities to Improve Investment Decisions*. February 2000. Accessible at http://www.gao.gov/assets/590/588838.pdf

[12] Congressional Research Service. Report for Congress: *National Infrastructure Bank: Overview and Current Legislation*. December 2011. Accessible at http://www.fas.org/sgp/crs/misc/R42115.pdf

[13] United States General Accounting Office. Report to the Congress: *U.S. Infrastructure: Funding Trends and Opportunities to Improve Investment Decisions*. February 2000. Accessible at http://www.gao.gov/assets/590/588838.pdf

[14] Congressional Budget Office. The Economic Effects of Federal Spending on Infrastructure and Other Investments. June 1998. Accessible at http://www.cbo.gov/sites/default/files/105th-congress-1997-1998/reports/fedspend.pdf

GAO recommends conducting an assessment of needs (which can be difficult to accurately define), identify excess capacity and current capabilities, identify unmet needs for maintenance and repairs, identify alternative approaches for investing, evaluate among alternatives while considering innovative funding approaches, and then appropriately manage the construction of infrastructure improvements.

Assessing the "need" of infrastructure investment is a difficult task. According to the CRS, "In the infrastructure context, funding needs estimates try to identify the level of investment that is required to meet a defined level of quality of service, but this depiction of need is essentially an engineering concept. It differs from economists' conception that the appropriate level of new infrastructure investment, or the optimal stock of public capital (infrastructure) for society is determined by calculating the amount of infrastructure for which social marginal benefits just equal marginal costs".[15]

It is difficult to perform benefit cost analyses of investment in infrastructure due to the difficulty in establishing a baseline ("what would happen without the infrastructure") and difficulty in determining which benefits are directly attributable to the infrastructure improvement. However, the co-benefits of infrastructure investment are multiple. Starting with programs of the New Deal, government investment in infrastructure has helped the development of roads, cities, and agriculture across the country. Infrastructure investment is correlated with increased efficiency in the transportation sector, lower prices for consumers, increased profitability for firms, increased productivity, increased property values, more economic growth, improved air quality, and reduced unemployment.[16] [17]

Within the transportation sector, "investments in infrastructure allow goods and services to be transported more quickly and at lower cost".[18] According to the Treasury, transportation infrastructure investment causes a clustering of business around the improved infrastructure. This clustering reduces average commute times, which reduces traffic congestion and improves air quality. This results in improved living standards and increased property values. Investment in building transportation infrastructure or improving the existing infrastructure also reduces unemployment, although this could be temporary. Several studies have established additional benefits of investing in transportation infrastructure. John Fernald argues that the construction of the interstate highway system correlated with an increase in productivity in vehicle-intensive industries. Edward Gramlich states that the greatest ROI in

[15] Congressional Research Service. *Legislative Options for Financing Water Infrastructure*. June 2016. Accessible at http://www.fas.org/sgp/crs/misc/R42467.pdf

[16] The White House National Economic Council and President's Council of Economic Advisers. *An Economic Analysis of Transportation Infrastructure Investment*. July 2014. Accessible at http://www.whitehouse.gov/sites/default/files/docs/economic_analysis_of_transportation_investments.pdf

[17] David Alan Aschauer. Is Public Expenditure Productive? Journal of Monetary Economics 23. 1989. pp. 177-200. Accessible at http://idrc.znufe.edu.cn/czx/html/xinxipingtai/jdwx/Eng/12%20Is%20Public%20Expenditure%20Productive.pdf

[18] Department of the Treasury and the Council of Economic Advisers. A New Economic Analysis of Infrastructure Investment. March 2012. Accessible at http://www.treasury.gov/resource-center/economic-policy/Documents/20120323InfrastructureReport.pdf

any sector of infrastructure is in the maintenance of existing highways.[19] Specific to water infrastructure investments, Grey and Sadoff (2007)[20] found positive relationships between investment in the water sector and economic development, though this is more important for developing countries.

Historic analyses of American government investment in infrastructure focus primarily on the impacts of the New Deal. According to the Institute on Research on Labor and Employment and UC Berkeley, infrastructure investments as a result of New Deal programs helped spur economic recovery in the Great Depression, allowing for growth of the Gross National Product (GNP), job creation, and support for housing and agriculture. Infrastructure investments correlated with economic growth in production, transportation, and household consumption.[21] This resulted in a truism of development theory that correlated general economic development with infrastructure investment. Due to the aforementioned difficulties of quantifying the benefits of public works, there are no quantifications of the direct economic costs and benefits of infrastructure investment resulting from New Deal programs. It is true, however, that the large-scale infrastructure investments of the New Deal resulted in job growth, promoted economic development, and stimulated consumption. Further, the New Deal catapulted the Interstate Highway System, which transformed US cities, the transportation sector, and residential communities.

2.1.1 Water Infrastructure Investment

In California, the New Deal resulted in the growth of the agricultural sector by transforming the Colorado River and the Central Valley.

The Colorado River Storage Project included the development of the Hoover Dam and the Colorado Aqueduct, which changed the landscape of Southern California.[22] By providing hydroelectricity and drinking water to Los Angeles, and irrigation water to Riverside, this investment in water infrastructure directly altered the patterns of growth in the West and had large economic impacts on the development of Southern California.

The Central Valley Project, with its connections of dams and associated canals, provided electricity and water to Northern California and the Central Valley. By supplying $300 million to the Central Valley Project, the federal government directly supported water infrastructure in the West which led to the growth of agriculture in the Central Valley, attracting migrant workers and supported the growth and development of the region.

The GAO reports that by Environmental Protection Agency (EPA) estimates, over the next 20 years, over $655 billion will need to be invested in water infrastructure nationally to

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[19] Edward Gramlich. Infrastructure Investment: A Review Essay. Journal of Economic Literature, Vol. 32, No. 3. September 1994. pp 1176-1196. Accessible at http://www1.worldbank.org/publicsector/pe/pfma07/EdwardGramlich.pdf

[20] Grey, D. and Sadoff, K., 2007. Sink or Swim? Water security for growth and development. Water Policy 9: 545 – 571.

[21] Richard A. Walker and Gray Brechin. The Living New Deal: The Unsung Benefits of the New Deal for the United States and California. 2010. IRLE Working Paper No. 220-10. Accessible at http://www.irle.berkeley.edu/workingpapers/220-10.pdf

[22] Richard A. Walker and Gray Brechin. The Living New Deal: The Unsung Benefits of the New Deal for the United States and California. 2010. IRLE Working Paper No. 220-10. Accessible at http://www.irle.berkeley.edu/workingpapers/220-10.pdf

maintain and upgrade necessary services.[23] Localities are generally the primary source of funding for water infrastructure projects, and it can be a challenge to ensure funding is available for all necessary proposals[24.] While federal SRF Capitalization Funds are the largest source of federal funding for water infrastructure, according to the CBO, "State and local governments have strong incentives to invest in infrastructure, even in the absence of federal assistance, since the majority of benefits accrue to local residents".[25] It is often questioned whether costly action is worth the benefits, particularly given the high costs of water infrastructure[26.] Coupled with water infrastructure, there are often high costs of conforming to water quality standards. The EPA contends that the benefits of water quality legislation exceed the costs of compliance, and that investing in pollution control creates economic activity and jobs, increases economic competitiveness, and supports existing communities. EPA urges the pursuit of water infrastructure investments that are cost-effective, resource efficient, and contribute sustainably to the community.[27] EPA also urges these investments to consider the impacts of climate change.

Unfortunately, EPA finds that water infrastructure investment has lagged behind public needs: "The level of renewal and reinvestment in the water sector has not kept pace with the need. […] Historically, investment has not been enough to meet the ongoing need to maintain and renew these systems. Over the coming decades, this pattern of underinvestment needs to change and practices put in place to sustain the water services provided by water infrastructure and utilities. Doing so is vital to public, economic, and environmental health."[28]

EPA's 2012 Clean Watershed Needs Survey (CWNS) finds that, nationwide, $271 billion is needed for capital wastewater and stormwater treatment and collection, including $198 billion for wastewater pipes and treatment facilities, $48 billion for Combined Sewer Overflow (CSO) correction, $19 billion for stormwater management, and $6 billion for recycled water treatment and distribution.[29] For the State of Washington, $1.3 billion is needed for CSO correction, $745 million is needed for conveyance system repair, $738 million is required for secondary wastewater treatment, and $529 million for advanced

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[23] United States General Accounting Office. Report to the Ranking Member, Subcommittee on the Environment and the Economy, Committee on Energy and Commerce, House of Representatives: *Water Infrastructure: Information on Selected Midsize and Large Cities with Declining Populations*. September 2016. Accessible at http://www.gao.gov/assets/680/679783.pdf

[24] Congressional Research Service. *Water Infrastructure Financing: The Water Infrastructure Finance and Innovation Act (WIFIA) Program*. February 2016. Accessible at http://www.fas.org/sgp/crs/misc/R43315.pdf

[25] Congressional Budget Office. The Economic Effects of Federal Spending on Infrastructure and Other Investments. June 1998. Accessible at http://www.cbo.gov/sites/default/files/105th-congress-1997-1998/reports/fedspend.pdf

[26] Congressional Research Service. Water Quality Issues in the 114th Congress: An Overview. February 2016. Accessible at http://nationalaglawcenter.org/wp-content/uploads/assets/crs/R43867.pdf

[27] EPA. Clean Water and Drinking Water Infrastructure: Sustainability Policy. Accessible at https://www.epa.gov/sites/production/files/2016-01/documents/clean-water-and-drinking-water-infrastructure-sustability-policy.pdf

[28] EPA. Building Sustainable Water Infrastructure. Last Updated March 2016. Accessible at https://www.epa.gov/sustainable-water-infrastructure/building-sustainable-water-infrastructure

[29] EPA. Clean Watershed Needs Survey (CWNS) – 2012 Report and Data. Updated August 2016. Accessible at https://www.epa.gov/cwns/clean-watersheds-needs-survey-cwns-2012-report-and-data

wastewater treatment.[30] Other needs include new conveyance systems, improved stormwater management, and recycled water distribution. This results in estimated needs of $4.1 billion to improve Washington's water management by the year 2032, at which point these systems will have to provide for a population 40 percent larger than in 2012 (at the time of the study).

One of the EPA's stated policies is to support the deployment of sustainable water infrastructure around the United States.[31] EPA argues that it is imperative that both citizens and decision makers understand the value of water infrastructure, stating "systems should have an on-going collaborative process with all stakeholders to determine where and how water infrastructure investments are made in their communities."

2.1.2 Infrastructure Investment and Employment

Infrastructure jobs are not only short-term; investing in infrastructure creates long-term jobs in maintenance and operation[32]. Infrastructure jobs also offer competitive wages with low barriers to entry. According to the Bureau of Labor Statistics, infrastructure jobs offer wages up to 30 percent more than wages generally offered to low-income and unskilled workers.

A report by Green for All (2011)[33] estimated the economic and job creation impact of a major investment in water infrastructure in the United States. The report estimates that an investment of $188.4 billion spread equally over the next five years would generate $265.6 billion in economic activity and create close to 1.9 million jobs. The authors also calculate the number of jobs that would be created in each of the 50 states and District of Columbia. In the State of Washington, it estimates that 27,882 to 39,904 jobs would be created during the study period based on the level of investment used in the study. The analysis presented in Hewes (2008)[34] also proves that green infrastructure and water efficiency retrofit projects (green roofs, water efficiency, and wetland restoration) have a significant stimulus effect on local, regional and national economies, especially through increased output, GDP, labor income, and job creation. A report by the Water Research Foundation (2014)[35] explored the significant impact the water utility sector has on the U.S. economy. Based on the planned operating and capital investments of 30 public water utilities, the research determined that

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[30] EPA. Clean Watershed Needs Survey (CWNS) – 2012 Report and Data – Washington State Fact Sheet. 2012. Accessible at https://www.epa.gov/sites/production/files/2015-10/documents/cwns_fs-wa.pdf

[31] EPA. Clean Water and Drinking Water Infrastructure: Sustainability Policy. Accessible at https://www.epa.gov/sites/production/files/2016-01/documents/clean-water-and-drinking-water-infrastructure-sustability-policy.pdf

[32] Joseph Kane and Robert Puentes. The Brookings Institution. *Expanding Opportunity through Infrastructure Jobs*. May 2015. Accessible at http://www.brookings.edu/research/expanding-opportunity-through-infrastructure-jobs/

[33] Green for All. 2011. Water Works – Rebuilding Infrastructure Creating Jobs Greening the Environment. http://www.pacinst.org/app/uploads/2013/02/water_works3.pdf

[34] Hewes, Will. 2008. Creating Jobs and Stimulating the Economy through Investment in Green Water Infrastructure. American Rivers and Alliance for Water Efficiency. http://www.allianceforwaterefficiency.org/uploadedFiles/News/NewsArticles/NewsArticleResources/American_Rivers_and_AWE-Green_Infrastructure_Stimulus_White_Paper_Final_2008.pdf

[35] Water Research Foundation. 2014. National Economic and Labor Impacts of the Water Utility Sector. http://www.waterrf.org/PublicReportLibrary/4566a.pdf AND http://www.waterrf.org/PublicReportLibrary/4566b.pdf

these water, wastewater, and stormwater utilities will contribute approximately $524 billion to the U.S. economy over the next decade and will support roughly 289,000 permanent jobs.

Pollin, Heintz, and Garrett-Peltier (2009)[36] examine the employment impacts of an expanded infrastructure investment program based on an assessment of the nation's infrastructure needs in four core areas—transportation, energy, water systems, and public school buildings. The results reveal that infrastructure investment spending will create about 18,000 total jobs for every $1 billion in new investment spending, including direct, indirect, and induced jobs. Infrastructure investments of $87 billion per year (to meet baseline needs) will generate about 1.6 million total new jobs within the U.S., while investments of about $148 billion per year (to accelerate the rebuilding of the U.S. infrastructure) will generate about 2.6 million new jobs. The $54 billion baseline increase in public infrastructure investment would yield an annual GDP increase of about $46 billion. This would provide an annual productivity dividend of about $150 for every U.S. resident. The $93 billion high-end increase in public infrastructure investment would yield an annual GDP increase of about $77 billion. This is a productivity dividend of about $260 per year for every U.S. resident.

2.2 Measuring Economic Benefits of Water Infrastructure Investment

The US Army Corps of Engineers (ACOE) and the Bureau of Reclamation follow the process of Economics and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G) outlined by the ACOE in the 1983. This is the generally accepted federal methodology for water infrastructure investment analysis. [37] Similarly, the State of California has adopted this methodology in order to be consistent with the federal program, but considers other methods and tools that may have more local relevance. For example, federal infrastructure investment primarily focuses on National Economic Development (NED), but the California Department of Water Resources (DWR) puts additional weight on Regional Economic Development (RED) and Other Social Effects (OSE) that result in a Locally Preferred Plan (LPP) and can change the decision making process. DWR states that "The RED account is particularly important if a proposed plan will have significantly different regional effects […] that might otherwise be irrelevant to the NED national perspective". [38] Furthermore, due to the dated nature of the P&G, it has recently been criticized for its lack of consideration and evaluation of environmental and other benefits relevant to water resource projects, which DWR considers vital to evaluating infrastructure investment for agricultural water.

[36] Pollin, Robert, James Heintz, and Heidi Garrett-Peltier. 2009. How Infrastructure Investments Support the U.S. Economy: Employment, Productivity and Growth. Political Economy Research Institute (PERI), University of Massachusetts-Amherst. http://www.peri.umass.edu/fileadmin/pdf/other_publication_types/green_economics/PERI_Infrastructure_Investments

[37] State of California Department of Water Resources. Economic Analysis Guidebook. January 2008. Accessible at http://www.water.ca.gov/pubs/planning/economic_analysis_guidebook/econguidebook.pdf

[38] State of California Department of Water Resources. Economic Analysis Guidebook. January 2008. Accessible at http://www.water.ca.gov/pubs/planning/economic_analysis_guidebook/econguidebook.pdf

2.2.1 Economic Efficiency and the Optimal Allocation of Water

The Food and Agriculture Organization of the United Nations (FAO) considers economic efficiency as the primary objective of water resource allocation, due to its importance as a social objective. [39] FAO admits that "economically efficient allocation of irrigation water is rarely attained in practice, analysis of economic efficiency provides a useful point of reference for understanding causes of inefficient allocation and mechanisms for improving the overall economic performance of irrigated production". An economically efficient outcome in this context would maximize the value of water across all economic sectors by allocating to water uses of high value to society and occurs when the marginal cost of supplying water (the cost of an additional unit) equals the marginal benefit of water use (the benefit provided by the additional unit of water).

Theoretically, economically efficient allocations occur when there is no reallocation that would improve someone's outcome without detracting from another's outcome. Quoting the FAO, "a change in allocation is considered desirable if at least one person gains in welfare and no one loses", yet this rarely occurs in practice. Instead, "a change in allocation is considered desirable if those individuals who gain from the change can hypothetically compensate those who lose and still be better off than they were previously." [40] In general, this consideration forms the basis for cost-benefit analyses, used to determine the economic efficiency of alternatives.

2.2.2 Distributional Considerations

The FAO recognizes that economic efficiency is not the only economic issue of importance: the distribution of costs and benefits affects equity. Although the costs and benefits are considered in sum to all of society, these costs and benefits may be distributed "unfairly" geographically, temporally, or socioeconomically. To address these equity concerns, weights can be used in the cost-benefit analysis, to weight the importance of benefits or costs to different societal groups. When applying temporal weights, this is called a discount rate: the needs of future generations are discounted by some factor to represent society's preference for consumption now versus in the future.

In regards to water, its allocation is often inefficient. This is because it doesn't have a true market value. According to the FAO, "The reasons why water has no price are often related to the historical, socio-cultural, and institutional context in which water is used and managed (e.g. the return of water use rights for groundwater or surface water on farmers' land). In addition, although water can be captured and shared, water flows can also be recycled. This often makes it difficult to break water down into marketable proportions. An important cause of this economically inefficient water use (where costs outweigh benefits) is the failure of institutions involvement with the allocation and management of water […] caused by markets, policies, and political and administrative factors [deriving] from a fundamental

[39] Food and Agriculture Organization: Natural Resources Management and Environment Department. Economic valuation of water resources in agriculture: Chapter 3: Economics of water allocation. Accessible at: http://www.fao.org/docrep/007/y5582e/y5582e06.htm

[40] Food and Agriculture Organization: Natural Resources Management and Environment Department. Economic valuation of water resources in agriculture: Chapter 3: Economics of water allocation. Accessible at: http://www.fao.org/docrep/007/y5582e/y5582e06.htm

failure of information or lack of understanding of the multitude of values that may be associated with water resources". [41]

In regards to water resources, allocation is often managed in a manner that doesn't maximize social welfare, by not setting the appropriate price or quantity of water, and often exceeding the socially optimum quantity of water. One way to mitigate this is to consider the marginal opportunity costs of water resource use, by considering the direct economic costs of water, the external costs of water use, and the environmental or sustainability costs of water use at the margin.

2.2.3 Multiple Benefit Projects (Green and Grey Infrastructure)

Demand for water infrastructure investment is increasing, due to deterioration of existing infrastructure, increased demand for water, and outside forces changing the needs from infrastructure. It is imperative that investments in water infrastructure are well planned and cost-effective. An "Infrastructure Report Card" from the American Society of Civil Engineers estimates that close to a $1 trillion investment is needed nationally to meet the quality and quantity needs of our drinking water infrastructure system alone.[42] Considering green infrastructure alternatives to grey infrastructure allows for decision makers to minimize mitigation costs, minimize losses from natural and human disturbances, minimize regulatory costs, and to maximize the net public benefits of infrastructure investments.[43]

As water infrastructure, and the needs and interactions of people and ecosystems, are better understood, an alternative to the traditional "grey" infrastructure (built infrastructure) has emerged: green infrastructure. Green infrastructure considers the natural environment when designing infrastructure solutions, by using and protecting forests, watersheds, and existing landscapes. Green infrastructure is the "strategically planned and managed network of natural lands, working landscapes, and other open spaces that conserves ecosystem values and functions and provides associated benefits to human populations".[44]

Protecting existing ecological services improves water quality, decreases the impacts of wildfires, decreases sedimentation, and increases water quantity; all of which reduce stress on existing grey water infrastructure, prolonging its lifespan, and decreasing the costs of maintenance and new construction needs. As an example, investing in forests through erosion control reduces flooding and the consequences of extreme precipitation; investing in snow pack maintenance and flow regulation decreases the incidence of summer drought; investing in riparian buffers that cool water runoff reduces water temperatures (important

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[41] Food and Agriculture Organization: Natural Resources Management and Environment Department. Economic valuation of water resources in agriculture: Chapter 3: Economics of water allocation. Accessible at: http://www.fao.org/docrep/007/y5582e/y5582e06.htm

[42] LaFrance, D., 2013. AWWA Statement on American Society of Civil Engineers Infrastructure Report Card, Mar. 13, 2013. Accessible at www.Allonewater.com

[43] Talberth, J. Gray, E., Yonavjak, L., and Gartner, T. *Green versus Gray: Nature's Solutions to Infrastructure Demands*. The Solutions Journal. January 2013. Vol 4 Issue 1 pg. 40-47. Accessible at https://www.thesolutionsjournal.com/article/green-versus-gray-natures-solutions-to-infrastructure-demands/

[44] USDA Forest Service. *Adaptation: Forests as Water Infrastructure in a Changing Climate*. RMRS_P-71.2014. Accessible at http://www.fs.fed.us/rm/pubs/rmrs_p071/rmrs_p071_313_327.pdf

for water quality and ecosystem health) and flow.[45] The health of forests in relation to water quality is exceptionally important, as, "the forests cycle water from precipitation through soil and ultimately deliver it as streamflow that is use to supply nearly two-thirds of the clean water supply in the United States [which influences] the quantity and quality of downstream water sources; in this way, forests and water are closely intertwined".[46]

All of these impacts, floods, extreme precipitation events, increased erosion and sedimentation, and drought, increase both the capital and variable costs of grey water infrastructure. Droughts can also affect hydroelectric generation and agriculture production.[47] Investing in green infrastructure can mitigate these impacts and reduce the costs of corresponding grey infrastructure: "By maintaining high source water quality through natural infrastructure investments, treatment plants may avoid capital costs for some of the processes in conventional treatment, such as coagulation, flocculation, sedimentation, and more advanced treatment processes like membrane filtration and activated carbon. Reduced sedimentation in source water also prevents sediment buildup in reservoirs and potential water intake clogging, leading to decreased maintenance costs such as dredging and repairing. Finally, treatment plants with high-quality raw water may also save on variable costs because more chemicals such as coagulants, disinfectants, and pH adjusters are needed when water quality degrades".[48]

A recent study by the US EPA found that "on average, every $1 spent on source-water protection saved an average of $27 in water treatment costs".[49] Other studies have found that investing in green water infrastructure to meet water quality requirements in the US, can lead to costs 60 to 96 percent lower than investing in grey water infrastructure to meet the same requirements.

The Forest Service implies caution, however, in blindly investing in green infrastructure, particularly forests: "As communities consider large-scale investments to conserve, restore, or manage forests and wetlands, however, decision makers must understand how a changing climate may impact their water-related functions. For example, changes in precipitation and temperature can contribute to changing species composition and increasing incidence of disturbance in forests. If not carefully managed, these impacts may affect the water-related function of upstream ecosystems, potentially compromising the ability of forests to serve effectively as natural infrastructure under a changing climate. Thus, even as we argue that […] forest functions […] help to mitigate climate risks to water services, we also call for

[45] USDA Forest Service. *Adaptation: Forests as Water Infrastructure in a Changing Climate*. RMRS_P-71.2014. Accessible at http://www.fs.fed.us/rm/pubs/rmrs_p071/rmrs_p071_313_327.pdf

[46] National Research Council. Hydrologic Effects of a Changing Forest Landscape. National Academies Press. 2008.

[47] USDA Forest Service. *Adaptation: Forests as Water Infrastructure in a Changing Climate*. RMRS_P-71.2014. Accessible at http://www.fs.fed.us/rm/pubs/rmrs_p071/rmrs_p071_313_327.pdf

[48] Gartner et al. American Water Works Association. *Protecting forested watersheds is smart economics for water utilities.* September 2014. 106:9. Accessible at http://aquadoc.typepad.com/files/awwa_watershed_paper.pdf

[49] Winiecki, E., 2012. Economics and Source Water Protection. Accessible at http://yosemite.epa.gov/r10/water.nsf/c6e3c862e806dd68882 5688200708c97/04a73c144395fda1882570 2e00650eb2/$FILE/Economics_of_ SWP_E_Winiecki_EPA.ppt#8

attention to the pathways whereby climate change impacts may compromise water-related forest functions".[50]

For example, climate change can increase the frequency and intensity of wildfire in forest regions, dramatically reducing the green infrastructure value provided by forests. These fires also affect erosion control and flow regulation, causing floods, increased sedimentation in water runoff, and poor water quality. Climate change also changes the species present in forest ecosystems, altering the natural ecosystem services provided by a forest; this also changes the flow and sedimentation of water runoff, decreasing water quality and changing water quantity. The Forest Service recommends investing in wildfire and invasive species management to actively combat the impacts of climate change and protect water supply.[51]

Uncertainty regarding climate change and responses and feedbacks to climate change increase the difficulty of the decisions made by planners. The Forest Service recommends developing a flexible adaptation pathway that triggers responses when certain thresholds are exceeded: "Determining which thresholds are relevant is a significant challenge, but once they have been identified, having monitoring systems in place for these thresholds is critical to the implementation of the adaptation pathway. Given likely changes in species composition and potential geographic movement of the overall forest system, as well as shifting water demand, critical thresholds for water provision may, in part, be distinct from critical thresholds for the ecosystem as a whole".[52] Employing green infrastructure where feasible can provide the rich kinds of multiple ecological services that can be expensive to restore and replace.[53]

2.2.4 Water Supply

Following the lead from the P&Gs, water supply benefits are often selected with the primary emphasis on the Net Economic Development (NED) benefit measures. Overall decision making is more responsive to local priorities and conditions, but the basic principles of benefit measurement are outlined in the document. These measures include municipal and industrial (M&I) water benefits, which cover domestic, commercial, and industrial water uses; benefits to agricultural, hydropower transportation, recreation, commercial fishing, and other direct benefits. The P&Gs also address how to measure the benefits of flood damage reduction, which will be described in the following section. All of the others pertain at least partially to water supply benefit measurement.

The fundamental measurement process is as described in the introduction to this report, and it involves step four of the six step planning process:

1. Specification of the water related problem
2. Inventory, forecast, and analyze conditions relevant to the problem

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[50] USDA Forest Service. *Adaptation: Forests as Water Infrastructure in a Changing Climate*. RMRS_P-71.2014. Accessible at http://www.fs.fed.us/rm/pubs/rmrs_p071/rmrs_p071_313_327.pdf

[51] Ibid.

[52] Ibid.

[53] For good discussion a of green infrastructure benefits, see Ozment, S., DiFrancesco, K., Gartner, T. (2015). The role of natural infrastructure in the water, energy and food nexus, summarizing information provided by the UN Environmental Program.

3. Formulate alternative plans,
4. Evaluate the effects of the alternative plans
5. Compare alternative plans
6. Select a recommended plan based on a comparison of the alternatives.

Detailed guidance is provided by the P&Gs for each step in the process. A summary of the benefit measurement related to water supply issues is shown in Table 2-1, below.

The table demonstrates a consistent theory about measuring the benefits of a proposed project in that benefits in general are measured at the marginal value of the additional goods and services (which may be the price in a market if a good market exists) that will be provided over and above those goods and services that will be provided in the absence of the project. Where there are challenges to measuring these benefits, the cost of providing the same benefits via the next best alternative may be used.

Although the original P&Gs provided fairly detailed and flexible approach to measuring costs and benefits at the federal level, the document has been criticized for years for shortcomings especially where the concept of ecosystem services is concerned. Consequently, new interagency Principles and Requirements for Federal Investments in Water Resources have been developed, and when paired with agency specific guidelines, these collectively are referred to as the PR&Gs. The updated PR&Gs were approved at the federal level in December 2014.

The guiding principles in the PR&Gs are far less rigid regarding appropriate metrics for making decisions about water infrastructure investment when compared with the P&G approach to measuring benefits in terms of the NED approach. The six guiding principles are:

- Healthy and Resilient Ecosystems
- Sustainable Economic Development
- Floodplains
- Environmental Justice
- Public Safety
- Watershed Approach

Table 2-1: Overview of water supply benefit measurement approaches as defined in the Principles and Guidelines for Water Resources Research

Type of Water Supply Benefit	Approach
Municipal and Industrial	Society's willingness to pay for the increase in the value of goods and services attributable to the water supply. . Price is an indicator where available but if no price can demonstrate the marginal cost, then the cost of the next best alternative may be used.
Agriculture	Two mutually exclusive types of benefits. 1) Those related to damage reduction (e.g. drought), where cropping patterns remain constant, and either there may be increased crop yields or decreased production costs. These are measured in terms of the increased net income to farmers. 2) Intensification benefits, such as where the benefits of a water project can bring about additional acreage for production – again measured in terms of the increase in net income..
Hydropower	Willingness to pay for additional energy. This could be measured in terms of prices (which in theory represent the marginal costs) or sometimes by other energy source prices though energy prices are complex and often based on average prices and not marginal prices.
Transportation	Reductions in the value of resources required to transport commodities. Reductions in the cost per trip for using the waterway, reductions in delays, more efficient loading of barges, etc.
Recreation	Willingness to pay for additional recreational resources, or improved quality of recreational resources. Because the public often pays very little for recreational visits, the changes are measured by estimating the monetary value of recreation by travel cost method, or other economic techniques.
Commercial Fishing	Either measured as cost savings to existing harvests (if no additional harvest is expected) or the change in net income if additional harvest
Other Direct Benefits	Those benefits that are incidental to the primary purpose of the water resource project. Could be incidental increases in the output of goods and services, or incidental reductions in costs.

For each of these principles, the measurement and evaluation of the principle is flexible and should be case-specific. But the overall measurement strategies that may be used to evaluate the projects for decision making involve a broader suite of economic strategies.

2.2.5 Flood Damage Reduction

The appropriate approach to measuring flood damage reduction benefits following from the P&Gs and other similar strategies begins with a forecast of anticipated flood frequencies in the basin and measuring the expected annual damages related to floods. To do this, an estimate of the value of the buildings and built infrastructure in a floodplain is most valuable. Ideally damages for floods with different probabilities are simulated in a geospatial database. There are three potential types of flood damages that can be evaluated: physical damages, income loss, and emergency costs. Physical damages are the losses of buildings, or parts of buildings, loss of contents of structures, equipment, bridges, roads, powerlines, etc. Income losses from flooding typically includes lost wages of provides from business disruptions, but are only counted for those losses of expenditures that were not delayed or spent at another location. Because flood damage reduction benefits involves a fairly complex calculation of flood frequencies and flood sizes, building values, and damage functions, estimates are often developed in an engineering model such as the ACOE HEC-FDA model or the FEMA Hazus model.

2.2.6 Stormwater Management

The benefits of stormwater management are more challenging to measure because the direct relationship between the management activity and the environmental 'lift' or improvement are often not well understood. Stormwater management improves water quality, water supply, and fisheries habitat while reducing the severity of flooding. The results of stormwater improvement on the shellfish industry and natural production may be some of the most direct, but as yet these relationships are poorly understood. Nonetheless, estimates of these types of benefits must be undertaken to know whether or not the often costly policy measure will be economically feasible. For large investment projects, a thorough analysis should be completed, and the results explored using sensitivity analysis.

As discussed in Section 3.4.6, Challenges to Investment in Stormwater Management, it is difficult to find the funding for the needed infrastructure to manage stormwater and wastewater, both of which are badly needed. However, like a flood event, the catastrophe that could occur with accidental water quality concern could be very costly and would ultimately necessitate the investment in an up to date system and maintenance. The question is whether a lower dollar value of funding can be accessed in time to avoid a human and ecosystem health risk in the future.

2.2.7 Fisheries and Habitat

The benefits related to investing in the restoration of fisheries are complicated by the multiplicity of factors generally categorized as hydropower (dams), habitat, harvest, and hatcheries. The following discussion points out that investment in fishery restoration may be useful when there is a good understanding of the factor that is actually limiting the recovery of a given species in a specific basin. If the investment is not targeted at addressing a limiting factor, then the expenditure may not be beneficial to fish species recovery.

Background Related to Limiting Factors and the Development of Project Lists

RCW 77.85.060 defined a critical pathways methodology to be used to develop a habitat project list. The pathways methodology was required to include a limiting factors analysis to identify priority projects. A limiting factor, in the true ecological sense, is the factor that limits the size of a population. The limiting factor can be a freshwater or saltwater habitat component, harvest, predation, disease, or other sources of mortality such as dams. The factor limiting population size in most of the basins in the state is generally not known. Section 10 of Engrossed Substitute House Bill 2496 (Salmon Recovery Act of 1998) directed the Washington State Conservation Commission, in consultation with local government and treaty tribes to invite private, federal, state, tribal, and local governments with appropriate expertise to convene a Technical Advisory Group (TAG) tasked with identifying limiting factors for salmonids. The Washington State Conservation Commission developed documents for most of the basins that addressed limiting factors; however, sufficient data was generally not available to complete a full habitat limiting factors analysis. Therefore, most of the limiting factor assessments were effectively a discussion of the factors that could be limiting the populations, based on the land uses present in each basin.

During the development of the fish recovery plans, lists of projects intended to improve habitat in the various basins containing population of fish listed under the Endangered Species Act (ESA) were developed and included in the recovery plans. In the absence of information regarding the true limiting factor in each basin, project lists developed for salmon recovery included all projects that addressed the suite of potential limiting factors in each basin. Therefore, a subset of the lists of projects will likely address the limiting factor in each basin and the rest may improve habitat, but will not necessarily improve the carrying capacity of the basin. Given this, only a subset of the identified projects is expected to have a net benefit to salmon and steelhead.

Viable Populations

National Marine Fisheries Service (NMFS) has developed estimates of the viability status for many of the ESA listed populations in the state. Generally, the populations as defined by NMFS (Evolutionarily Significant Units or ESUs) occupy several basins. In some cases, NMFS has determined that some of the populations within the ESU are viable, meaning they meet the NMFS recovery targets in terms of population abundance. Where viable populations are present, habitat projects that add additional carrying capacity may improve abundance but will not necessarily provide benefits related to the delisting of fish. Benefits may, however, be attained through larger allowable harvests, greater sport fishing opportunities, and the general satisfaction that the public attains by knowing that abundant fish populations are present.

2.2.8 Discounting

A discount rate is used to put a present value on costs and benefits that will be realized in the future. Individuals tend to value the near term more than the far term and discounting accounts for this preference; a $100 gift is worth more to an individual today than a $100 gift in one year or in ten years.

The discount rate is a function of pure time preference and the growth rate of per capita consumption. If the pure time preference or growth rate of per capita consumption increase, then the discount rate increases. A large pure time preference (and consequently, large discount rate) implies that the future is heavily discounted, or that benefits in the present are more valuable. This causes the net present value of benefits to be given more importance in the short term and less importance in the long term. A high discount rate will result in a lower net present value than a low discount rate. The only difficulty is determining the extent to which the present is more important than the future, i.e. determining the discount rate.

Multiple contingent valuation studies have attempted to identify the true discount rate, and how it varies with time.[54] Most of the studies report widely varying discount rates far higher than those typically used, ranging from 0 to 270 percent. The Bureau of Reclamation

[54] For a summary, please see Table 65 on page 186-187 of the Benefit-Cost Analysis of the Yakima Basin Integrated Plan Projects Report to the Washington State Legislature, December 15 2014.

annually publishes the discount rate to be used in water resource planning for the fiscal year. One can see that, since 2012, the discount rate has trended down, implying that the Bureau of Reclamation believes that the future should be valued more so than in previous years.

Table 2-2: Overview of discount rates used in Federal water infrastructure investment

Source	Discount Rate
Bureau of Reclamation - 2017 Fiscal Year	2.875%
Bureau of Reclamation - 2013 Fiscal Year	3.5%
Yakima River Basin Four Accounts Analysis[55], Yakima River Basin Benefit-Cost Analysis[56], Bureau of Reclamation - 2012 Fiscal Year	4%

There is a substantial literature in regard to the true discount rate, with the most prolific argument from economists occurring between Nicholas Stern[57] and William Nordhaus[58]. Stern believes the discount rate should be very low (1.4 percent), with high value for the future, while Nordhaus believes the true discount rate is closer to 4.3 percent. Other organizations (the UK Green Book[59], for example) adopt a time-based discount rate function, arguing that the current discount rate is 3.5 percent, but that for long-term valuations, the discount rate should drop to 2.5 percent after 75 years and to 1 percent after 300 years. The declining discount rate is due to uncertainty in regards to the future.[60]

Every fiscal year, federal agencies release the discount rate that should be used in analyses to comply with NED requirements. Both the Yakima River Basin Four Accounts Analysis (2012) and the Yakima River Basin Benefit-Cost Analysis (2014) use the Bureau of Reclamation's discount rate for 2012 (4 percent), in order to be consistent between reports and the NED requirements. A cost benefit analysis performed today would use the lower discount rate of 2.875 percent, which would result in a higher net present value.

2.3 Ecosystem Services

Recent efforts nationally and internationally support the inclusion of ecosystem services in economic decision making that affects the environment. This conclusion holds regardless of the degree to which those ecosystem services are involved in other market transactions. The

[55] US Bureau of Reclamation. Yakima River Basin Integrated Water Resource Management Plan: Four Accounts Analysis of the Integrated Plan. October 2012.

[56] Benefit-Cost Analysis of the Yakima Basin Integrated Plan Projects: Report to the Washington State Legislature. December 15, 2014.

[57] Stern, Nicholas for the HM Treasury Office of Climate Change. The Economics of Climate Change. 2007. Accessible at http://www.hm-treasury.gov.uk/stern_review_report.htm

[58] Nordhaus, William. A Review of the Stern Review on the Economics of Climate Change. 2007. Journal of Economic Literature 45: 686-702.

[59] HM Treasury. The Green Book: Appraisal and Evaluation in Central Government. 2013. Accessible at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/220541/green_book_complete.pdf

[60] Weitzman, Martin. Why the Far-Distant Future Should be Discounted at Its Lowest Possible Rate. Journal of Environmental Economics and Management. 36. 201-208 (1998). Accessible at http://scholar.harvard.edu/files/weitzman/files/why_far-distant_future.pdf

recent efforts have evolved from environmental economics research that attempts to assign a monetary value to ecosystem services (recreation was one of the earliest services to gain attention). Such efforts were pioneered in the 1960s and 1970s and often funded by public agencies such as the ACOE,[61] which helped to formalize BCA (benefit-cost analysis) for water infrastructure investment. Since that time, the growing interest in valuing the stock of ecosystem services (natural capital) has taken many forms, including the 2005 global statement on ecosystem services developed through the Millennium Ecosystem Services Assessment[62], which supports research on formal methods of ecosystem services analyses.

More recently, a 2015 White House Memorandum directs federal agencies to consider ecosystem services in decision making.[63] To assess ecosystem services, agencies need ecological trend data, models of different management alternatives, and social data on resource use and valuation.[64] Traditional ecosystem services systems, such as fish, timber, and hiking, have more data and sophisticated models, but other ecosystem services, including water quality, biodiversity, and cultural services, need to be better understood. There is currently not a consistent methodology for evaluating ecosystem services. Given the pressure from the federal government to include ecosystem service valuations in decision-making, there is a significant need for federal agencies to improve data and methodology for ecosystem service valuation. Recognizing the importance of addressing data gaps and methodological discrepancies, there has recently been significant effort to expand data and modeling infrastructure.

In order to complete an ecosystem service valuation, data are needed on land use or land cover change, biodiversity (land and freshwater), infrastructure, fresh water supply, marine and coastal ecosystems, cities and urban areas, sociocultural data, sociodemographic data, wildlife resource valuation, recreational use of wildlife, nature, and biodiversity, water supply, coastal and marine services, and the use of valuation, depending on how and where a project is implemented. Ecosystem service valuation needs models of the existence of these ecosystem services, the values they provide, and their impacts, considering outside stressors. Examples of the values provided by ecosystem services include climate stability through carbon sequestration and carbon storage, wildfire risk mitigation, reduced flooding, and reduced coastal inundation and storm surge.

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[61] See the 1983 "Economic and Environmental Principles and Guidelines for Water and Related Land Resource Implementation Studies" from the Water Resources Research Council, available at http://planning.usace.army.mil/toolbox/guidance.cfm?Id=269&Option=Principles%20and%20Guidelines or Myrick Freeman's "The Benefits of Environmental Improvement: Theory and Practice", Baltimore: Johns Hopkins University Press,1979.

[62] www.mea.org

[63] Donovan, S., C. Goldfuss, and J. Holdren. 2015. Memorandum for Executive Departments and Agencies. M-16-01. https://www.whitehouse.gov/sites/default/files/omb/memoranda/2016/m-16-01.pdf.

[64] Lydia Olander, Gregory W. Characklis, Patrick Comer, Micah Effron, John Gunn, Tom Holmes, Robert Johnston, James Kagan, William Lehman, John Loomis, Timon McPhearson, Anne Neale, Lauren Patterson, Leslie Richardson, Martin Ross, David Saah, Samantha Sifleet, Keith Stockmann, Dean Urban, Lisa Wainger, Robert Winthrop, and David Yoskowitz. 2016. "Data and Modeling Infrastructure for National Integration of Ecosystem Services into Decision Making: Expert Summaries." NESP WP 16-02. Durham: National Ecosystem Services Partnership.

www.nicholasinstitute.duke.edu/publications.

Several of the environmental assets that give rise to ecosystem services are at risk due to climate change impacts including inundation of watersheds and surrounding landscapes. For example, the recreation provided by hiking, hunting and fishing could experience a reduction of the quality and quantity of those recreational days and possibly result in a reduction of tourism activity that supports hotels and other economic activity in the area. Groundwater, which provides a percentage of rural drinking water, is at risk from overuse when surface water is curtailed.

There are multiple ways to consider ecosystem service values in BCA. Most convenient is to estimate the monetary value of environmental improvement/decline and add these values to the financial costs and benefits. However, there may not be good estimates of value for the ecosystem services available, and due to debate on the methodologies used in valuation studies, results of studies may not be widely accepted. Even in cases where markets exist for ecosystem services, these markets are not always functioning in a way that provides an accurate measure of value. Consequently, using monetary values in a benefit cost analysis has limitations. As an alternative, Ramboll Environ has often advocated employing non-monetary approaches to estimating ecosystem service losses and gains.

2.3.1 Monetary Measures of Ecosystem Service Value

There are different approaches to estimating the change in services from the environment that may be expected with a project such as investment in water infrastructure. As mentioned above, changes in ecosystem services can be measured in monetary terms using a benefit transfer approach, or other methods such as travel cost method and contingent choice modeling. The latter two approaches can be costly albeit more widely accepted as accurate measures of value. Benefit transfer approach refers to methods that adapt estimates in the economic literature to the project location by adjusting values to reflect population, income and other relevant factors. This approach results in an estimated value of 'willingness-to-pay' or the value which people would pay to preserve an ecosystem service. Naturally the transfer process is rarely perfect and so these values are imperfect measures but often better than no estimate of value. Still, for measures of recreation, water for agriculture, and for the supporting ecosystem service of providing habitat for fish, relatively good monetary measures of ecosystem service values have been developed and are often included in BCA for water infrastructure investment.

The more challenging task comes when attempting to measure more than just one ecosystem service value. For example, investing in natural stormwater management strategies can improve water quality, improve habitat, prevent flooding, help recharge aquifers, and provide other ecosystem services at the same time. It is challenging to estimate the value of several ecosystem services that may be provided – and include a value for each type of ecosystem service appropriate to the project or site under consideration – without double counting monetary value. Most of the economics literature that has measured value has done so by attempting to isolate the value of one service.

2.3.2 Habitat Equivalency Analysis

One method that has been widely used in Natural Resource Damage litigation and restoration compensation addresses some of the difficulties associated with measuring ecosystem service values using monetary estimates. Habitat Equivalency Analysis (HEA) uses ecologic metrics to estimated values for the different ecosystem services. These are then aggregated together through time, and an appropriate discount value is used to present the flow of services in present value terms. HEA is a methodology that uses economic methods to estimate the flow of services over time from different habitat types. This methodology results in discounted-service-acre-years (dSAY's), ecological units that represent the dynamic aggregation of service flows from a given habitat. These methods can be used independently or jointly.

The HEA model has been widely adopted by state and federal agencies for quantifying the relative value of ecosystem services.[65] Under HEA, ecosystem service flows are quantified based on the area of land cover type or habitat type required to maintain them, thus allowing for direct comparison of services gained through management actions that restore habitats with losses that result from elimination or injuries to natural resources or habitats.

The level of ecosystem services provided is generally assumed to be directly proportional to the habitat quality score. This approach was developed by the NOAA to quantify potential damages associated with habitat degradation (e.g. contamination) and potential credits associated with compensatory restoration actions[66]. This general approach has been adopted at many sites throughout the U.S.by NOAA, the ACOE, and others.

2.4 Risk and Uncertainty in Water Resources Planning

The manifestation of short and long-term climatic conditions, in addition to changes in land and water use, among other factors, are influencing the demands of water infrastructure. These changes cause increased vulnerability to natural hazards, some of which may occur more frequently and at greater intensity, stressing existing infrastructure. Investing in water infrastructure can help mitigate some of the unknown future damages from natural hazards and mitigate challenges due to changes in supply and demand. In order to adapt, one must plan for impacts by "building resilience to those impacts, and improving society's capacity to respond and recover".[67]

Water infrastructure investment needs to address the risk and uncertainty in future natural events, and risk and uncertainty in the use and demand for water. By considering the expected changes in the frequency of floods, drought, storms, sea level rise, and extreme precipitation events, the State of Washington can mitigate risk and more easily adapt to future unknowns, and natural or anthropogenic variability, through water infrastructure investments.

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[65] Dunford, R.W., Ginn, T.C.,Desvousges, W.H., 2004. The use of habitat equivalency analysis in natural resource damage assessments. Ecological Economics 48, 49-70. NOAA. 2006. Habitat Equivalency Analysis: An Overview. National Oceanic and Atmospheric Administration, Damage Assessment and Restoration Program. March 21. Revised 2000, 2006. 23. http://www.darrp.noaa.gov/library/pdf/heaoverv.pdf

[66] Chapman, D.J. and R.A. Taylor. 2002. Hylebos Waterway Natural Resource Damage Settlement Proposal Report. Appendix F: Equating Contaminant-Related Ecological Service Losses and Restoration-Generated Service Gains for the Hylebos Waterway Using Habitat Equivalency Analysis. National Oceanic and Atmospheric Administration. Seattle, WA. March 1. http://www.cbrestoration.noaa.gov/documents/cbhy-f.pdf

[67] American Meteorological Society. Climate Change Risk Management. October 2014. Accessible at https://www.ametsoc.org/ams/index.cfm/policy/studies-analysis/climate-change-risk-management/

Many cities in Washington State have pursued infrastructure investment.[68] For example, Anacortes, anticipating increased flooding risk from sediment loading in the Skagit River, constructed a new $65 million water treatment plant to mitigate risk to infrastructure from natural disasters. King County, seeking to mitigate risk from increased drought severity and frequency, built a new 8-mile water pipeline to supply water to agriculture and industry in the Sammamish River Valley.

2.4.1 Risk and Uncertainty

Both risk and uncertainty influence decision-making and planning within water infrastructure. Risk refers to the probability of specific outcomes, where there is a known probability distribution over these outcomes. Uncertainty refers to unknown outcomes with unknown probabilities of occurrence. Risk can be measured; uncertainty cannot.

Water infrastructure needs to respond to both risk and uncertainty; there are known probabilities of outcomes (risk) and there are unknown outcomes with unknown probabilities (uncertainty). Water infrastructure also needs to respond to and expect changes in supply and demand as populations, water availability, and water use vary.

When undertaking a risky planning decision, decision-makers can choose the optimal investment decision based on expected, or most likely outcome. Depending on the distribution of outcomes, this can be difficult; if a catastrophic scenario is possible, its impact should be weighted so as to prepare for its consequences, even if it is an unlikely outcome. Uncertainty can further complicate decision-making; if the outcomes are unknown, it is even more difficult to plan the optimal level of infrastructure investment.

According to ACOE, "When information is imprecise or absent, that is uncertainty. […] Uncertainty is inherent in any future-oriented planning effort. […] Many of the problems [that planners] are trying to solve are characterized by the hazards that arise from so many random natural processes and systems. To complicate matters further, there is uncertainty about these hazards".[69] Natural hazards follow a stochastic occurrence and lead to classical risk situations. "Superimposed on these stochastic processes is uncertain and unpredictable human behavior". Within infrastructure planning, it is essential for the planner to identify risk and uncertainty for the consideration of the decision-maker in the decision-making process.

2.4.2 Probability and Water Planning

Probability and risk are key considerations within water management; severe floods are defined probabilistically (a "100-year flood" is a flood of such magnitude that it is only expected to occur once every century). Similarly, droughts and precipitation events of certain magnitude are only so likely to occur every year. Based on past events, it is possible to

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[68] Mauger, G.S., J.H. Casola, H.A. Morgan, R.L. Stauch, B. Jones, B. Curry, T.M. Busch Isaksen, L. Whitely Binder, M.B. Krosby, and A.K. Snover, 2015. *State of Knowledge: Climate Change in Puget Sound*. Report prepared for the Puget Sound Partnership and the National Oceanic and Atmospheric Administration. Climate Impacts Group, University of Washington, Seattle. doi: 10.7915/CIG93777D. Accessible at https://cig.uw.edu/resources/special-reports/ps-sok

[69] USACE. Guidelines for Risk and Uncertainty Analysis in Water Resources Planning. March 1992. Accessible at http://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/92r1.pdf

estimate the likelihood of an "event" (flood, drought, storm, extreme precipitation, etc.) of a particular magnitude in any given year.

According to the USGS, a 100-year flood event was defined as the basis for the National Flood Insurance Program:

> "In the 1960's, the United States government decided to use the 1-percent annual exceedance probability (AEP) flood as the basis for the National Flood Insurance Program. The 1-percent AEP flood was thought to be a fair balance between protecting the public and overly stringent regulation. Because the 1-percent AEP flood has a 1 in 100 chance of being equaled or exceeded in any 1 year, and it has an average recurrence interval of 100 years, it often is referred to as the "100-year flood". Scientists and engineers frequently use statistical probability (chance) to put a context to floods and their occurrence. If the probability of a particular flood magnitude being equaled or exceeded is known, then risk can be assessed. […] More recently, people talk about larger floods, such as the "500-year flood," as tolerance for risk is reduced and increased protection from flooding is desired. The "500-year flood" corresponds to an AEP of 0.2-percent, which means a flood of that size or greater has a 0.2-percent chance (or 1 in 500 chance) of occurring in a given year."[70]

USACE manages these risks from floods by structurally reducing the probability of flooding, and also managing floodplains to reduce the consequences from flooding.[71] There are four phases of reducing flood risk: mitigation planning, preparation, response, and recovery. In each of these stages, risk and uncertainty abound.

Within water resource planning, the ACOE advises that "it is not as important to accurately label a situation as risk or uncertainty as it is to investigate how the lack of complete certainty may affect project formulation, evaluation, selection, and implementation. […] [It] is important to identify all situations that fall within the ride region bounding risk and between the extremes of complete certainty or ignorance, in order to consider the important effects in the planning process".[72]

Uncertainty is a key consideration within water infrastructure planning, and while it is possible to mitigate some of the impacts resulting from uncertainty, there are outside factors changing the existing decision-making environment. For example, a 100-year flood in 2016 is a different 100-year flood than the 100-year flood of 1980. Planners need to adapt to and recognize the *changing* probability distributions that describe the occurrence of natural hazards.

[70] United States Geological Survey. The 100 Year Flood: It's All About Chance. Last modified October 2016. Accessible at http://water.usgs.gov/edu/100yearflood-basic.html

[71] USACE. National Flood Risk Management Program Initial Guidance Letter. October 2009. Accessible at http://www.iwr.usace.army.mil/Portals/70/docs/frmp/USACE_National_Flood_Risk_Management_Guidance_Letter.pdf

[72] USACE. Guidelines for Risk and Uncertainty Analysis in Water Resources Planning. March 1992. Accessible at http://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/92r1.pdf

2.4.3 Shifting Probability Distributions

Many factors cause the probability distribution of potential climate outcomes to shift; in Washington, some examples of these factors include land use and climate change. Land use alters water demand, local ecology and natural sedimentation processes, leading to increased incidence of flooding and higher damages from flooding events. Climate change disrupts precipitation patterns and the frequency of occurrence of extreme precipitation events, leading to droughts, landslides, and floods. The impacts of these changes could be more easily mitigated through improved water infrastructure and management, by first understanding how natural processes, such as land use and climate change, cause probability distributions to shift. By understanding the shift in probability distributions, the possibilities of outcomes are better understood, which allows for improved planning. By planning for and investing in improved water infrastructure, much of the damage associated with shifted probability distributions (towards drought, or flooding, or stronger storms, among other outcomes) can be mitigated.

According to the UN's Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5), climate change is expected to increase the incidence of long-lasting heat waves, increase the intensity and frequency of extreme precipitation events, and a lead to a rise in sea levels (with projections ranging from 0.2 to 1m).[73] Freshwater resources are at significant risk from increased temperatures. Drought frequency is expected to increase in dry regions. Climate change and changes in land use can reduce water quality as heavy rainfall and land-use changes increase sediment, nutrient, and pollutant loadings, as droughts increase concentration of pollutants, and as flooding disrupts treatment facilities. Due to forecasted sea level rise, coastal systems can expect to see submergence, coastal flooding, and erosion. This is exacerbated by changes in how communities and industry use and manage the land. Expected population growth and economic development in Washington will increase the human pressures on coastal ecosystems and exacerbate the impacts of climate change on coastal areas. Depending on the region of Washington, communities can be impacted by heat stress, extreme precipitation, inland and coastal flooding, drought, and water scarcity, caused and exacerbated by climate change or changes in land use.

The IPCC's AR5's Working Group on Impacts, Adaptation, and Vulnerability stresses the risks associated with climate change, stating that impacts from recent climate extremes (heat waves, droughts, and floods) "reveal significant vulnerability and exposure of [systems] to current climate variability".[74] These impacts are significant for both developed and developing countries and demonstrate a "significant lack of preparedness for climate variability". The list of impacts due to climate change on water infrastructure is long and foreboding; it includes the increased risk of death and injury in coastal zones due to storm surges, coastal flooding, and sea level rise; the risk of ill-health and disrupted livelihood for

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[73] Intergovernmental Panel on Climate Change. Climate Change 2014 Synthesis Report Summary for Policy Makers. 2014. From IPCC's Fifth Assessment Report. Accessible at https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf

[74] Intergovernmental Panel on Climate Change. Climate Change 2014: Impacts, Adaptation, and Vulnerability Summary for Policy Makers. 2014. From IPCC's Fifth Assessment Report. Accessible at https://www.ipcc.ch/pdf/assessment-report/ar5/wg2/ar5_wgII_spm_en.pdf

urban populations due to flooding; the risk of breakdown in infrastructure and critical services due to increased incidence of extreme weather events; the risk of food insecurity due to warming, drought, flooding, and precipitation variability and extremes; the loss of marine and coastal ecosystems and biodiversity; and the loss of terrestrial and inland water ecosystems and biodiversity. Floods are expected to cause property and infrastructure damage, disrupt supply chains and ecosystems, and reduce water quality. Depending on emission pathways over the next century, the expected warming is projected to be between 2 and 5 degrees Celsius. As the magnitude of warming increases, these impacts are exacerbated. Further, as land use changes and stresses existing water infrastructure, the impacts of climate change are exacerbated.

It is well-established in economics literature that the distribution of potential outcomes under climate change has "fat tails". A fat-tailed probability distribution is one in which extreme and unlikely events (the "tails" of the probability distribution) are fatter; that is, the extreme events are more likely. These fat tails arise from a combination of different factors, including structural uncertainty and the positive feedbacks associated with climate change outcomes. You can see an example of these fat tails in Figure 2-1; as uncertainty increases and extreme scenarios cannot be "ruled out", these extreme scenarios have a higher probability of occurring (see the transition from the baseline - a world without climate change - to the climate change scenario, which has a higher likelihood of extreme consequences.

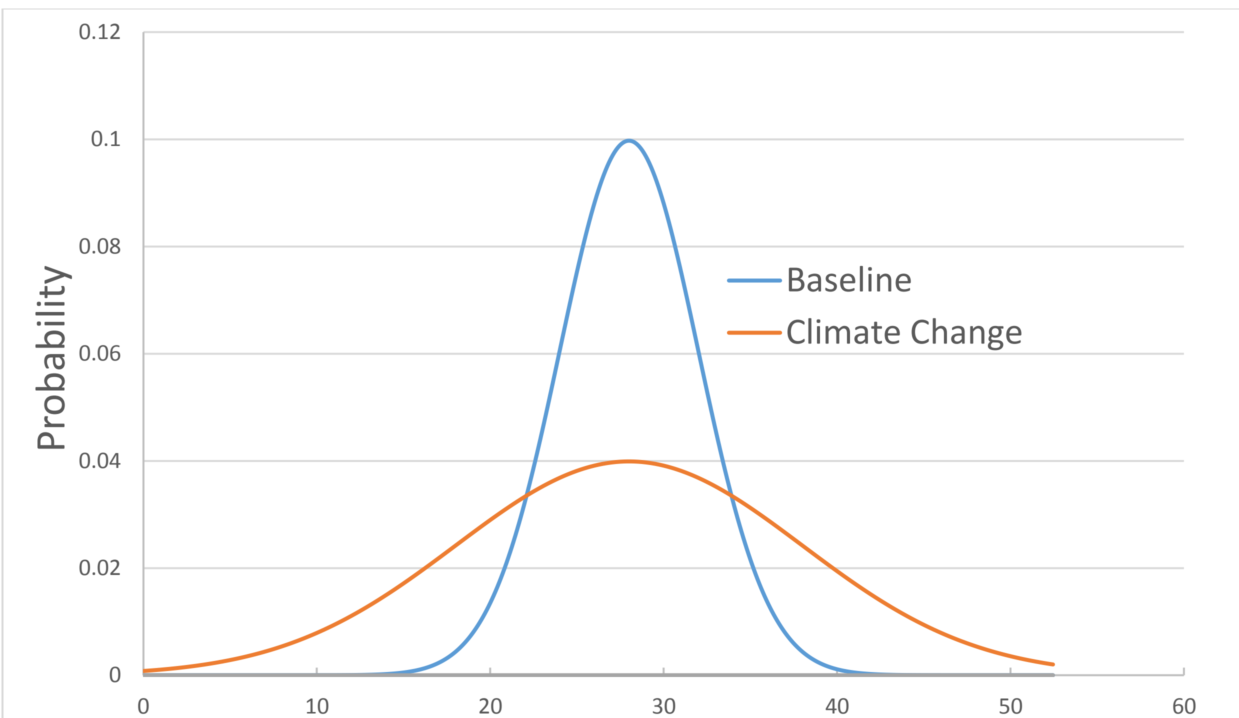

Figure 2-1: Example of Fat Tailed Probability Distribution with Same Mean

Note that both scenarios still have the same mean, or expected outcome, but that under climate change scenario, the variance is increased ("fat tail"), and extreme scenarios are more likely than in the baseline. Despite the expected value of both scenarios being equivalent, the increased likelihood of catastrophic events (the "fat tail") and decreased likelihood of a less catastrophic event, should be a consideration in planning decisions.

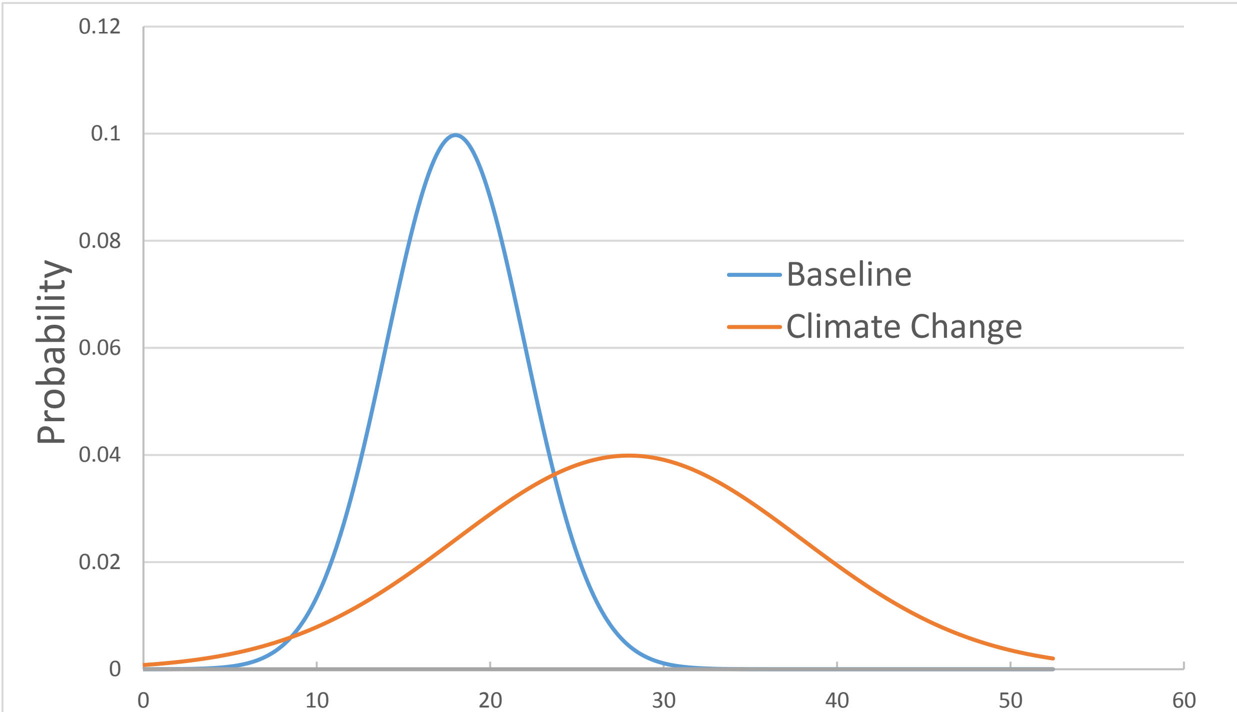

Figure 2-2: Example of Fat Tailed Probability Distribution with Different Mean

In Figure 2-2 we see both scenarios again, but where each has a different mean, or expected value. In this instance, both the means and the variance differ between the two scenarios. Since the expected value is larger for second, and the tail is "fatter", the likelihood of extreme events is increased as compared to the blue baseline. Once again, the increased likelihood of catastrophic events (the "fat tails") should be a consideration in planning decisions.

Resources for the Future states that the tails of probability distributions (the "tails" represent less-likely, but more extreme scenarios), which assign a probability to potential outcomes, are important when considering the risks of climate change.[75] Climate change causes the tails of the probability distributions to fatten for multiple reasons. Natural disasters follow distributions with thicker tails and climate change is associated with more frequent occurrences of some natural hazards. And, the structural uncertainty surrounding climate change also causes the tails of the probability distribution of the outcomes to fatten. In simple terms, this means that climate change has a relatively higher probability of generally low-probability extremely catastrophic events.

[75] Resources for the Future. Climate Change and Risk Management: Challenges for Insurance, Adaptation, and Loss Estimation. February 2009. Accessible at http://www.rff.org/files/sharepoint/WorkImages/Download/RFF-DP-09-03.pdf

According to Weitzman, climate change has fat tails because there is no prior information on damages to constrain probability distribution curves.[76] Unfortunately, traditional economic interpretations of cost-benefit analysis and calculating expected utility work best with thin-tailed probability distributions over outcomes. Probability distributions with fat tails (high impact, low probability catastrophes) due to structural uncertainty can have a significant impact on the outcome of a cost-benefit analysis. These fat-tailed distributions thus have significant consequences for decision-making. Weitzman argues that the structural uncertainty manifesting itself in the thick tails of probability distributions is the biggest issue in regards to decision-making under climate uncertainty; the uncertainty matters more than the risk.[77]

There is significant evidence that in regards to climate change and natural hazards, bad outcomes can occur together, otherwise known as tail dependence: one variable taking an extreme value causes another variable to also take on an extreme variable. Or a third variable pushes two variables to extremes; for example, a hurricane with wide-reaching damages causes extreme damages in both electricity and housing sectors. These tail dependencies can occur across multiple variables. To quote RFF, "[For example,] with more heat waves, events in the tail of the distributions related to mortality, crop yields, wildfires, and electricity pricing are more likely to occur together". These tail dependencies can affect loss estimates, adaptation policies, and the insurance market for natural disasters.

2.5 Summary

This chapter summarized background information on economics and water infrastructure investment. It is important for government decision makers to note that spending on infrastructure does not always lead to economic growth, but this is not the goal of improving infrastructure; often, particularly in regards to water infrastructure, the goal of infrastructure investment is improved public health and safety. Yet, investing in infrastructure can lead to temporary (often long-term) job creation and economic co-benefits, including industry growth, improved fish habitat, reliable water supply for agriculture, and flood damage reduction.

According to government agencies (including the GAO, EPA), water infrastructure investments are critical to meet current and future needs. Other agencies, such as the ACOE, stress the need for local decisions in regards to water infrastructure and water allocation. Distributional considerations are important, as are a consideration of ecosystem services provided by investments. Increasing pressure from federal agencies to incorporate ecosystem services into infrastructure investment decisions encourages the consideration of green infrastructure as an alternative to traditional grey infrastructure to provide multiple benefits from one investment.

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[76] Weitzman, Martin L. 2009. On modeling and interpreting the economics of catastrophic climate change. Review of Economics and Statistics. 91(1): 1-19. Accessible at https://dash.harvard.edu/bitstream/handle/1/3693423/Weitzman_OnModeling.pdf?sequence=2

[77] Weitzman, Martin L. A review of *The Stern Review* on the economics of climate change. Journal of Economic Literature. Vol. XLV (September 2007), pp. 703-724. Accessible at http://scholar.harvard.edu/files/weitzman/files/review_of_stern_review_jel.45.3.pdf

As a final note, it is important that decision makers consider the risk and uncertainty associated with investment planning. Climate change and changes in land use are shifting probability distributions, forcing a consideration of risk and uncertainty in decision-making. These considerations are particularly important in water infrastructure, where decision choices are affected by the probability of floods, drought, storms, sea level rise, and extreme precipitation events.

3. BACKGROUND INFORMATION: INVESTING IN WASHINGTON WATER RESOURCES

Water infrastructure investment in Washington state, and failing to invest in water infrastructure has far-reaching economic implications for a wide variety of interest groups ranging from farmers, to shellfish growers, to city planners, households, the transportation sector, Indian Nations, and many others. This chapter provides an overview of the importance of investing in Washington water resources. The first subsection provides a broad summary of water use and allocation in Washington. The following subsection provides comments on how other States have attempted to manage water resources and what this means for Washington. The following subsections discuss the importance of investments to manage flooding, stormwater, and fisheries. Water can bring economic gains and strengthen the resilience of communities, but water can also be a hazard. Properly managed water resources can help prevent damages from flooding and stormwater, and also provide economic benefits.

3.1 Water Resources in Washington

In the State of Washington, similar to many other states, population growth, climate change, and instream flow requirements continue to stress water supplies, and lead to localized water shortages. This has led to intensive management of this resource in order to meet the many competing demands, such as irrigation, municipal and industrial use, hydropower generation, navigation, protection of salmonid species, tribal treaty rights, flood control, and recreation. Availability of reliable water supplies are not only key to current and future economic development, but also essential for cultural and environmental enhancement.

The water supply systems in the State were not built to withstand the stress from the current and future changes in water supply and demand. Many factors influence water supply and demand, such as agricultural market conditions, climate change, input costs, power demands, production decisions, global trade conditions, temperature and precipitation patterns, water management policies, and water storage capacity.

This section looks into the water use in Washington, and then delves into a discussion of the legal context. It also presents the implications of climate change on this resource.

3.1.1 Water Use in Washington

Water use in Washington has evolved during the past century from meager domestic and stock water needs to the current complex requirements of public-supply systems, domestic-water users, large irrigation projects, industrial plants, and numerous other uses, such as fish habitat and recreational activities. While it is difficult to keep accurate accounts of the actual volume of withdrawn and used water, the increasing competition for water (especially during periods of drought) makes water-use information extremely valuable.

This section looks at the water use data in two distinct regions of the State of Washington: Western Washington and Eastern Washington. The north-south-trending Cascade Range and the prevailing wind patterns divide Washington State into these two regions with distinctly different climates. Western Washington has a predominantly marine climate with cool, dry summers and mild, wet winters. Precipitation averages about 70 inches per year, but ranges from less than 20 to about 200 inches per year. Potential evaporation ranges from 20 to 25 inches per year, and is generally less than precipitation. Eastern Washington has characteristics of both continental and marine climates, with hot, dry summers and cold, wet winters. Precipitation averages about 20 inches per year, but ranges from less than 7 to about 40 inches per year. Potential evaporation ranges from 25 to 45 inches per year, and generally exceeds precipitation.

Table 3-1 presents water withdrawal information for 2010 in the state as whole, as well as in Western and Eastern Washington. Freshwater withdrawals in Washington in 2010 totaled 4,885 million gallons per day (Mgal/d), with estimated county withdrawals ranging from 0.69 to 1,070 Mgal/d. Groundwater accounted for 33 percent (1,600 Mgal/d) and surface water accounted for 67 percent (3,285 Mgal/d) of the state total. The per capita withdrawal rate for Washington was 726 gallons per day (gal/d), with estimated county rates ranging from 113 to 12,100 gal/d.

Freshwater withdrawals in Western Washington totaled 1,295 Mgal/d, with estimated county withdrawals ranging from 0.69 to 260 Mgal/d. Groundwater accounted for 40 percent (514 Mgal/d) and surface water accounted for 60 percent (779 Mgal/d) of the regional total. The per capita withdrawal rate for Western Washington was 247 gal/d, with estimated county rates ranging from 113 to 2,080 gal/d.

Freshwater withdrawals in Eastern Washington totaled 3,590 Mgal/d, with county withdrawals ranging from 3.03 to 1,070 Mgal/d. Groundwater accounted for 30 percent (1,085 Mgal/d) and surface water accounted for 70 percent (2,505 Mgal/d) of the estimated regional total. The per capita withdrawal rate for Eastern Washington was about 2,400 gal/d, with estimated county rates ranging from 199 to 12,100 gal/d.

It is important to note how these withdrawals have changed between 2005 and 2010. The overall water withdrawals in the State, as well as in both Western and Eastern Washington, have declined. However, groundwater withdrawal went up by 14 percent in Eastern Washington, and by 7 percent in the State as a whole between 2005 and 2010. This trend is important to note because it may not be sustainable. For example, the Odessa Aquifer is an example of how increasing economic activity associated with groundwater can lead to aquifer depletion, and the subsequent investment in an infrastructure project to instead provide surface water to irrigators, has avoided the increased pressure on the groundwater resource.

Table 3-1: Freshwater Withdrawal in Washington in 2010

Type of Water Use/Population	Total Withdrawals (in Mgal/d)		
	Western WA	Eastern WA	WA Total
Population (2010 Census)	5,230,000	1,495,000	6,725,000
Total Withdrawals	1,295	3,590	4,885
Groundwater	514	1,085	1,600
Surface Water	779	2,505	3,285
% Change from 2005-2010*	-3	-10	-8
Groundwater	-5	14	7
Surface Water	-1	-8	-14
Public-supply	625	285	910
Groundwater	227	244	471
Surface Water	398	41	439
Domestic Water	520	226	747
Self-supplied Groundwater	63	50	113
Public-supplied Deliveries	458	176	634
Irrigation	127	3,020	3,145
Groundwater	84	713	798
Surface Water	45	2,305	2,350
Livestock	10	17	28
Groundwater	6	13	19
Surface Water	4	5	9
Aquaculture	150	63	213
Groundwater	59	28	86
Surface Water	91	36	127
Industrial Self-supplied	306	152	458
Groundwater	65	34	99
Surface Water	241	118	358
Mining	12	5	17
Groundwater	10	4	13
Surface Water	2	1	3
Thermoelectric-power**			40
Self-supplied Groundwater			2
Self-supplied Surface Water			36

Values may not sum to totals due to independent rounding.
* Negative values indicate decrease; unsigned values indicate increase.
** Regional data for thermoelectric-power withdrawals are not included in this report due to privacy considerations.
Source: Developed from data in Lane, R.C., and Welch, W.B. 2015. Estimated freshwater withdrawals in Washington, 2010: U.S. Geological Survey Scientific Investigations Report 2015-5037. 48 p. Available at (https://pubs.usgs.gov/sir/2015/5037/).

As indicated previously, there is a distinct variation in the uses of water between Western and Eastern parts of the State. Figure 3-1, Figure 3-2, and Figure 3-3 show the percentages of water used for various purposes in the state overall, as well as separately for Western and Eastern Washington. Irrigation use accounts for most of water used in the state, particularly in Eastern Washington while considerably smaller in Western Washington. Water use in Western Washington is dominated by domestic and industrial uses.

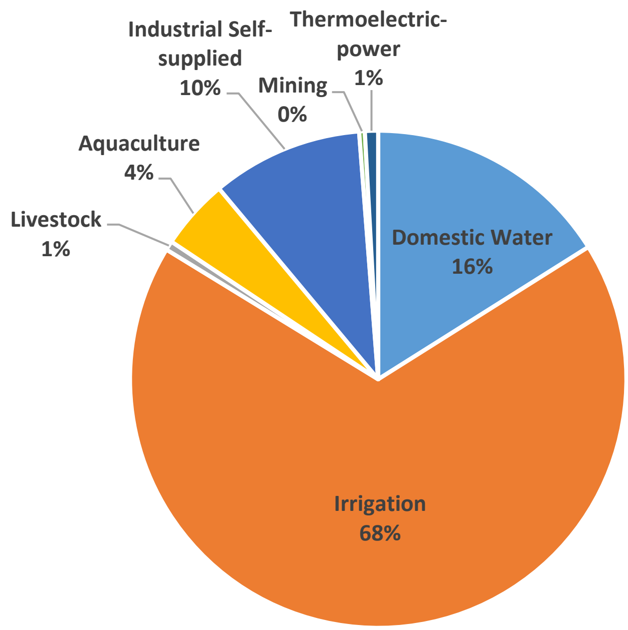

Figure 3-1: Water Use in the State of Washington, 2010

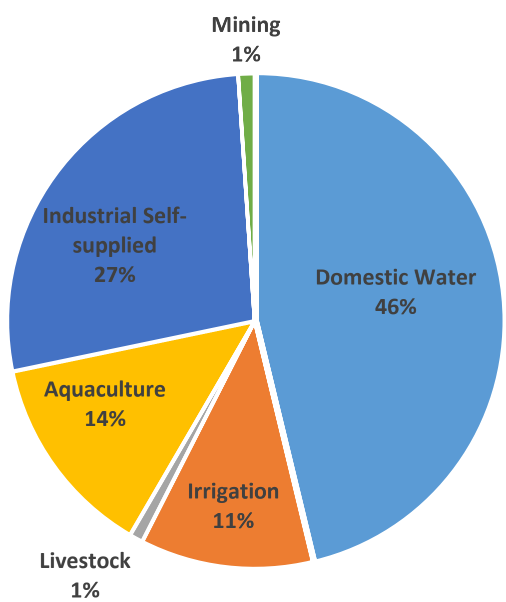

Figure 3-2: Water Use in Western Washington, 2010

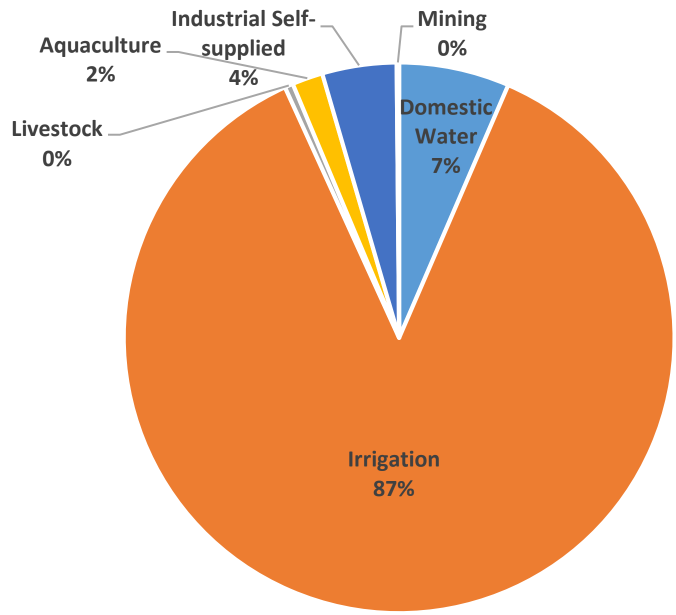

Figure 3-3: Water Use in Eastern Washington, 2010

3.1.2 The Legal Context

The waters of Washington state collectively belong to the public and cannot be owned by any one individual or group. Instead, individuals or groups may be granted rights to use them.[78] The Washington state Department of Ecology (Ecology) is responsible for the management of water resources in Washington. This management is bound by numerous laws, regulations, agreements and case law.

Growth Management Act

The Growth Management Act (GMA) was enacted by the Washington Legislature in 1990 in response to rapid population growth and concerns with suburban sprawl, environmental protection, quality of life, and related issues. The GMA has been amended several times, and is codified in many chapters, but primarily in Chapter 36 70A. The GMA requires the fastest growing counties and the cities within them to plan extensively in keeping with the state GMA goals, including:

- Sprawl reduction
- Concentrated urban growth
- Affordable housing
- Economic development
- Open space and recreation

[78] Washington State Office of Attorney General. January 2000. An Introduction to Washington Water Law. Available at (https://fortress.wa.gov/ecy/publications/publications/0011012.pdf), accessed December, 2016.

- Regional transportation
- Environmental protection
- Property rights
- Natural resource industries
- Historic lands and buildings
- Permit processing
- Public facilities and services
- Early and continuous public participation
- Shoreline management

In addition to the 13 original GMA goals, the legislature added the goals and policies of the Shoreline Management Act (SMA) as the fourteenth GMA goal. Washington's SMA was passed by the state Legislature in 1971 and adopted by voters in 1972. The overarching goal of the SMA is "to prevent the inherent harm in an uncoordinated and piecemeal development of the state's shorelines."

Twenty -nine counties are either required to fully plan under the GMA, or have chosen to do so. These counties make up about 95 percent of the state's population. The remaining ten counties must plan for critical areas and natural resource land only under the GMA.

The GMA provides a framework for regional coordination, and counties planning under the GMA are required to adopt county-wide planning policies to guide plan adoption within the county and to establish Urban Growth Areas (UGAs). Local comprehensive plans must include the following elements: land use, housing, capital facilities, utilities, transportation, and, for counties, a rural element. Shoreline master program policies are also an element of local comprehensive plans. Implementation of required parks and economic development elements is on hold until adequate state funding is available. Local comprehensive plans may also include optional elements.

The GMA establishes the primacy of the comprehensive plan. The comprehensive plan is the starting point for any planning process and the centerpiece of local planning. Development regulations (zoning, subdivision, and other controls) must be consistent with comprehensive plans. State agencies are required to comply with comprehensive plans and development regulations of jurisdictions planning under the GMA.

Water Rights

The waters of Washington state collectively belong to the public and cannot be owned by any one individual or group. Instead, individuals or groups may be granted rights to use them.[79] A water right is a legal authorization to use a predefined quantity of public water for a designated purpose. This purpose must qualify as a beneficial use. Beneficial use involves

[79] Washington State Office of Attorney General. January 2000. An Introduction to Washington Water Law. Available at (https://fortress.wa.gov/ecy/publications/publications/0011012.pdf), accessed December, 2016.

the application of a reasonable quantity of water to a non-wasteful use, such as irrigation, domestic water supply, or power generation.[80]

Washington initially followed a mix of the two doctrines; prior appropriation and riparian. Under the prior appropriation doctrine, "first in time, first in right," awards water rights to the parties who first take water and put it to beneficial use. In its classic form, the riparian doctrine ties the right to use a particular body of water to the ownership of the land over, under, and adjacent to the water in question.[81] However, in a series of court cases, the courts in Washington gradually retreated from the riparian doctrine. Today, while the state is theoretically a "mixed" system, it leans heavily towards the prior appropriation doctrine, with riparian rights either not present or indistinguishable from prior appropriation rights.[82]

State law requires certain users of public waters to receive approval from Ecology prior to using water - in the form of a water right permit or certificate. Any use of surface water (lakes, ponds, rivers, streams, or springs), which began after the state water code was enacted in 1917, requires a water-right permit or certificate. Likewise, withdrawals of groundwater from 1945 onward, when the state groundwater code was enacted, require a water right permit or certificate, unless the use is specifically exempt from state permitting requirements. While "exempt" groundwater uses are excused from needing a state permit, they still are considered to be water rights.[83]

In 1969, the Washington legislature enacted the Minimum Flows Act, followed by the Water Resources Act (WRA) of 1971. These two statutes directed Ecology to adopt instream flow rules for all of Washington's rivers, to protect instream resources and determine how much water would be available for future allocation. Since the adoption of WRA, legal recognition of instream water uses to preserve fish, wildlife, and other environmental values have become firmly entrenched in Washington water law.

Over Appropriation

In many parts of the state, water supplies are already over-tapped, as people have been granted the right to take more water than a river, stream, or aquifer can sustainably provide. This depletion in the natural flow of the rivers and other water bodies comes with great consequences as one quarter of the state's 62 Water Resource Inventory Areas (WRIAs) do not have sufficient water to meet the needs of both the people and the fish.[84]

This over-appropriation of water resources implies that it has become more difficult to acquire new water rights, especially for purposes that do not help protect fish.

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80 Washington State Office of Attorney General. January 2000. An Introduction to Washington Water Law. Available at (https://fortress.wa.gov/ecy/publications/publications/0011012.pdf), accessed December, 2016.

81 U.S. Fish and Wildlife Service. Water Rights Definitions. Available at (http://www.fws.gov/mountain-prairie/wtr/water_rights_def.htm), accessed December, 2016.

82 Washington State Office of Attorney General. January 2000. An Introduction to Washington Water Law. Available at (https://fortress.wa.gov/ecy/publications/publications/0011012.pdf), accessed April 7, 2015.

83 Washington State Department of Ecology. July 2006. Washington State Water Law – A Primer. Available at (https://fortress.wa.gov/ecy/publications/publications/98152.pdf), accessed December, 2016.

84 Center for Environmental Law & Policy and the Washington Environmental Council. March 2002. Dereliction of Duty: Washington's Failure to Protect our Shared Waters. Available at (http://wecprotects.org/issues-campaigns/water-for-washington/dereliction.pdf), accessed December, 2016.

Recent Court Rulings

It should be noted that Washington water law is constantly evolving. In recent years, Washington state has enacted and implemented new laws addressing a range of water resource-related issues, related to water resource planning, conservancy boards, trust water rights, and reclaimed water. State law is likely to continue changing in the near future in light of rapid population growth (much of the available water is already being used), changes in priorities for water, the difficulty and cost of new water development, and demands to improve the health of streams.

Some recent court rulings have significantly altered how water is managed in the state, including rural domestic (permit-exempt) uses, and brings Washington state counties into the calculus, as counties must now demonstrate legal water availability in addition to physical availability under the GMA. Key court decisions that have altered the landscape of water supply in the state include:

- Ecology v. Campbell & Gwinn (2002)
- Kittitas v. EWGMHB (2011)
- Knight v. City of Yelm (2011)
- Foster v. Yelm and Ecology (2015)
- Fox v. Skagit County (2016)
- Swinomish Indian Tribal Community v. Skagit Co. (2007)
- Swinomish Indian Tribal Community v. Ecology (2013)
- Hirst v. Whatcom County (2016) (affects counties' responsibilities under the GMA to review permit-exempt (e.g. household) wells for building permits. What this implies for each county and for property owners has yet to be determined.)

Water resources vary by region, but population growth and traditional use stress the current allocations. Jurisdictions are required to prepare comprehensive plans detailing how the goals of the GMA are being pursued. The constantly evolving water law of Washington state will influence and shape the goals of future water planning initiatives.

3.1.3 Impacts from Climate Change

The threat to infrastructure from natural disasters intensifies as the probability of natural disaster occurrence increases with climate change. A November 2015 report by the Climate Impacts Group at the University of Washington[85] finds that "Puget Sound's built environment – transportation, wastewater and water conveyance, urban centers, and energy systems – is projected to be affected by a continued rise in sea level, more intense heavy rains, more and hotter heat waves, and increased wildfire activity. These changes have

[85] Mauger, G.S., J.H. Casola, H.A. Morgan, R.L. Stauch, B. Jones, B. Curry, T.M. Busch Isaksen, L. Whitely Binder, M.B. Krosby, and A.K. Snover, 2015. *State of Knowledge: Climate Change in Puget Sound*. Report prepared for the Puget Sound Partnership and the National Oceanic and Atmospheric Administration. Climate Impacts Group, University of Washington, Seattle. doi: 10.7915/CIG93777D. Accessible at https://cig.uw.edu/resources/special-reports/ps-sok

significant implications for infrastructure, are likely to cause transportation closures, delays, or detours, and will be most pronounced for facilities and transportation lines located in or near coastal and low-lying areas". Coastal infrastructure faces risks from sea level rise. Projected increases in heavy rainfall and river flooding will affect many communities, who will have to assess impacts and develop response plans, in some cases investing in infrastructure improvements to mitigate risks.

A joint study released by the University of Washington Climate Impacts Group and The Nature Conservancy[86] identifies five climate change drivers (rising air temperatures, increasing carbon dioxide, rising sea levels, ocean acidification, and precipitation changes) with impacts on systems that negatively affect humans and local communities. These impacts will be realized across stormwater management, roads and infrastructure, human health, drinking water, fish habitat, power generation and dam management, housing, recreation, river and coastal flood management, forests, and agriculture and food systems, due to higher winter streamflows, increased flooding, higher high tides and storm surges, reduced flood capacity due to increased sedimentation in rivers, low summer river flows, and changes in water quality.

While no modeling is available to quantitatively estimate natural hazard risks from climate change[87], a qualitative discussion is still possible. Expected impacts of climate change include drier summers (an average of 22 percent reduction in summer rainfall) and a fivefold increase in the frequency of the heaviest rain events by the 2080s, increasing flood risk[88]. Changes in precipitation patterns will be one of the largest impacts of climate change in the Puget Sound, altering river flows, affecting dams, reservoirs, power generation, and water supply, while intensifying droughts and flooding. Increased sedimentation due to decreasing snow and ice will further exacerbate flooding. Many residential communities are built on flood plains and will be forced to reconsider flood management. In the city, intense rainfall events will put pressure on urban stormwater and drainage, increasing costs of infrastructure and decreasing water quality.

By the 2040s, models predict that the Skagit River's 100-year floods will become 22 year-floods, and 30-year floods will be seven-year floods. The Snohomish River will see 100-year floods turn into 30-year floods. In the Chehalis Sub-Basin, higher winter streamflow (between 18 and 90 percent) is likely, causing potential for more winter flooding.[89] By 2080,

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[86] Climate Impacts Group (University of Washington) and The Nature Conservancy. Adapting to Change: Climate Impacts and Innovation in Puget Sound. Edited by J. Morse, J. Israel, L. Whitely Binder, G. Mauger, and A.K. Snover. April 2016. Accessible at https://cig.uw.edu/wp-content/uploads/sites/2/2014/11/Adapting-to-Change-booklet_final.pdf

[87] King County Office of Emergency Management. King County Regional Hazard Mitigation Plan Update. July 2015. Accessible at http://www.kingcounty.gov/depts/emergency-management/emergency-management-professionals/regional-hazard-mitigation-plan.aspx

[88] Mauger, G.S., J.H. Casola, H.A. Morgan, R.L. Stauch, B. Jones, B. Curry, T.M. Busch Isaksen, L. Whitely Binder, M.B. Krosby, and A.K. Snover, 2015. *State of Knowledge: Climate Change in Puget Sound*. Report prepared for the Puget Sound Partnership and the National Oceanic and Atmospheric Administration. Climate Impacts Group, University of Washington, Seattle. doi: 10.7915/CIG93777D. Accessible at https://cig.uw.edu/resources/special-reports/ps-sok

[89] WSDOT. Chehalis River Basin I-5 Flood Protection Near Centralia and Chehalis. November 2016. Accessible at http://chehalisbasinstrategy.com/wp-content/uploads/2015/09/WSDOT-I-5-Chehalis-Flood-Report_Final.pdf

a once in a century flooding event is expected to occur as frequently as once per decade[90]. Climate change is expected to cause a 3 to 10 percent increase in rainfall during extreme events, exacerbating flooding, a 5 to 10 percent decrease in stream flow, and a 5 to 15 percent reduction in crop yield. April 1 snowpack is expected to decrease by 59 percent by the 2080s.

Sea level rise predictions range from 4 to 56 inches (average of 24 inches)[91], which will harm coastal infrastructure, commercial and industrial areas, and negatively impact fisheries. Climate change will also increase the risk of landslides, due to a greater risk of extreme weather events and altered precipitation patterns, altering existing and planned developments[92].

The infrastructure of the Puget Sound (including transportation, drinking water, wastewater, and energy systems) will be subject to greater risk from extreme weather. Failure to invest in improving infrastructure to mitigate risk will result in flooding and damage of existing infrastructure, harming quality of life of the population served by the existing infrastructure.

The King County Hazard Mitigation Plan [93] from July 2016 identified priorities for mitigation, including increasing infrastructure resilience and better understanding key vulnerabilities and the necessary implementations to mitigate hazards. Other priorities include retrofitting and relocating structures in high hazard areas. The Plan rates severe weather and severe winter weather are rated as "High" hazard risks to communities in King County. Floods and landslides are rated as "Medium" hazard risks. Over 700 mitigation actions were identified as a result of the Mitigation Plan.

The mitigation actions that result in improvements in infrastructure will be necessary considering that climate change and natural disasters are already impacting infrastructure, including water resources and management. To quote the King County Hazard Mitigation Plan, natural resource managers already observe that:

- "Historical hydrologic patterns can no longer be solely relied upon to forecast the water future
- Precipitation and runoff patterns are changing, increasing the uncertainty for water supply and quality, flood management, and ecosystem functions
- Extreme climatic events will become more frequent, necessitating improvement in flood protection, drought preparedness, and emergency response"

[90] King County Office of Emergency Management. King County Regional Hazard Mitigation Plan Update. July 2015. Accessible at http://www.kingcounty.gov/depts/emergency-management/emergency-management-professionals/regional-hazard-mitigation-plan.aspx

[91] Mauger, G.S., J.H. Casola, H.A. Morgan, R.L. Stauch, B. Jones, B. Curry, T.M. Busch Isaksen, L. Whitely Binder, M.B. Krosby, and A.K. Snover, 2015. State of Knowledge: Climate Change in Puget Sound. Report prepared for the Puget Sound Partnership and the National Oceanic and Atmospheric Administration. Climate Impacts Group, University of Washington, Seattle. doi: 10.7915/CIG93777D. Accessible at https://cig.uw.edu/resources/special-reports/ps-sok

[92] King County Office of Emergency Management. King County Regional Hazard Mitigation Plan Update. July 2015. Accessible at http://www.kingcounty.gov/depts/emergency-management/emergency-management-professionals/regional-hazard-mitigation-plan.aspx

[93] Ibid.

The Mitigation Plan concludes that, "The changing hydrograph caused by climate change could have a significant impact on the intensity, duration, and frequency of storm events. […] The risk associated with the flood hazard overlaps the risk associated with other hazards, such as earthquake and landslide. This provides an opportunity to seek mitigation alternatives that can reduce risk for multiple hazards". The vulnerability associated with increased risk of natural hazards can be reduced by improving infrastructure and reducing natural hazard exposure by creating and maintaining existing structures and infrastructure.

Water planners in Washington must consider the impacts of climate change. As discussed in Section 2.4, risk and uncertainty are important considerations in water infrastructure planning and both impact mitigation activities for climate change

3.2 Water Resources Planning in other States

Many states have already implemented or are in the process of developing their water plans. The larger goals of these efforts are to ensure there are sufficient and secure water supplies to meet the needs of growing populations, agricultural growth, and industrial expansions. This section discusses a few examples of state-level water plans.

3.2.1 Colorado[94]

The state of Colorado unveiled a $20 billion water plan on November 19, 2015 with the objective of accommodating rapid population growth by conserving, reusing, storing and sharing more between farmers and cities, as well as diverting less from west to east across the mountains. The plan prioritizes everyone using less water, protecting against the loss of irrigated cropland as suburbs expand, and supporting water projects that meet certain factors (such as building more reservoirs to capture water as permitted under interstate compacts). In addition, local authorities in the state have developed individual basin plans.

The state officials estimate a need for government to raise $3 billion to $6 billion by 2050 for implementing the plan, and will investigate options to raise additional revenue in the amount of $100 million annually ($3 billion by 2050) starting in 2020. Some options being considered include greater use of severance tax funds for storage expansion and a possible water tax. The plan depends on voluntary compliance, since the Colorado Water Conservation Board lacks regulatory power. Colorado's state engineer and the state Department of Public Health and Environment are the main state regulators around water.

The main elements of the plan include:

- A statewide water-saving target of 130 billion gallons a year for cities and industry. Communities are left largely on their own to cut water use in homes, at industrial sites, and on lawns.
- Goals of increasing reservoir and aquifer storage space by 130 billion gallons statewide, and encouraging re-use of wastewater.

[94] Colorado's Water Plan. 2015. Available at (https://www.colorado.gov/pacific/cowaterplan), accessed December, 2016.

- A framework for assessing possible unspecified new trans-mountain diversions of water from the western side of the Continental Divide, when this can be done without harming rivers and streams.
- A proposal to develop stream and river protection plans covering 80 percent of "critical watersheds" by 2030.
- A strategy for slowing the loss of irrigated agricultural land as Front Range utilities buy up water rights, which threatens 700,000 more acres, or 20 percent of currently irrigated acres statewide. The plan calls for temporary transfers where farmers and ranchers lease water to cities and suburbs but retain ownership of agricultural water rights.
- A goal of linking county land use planning with water supply planning so that, by 2025, 75 percent of residents live in communities where new development is tied to water availability.
- Proposals for streamlined permitting of water projects designated by state planners for official support.

3.2.2 California [95]

In California, the California Water Plan is the state's long-term strategic plan for managing and developing water resources throughout the state. The Water Plan is mandated by California Water Code, and the California DWR is required to update the plan every five years. Although the plan does not create mandates, propose specific projects, or authorize funding, the Water Code defines the plan and its updates as "the master plan which guides the orderly and coordinated control, protection, conservation, development, management and efficient utilization of the water resources of the state."

Eleven updates to the plan have been prepared since the release of the first Water Plan in 1957. Each update makes neither project-specific nor site-specific recommendations, and policy-makers and lawmakers must take definitive steps to authorize the specific actions proposed in the Water Plan and appropriate the funding needed for their implementation. The latest update was done in 2013, while the 2018 update is currently under development.

The 2013 update has three core themes:

- Commit to Integrated Water Management: Integrated water management (IWM) promises to provide multiple benefits across the state's diverse stakeholder communities and accelerate implementation of water projects by generating broader support.
- Strengthen Government Agency Alignment: A key principle of IWM seeks to improve the way governments interact and ultimately deliver services. Aligning agencies in a collaborative manner, across jurisdictional boundaries at the appropriate geographic scale, provides for more efficiency in addressing water problems. The alignment would

[95] California Water Plan. Available at (http://www.water.ca.gov/waterplan/about_us/about_us.cfm), accessed December, 2016.

include management of data, planning, policy-making, and regulation across local, state, tribal, and federal governments.

- Invest in Innovation and Infrastructure: To reduce flood risk, provide reliable water supplies, and protect ecosystems, California will need up to $200 billion over the next 10 years just to maintain current levels of service and system conditions. It is projected that California will need up to $500 billion in future investment over the next few decades to reduce flood risk, provide reliable and clean water supplies, and restore and enhance ecosystems.

As stated above, the 2013 update also focuses on the need for stable funding for investments in water innovation and infrastructure. According to the document, local entities such as water districts, cities, counties, and utilities spend about $18 billion a year on water, as compared with the roughly $2 billion spent annually by the state and federal governments. The 2013 update predicts that California will need investments of $200 billion over the next few decades just to maintain its current system and about $500 billion to upgrade it.

For the first time in the history of this plan, the 2013 update is designed to work in tandem, and help implement, the governor's California Water Action Plan.[96] The 2013 update contains 300 specific actions to support the governor's Water Action Plan, which include expanding water storage capacity, providing safe drinking water and making conservation a way of life. The five-year Water Action Plan, originally released in January 2014 and updated in 2016, outlines actions intended to bring reliability, restoration, and resilience to California's water resources. It takes into account an anticipated population increase from the current 38 million, to an estimated 50 million by 2049. At the core of the Water Action Plan are ten actions and associated sub-actions designed to address water challenges and support three overarching goals: reliability, restoration, and resilience.

3.2.3 Nevada[97]

The most recent Nevada state Water Plan was developed in 1999, about 25 years after the first state water plan was completed. The Nevada Division of Water Resources (at that time the Division of Water Planning) is the implementing authority.

The Nevada state Water Plan is designed to help guide the development, management and use of the state's water resources. The plan assesses the quantity and quality of Nevada's water resources, and identifies constraints and opportunities which affect water resource decision making. The plan looks at historical and current water use, and projects demands out to the year 2020. The most current and accepted hydrologic and socioeconomic data sets available were used to develop the plan's forecasts.

Along with providing data about water supplies and water use, the state water plan identifies pressing water management issues and recommends policy directions and actions designed to assist water managers throughout the state and all levels of government. Thus, the plan

[96] California Water Action Plan. 2014 and 2016. Available at (http://resources.ca.gov/california_water_action_plan/), accessed December, 2016.

[97] Nevada State Water Plan. 1999. Available at (http://water.nv.gov/programs/planning/stateplan/summary/), accessed December, 2016.

establishes a common base of knowledge and understanding which is critical if Nevadans are to reach consensus on future water management issues.

The Nevada state Water Plan is designed to be a policy and planning guide, not a water supply plan. Per the plan, many of the decisions regarding how to meet a particular water supply objective are determined and implemented at the local level. And in fact, many local governments have taken a close look at their own water supply needs and charted a course to meet those needs. Thus, while the plan summarizes local and regional water planning efforts, it focuses on a broad array of water planning issues which affect water planning, management and allocation of water resources statewide.

3.2.4 Implications for Washington

The objectives of state water plans are to provide a collaborative planning framework for integrated water resources management, to communicate best management practices, to evaluate status of state water issues, and to provide recommendations for solutions. It is not necessary for all states to put together water plans, with some not going through this process at all, while other not updating these on a regular basis. There is also a wide variation in these plans in terms of content and priorities. For example, "maintaining supply is a dominant goal in water plans for western states, while eastern states's principal concerns are with storm- and wastewater management and drinking water quality."[98] Plans vary in length as well, with some filled with water usage data, and others with little or none at all. Moreover, while some states' water plans offer many specific policy recommendations, others are less specific.

While the focus of most western states plans is on meeting future water demands, these adopt different strategies to do so depending on the specific conditions in the state. According to a 2015 study, some "prioritize drought management and interstate compacts," while others "emphasize water resource development, or concentrate on interbasin transfers and water quality."[99] Environmental goals are referenced in varying ways, as well, including addressing global warming and discussing the potential effects in a separate state drought plan, including a section on climate variability but not defining causes of climate variability as anthropogenic. For example, because of the recent drought, the "2009 California State Water Plan contains a lengthy climate change adaptation strategy and the 2013 update has a full chapter devoted to future water uncertainties."[100]

At present, Washington does not have a state-wide water plan. However, there are good examples and lessons available from other western states once the relevant state agencies decide to take that step.

[98] Casado-Pérez, Vanessa, Bruce E. Cain, Iris Hui, Coral Abbott, Kaley Dodson, Shane Lebow, Cain, and Bruce E. 2015. All Over the Map: The Diversity of Western Water Plans.

[99] Ibid.

[100] Ibid..

3.3 Flood Prevention Infrastructure Investment

Over the past decades, less federal money has been spent on flood hazard reduction projects and more has been spent on communicating the risks of living in flood-prone areas.[101] This represents a shift away from the construction of flood mitigation infrastructure and follows the arguments of Grey and Sadoff (2007)[102] who argue that developed countries should make "management investments" (support institutions and water management), as opposed to infrastructure investments. The ACOE faces a limited budget, and the majority of its work is to educate communities on changes in flood risk and how to enhance and maintain existing levees to mitigate risk from floods. Other federal education tools include Federal Emergency Management Agency (FEMA) through the National Flood Insurance Program (NFIP) and free mapping tools, NOAA through storm surge and sea level rise mapping, and the United States Geological Survey (USGS) uses the Flood Inundation Mapping Program to communicate flood risk information. Congress passed the Homeowners Flood Insurance Affordability Act in early 2014 which requires FEMA to communicate flood risk to property owners. Resources for the Future (RFF) argues that the federal focus on flood risk communication, as opposed to flood mitigation infrastructure, reflects the "recognition that elected and appointed officials in local government jurisdictions, as well as individual landowners, renters, and business owners, are most responsible for decisions on floodplain land use and the adoption of flood risk reduction and management actions. The federal role, therefore, is often limited to influencing those choices through information provision and communication of expert knowledge".[103]

The goal of flood risk communication is to increase the understanding of flood risk so that informed decision-makers can better plan risk and mitigation choices for the community. RFF cautions that flood risk management is complex, balancing "financial and physical constraints, perceptions of benefits and costs of location choices, attitudes toward risk taking, and alternative systems of thinking. As a result, no risk communication program can guarantee that people's decisions will be different than they would have been in its absence".[104] For example, RFF cites a Bollens et al study from 1988[105] that "a survey of 10 cities found that only 40 percent of property owners who reported that they were aware they were in a floodplain area carried flood insurance, where only 13 percent of property owners who were unaware did so. This finding suggests that although data and information on flood risk may affect choice behavior for some individuals, the complexity of their decision

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101 Kousky, C. and Shabman, L. Understanding Flood Risk Decision making: Implications for Flood Risk Communication Program Design. Resources for the Future Discussion Paper. February 2015.

102 Grey, D. and Sadoff, K., 2007. Sink or Swim? Water security for growth and development. Water Policy 9: 545 – 571.

103 Kousky, C. and Shabman, L. Understanding Flood Risk Decision making: Implications for Flood Risk Communication Program Design. Resources for the Future Discussion Paper. February 2015.

104 Kousky, C. and Shabman, L. Understanding Flood Risk Decision making: Implications for Flood Risk Communication Program Design. Resources for the Future Discussion Paper. February 2015.

105 Bollens, S. A., E.J. Kaiser, and R.J. Burby. 1988. Evaluating the effects of local floodplain management policies on property owner behavior. *Environmental Management* 12(3): 311-25.

frameworks means that improved understanding of flood risk will not necessarily change everyone's choices".[106]

It is important that the appropriate entities invest in flood protection infrastructure, due to the potential damages from flooding and due to the difficulties in communicating the extent of flood risk to those who locate on flood plains. The ACOE estimates the damages avoided by investments from ACOE in flood control and flood mitigation, including damages avoided from investing in reservoir projects, levees, and emergency operations. ACOE estimates that between 1928 and 2000, over $710 billion in flood damages was avoided nationwide via the construction and operation of flood control reservoirs and levees.[107] ACOE further estimates that $21.7 billion in flood damages was saved annually from 1993 to 2002, resulting in a flood damage reduction benefit to cost ratio of $6.35 (for every $1 invested in flood damage reduction, $6.35 is saved in flood damages). Further, the ACOE concludes that "each year the benefits continue to grow because annual O&M [(operation and maintenance)] costs are only about 7 percent of the annual benefits". The ACOE cautions that outdated information has the potential to affect these estimates, and that "older floodplain inventories probably underestimate the actual amount of damages prevented".

The USGS estimated flood-related risks for floodplains along the 17 major rivers in the Puget Sound Basin.[108] The study focused on five floodplain functions (storing and conveying floods, regulating sediment in river networks, retaining nutrients and contaminants, supporting forest ecosystems, and providing aquatic habitats) and five floodplain hazards (inundation, channel occupation, key facility exposure, land use exposure, and road exposure). The study finds that nearly one-half of flood plain areas are disconnected from their natural rivers by constructions; the USGS suggests that reconnecting the floodplains "could improve ecological function and reduce flood risk".[109] The disconnected floodplains limit water flow, materials transport, and natural species migration across floodplains. The USGS reports that "prior to construction of this infrastructure [roads, levees, and railroad], most floodplains in Puget Sound were in contiguous areas of at least 100 km^2. Currently, most floodplains are in fragments less than 10 km^2". This disconnectedness is one of the primary factors influencing flood risk to people on floodplains. The study concludes that "Both connectivity and land cover/land use would have to be addressed to improve function and reduce risk on most floodplains. […] In general, the most feasible opportunities to improve floodplain function may be in areas that

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106 Kousky, C. and Shabman, L. Understanding Flood Risk Decision making: Implications for Flood Risk Communication Program Design. Resources for the Future Discussion Paper. February 2015.

107 US ACOE, Institute for Water Resources. Overview of Flood Damages Prevented by US Army Corps of Engineers Flood Control Reduction Programs and Activities. Journal of Contemporary Water Research and Education. Issue 130, Pages 13-19. March 2005.

108 Konrad, C.P., 2015. Geospatial assessment of ecological functions and flood-related risks on floodplains along major rivers in the Puget Sound Basin, Washington: U.S. Geological Survey Scientific Investigations Report 2015-5033, 28 p. Accessible at http://dx.doi.org/10.3133/sir20155033

109 Konrad, C.P., 2015. Geospatial assessment of ecological functions and flood-related risks on floodplains along major rivers in the Puget Sound Basin, Washington: U.S. Geological Survey Scientific Investigations Report 2015-5033, 28 p. Accessible at http://dx.doi.org/10.3133/sir20155033

either have been disconnected or developed, but not both. Likewise, the greatest opportunities to reduce risk may be in connected floodplain areas with development".[110]

A joint study released by the University of Washington Climate Impacts Group and The Nature Conservancy[111] find that climate change will have significant impacts on stormwater management, roads and infrastructure, human health, drinking water, fish habitat, power generation and dam management, housing, recreation, river and coastal flood management, forests, and agriculture and food systems, due to higher winter streamflows, increased flooding, higher high tides and storm surges, reduced flood capacity due to increased sedimentation in rivers, low summer river flows, and changes in water quality. While no modeling is available to quantitatively estimate these natural hazard risks from climate change[112], it is expected that climate change will cause drier summers (an average of 22 percent reduction in summer rainfall) and a fivefold increase in the frequency of the heaviest rain events by the 2080s, increasing flood risk[113]. Changes in precipitation patterns will be one of the largest impacts of climate change in the Puget Sound, altering river flows, affecting dams, reservoirs, power generation, and water supply, while intensifying droughts and flooding. Increased sedimentation due to decreasing snow and ice will further exacerbate flooding. Many residential communities are built on flood plains and will be forced to reconsider flood management. By the 2040s, models predict that the Skagit River's 100-year floods will become 22 year-floods, and 30-year floods will be seven-year floods. The Snohomish River will see 100-year floods turn into 30-year floods. By 2080, a once in a century flooding event is expected to occur as frequently as once per decade.[114]

3.4 Stormwater Management in Washington

Stormwater, the water runoff from roads, roofs, and grassy surfaces during precipitation events, is a leading contributor to water quality impairments in urban areas of Washington state. Stormwater impacts water quality by collecting pollutants as it flows over surfaces in urban areas into surface water bodies. Over the last several decades the primary focus of stormwater management efforts has been on improving impacts to receiving waters by focusing on point sources from municipal wastewater treatment plants and industrial

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[110] Konrad, C.P., 2015. Geospatial assessment of ecological functions and flood-related risks on floodplains along major rivers in the Puget Sound Basin, Washington: U.S. Geological Survey Scientific Investigations Report 2015-5033, 28 p. Accessible at http://dx.doi.org/10.3133/sir20155033

[111] Climate Impacts Group (University of Washington) and The Nature Conservancy. Adapting to Change: Climate Impacts and Innovation in Puget Sound. Edited by J. Morse, J. Israel, L. Whitely Binder, G. Mauger, and A.K. Snover. April 2016. Accessible at https://cig.uw.edu/wp-content/uploads/sites/2/2014/11/Adapting-to-Change-booklet_final.pdf

[112] King County Office of Emergency Management. King County Regional Hazard Mitigation Plan Update. July 2015. Accessible at http://www.kingcounty.gov/depts/emergency-management/emergency-management-professionals/regional-hazard-mitigation-plan.aspx

[113] Mauger, G.S., J.H. Casola, H.A. Morgan, R.L. Stauch, B. Jones, B. Curry, T.M. Busch Isaksen, L. Whitely Binder, M.B. Krosby, and A.K. Snover, 2015. *State of Knowledge: Climate Change in Puget Sound.* Report prepared for the Puget Sound Partnership and the National Oceanic and Atmospheric Administration. Climate Impacts Group, University of Washington, Seattle. doi: 10.7915/CIG93777D. Accessible at https://cig.uw.edu/resources/special-reports/ps-sok

[114] King County Office of Emergency Management. King County Regional Hazard Mitigation Plan Update. July 2015. Accessible at http://www.kingcounty.gov/depts/emergency-management/emergency-management-professionals/regional-hazard-mitigation-plan.aspx

discharges to water ways. There has been significant progress in improving treatment levels at these types of facilities. Stormwater is problematic to control because it is a ubiquitous issue, with every rainfall event stormwater gathers, collects and discharges contaminants to receiving waters. These contaminants include sediment, nutrients, bacteria, metals, oil and grease. Stormwater runoff can also result in temperature increases, which are of particular concern to certain aquatic species. These contaminants can be toxic to aquatic plants and animals and can cause poor drinking water quality. Untreated stormwater can harm humans (making water unsafe to drink or contact), salmon mortality (erodes stream channels, increases pre-spawn mortality in urban streams, exposure to toxic pollutants), drinking water (stormwater can contaminate drinking water aquifers), economic development[115] (affects salmon and shellfish industries and water recreation), the shellfish industry (exposure to bacteria), and degrade water bodies. According to the 2005 Municipal Stormwater National Pollutant Discharge Elimination System (NPDES) Permit Program Report to the Washington Legislature, "stormwater contributes about 7 percent of the total flow from all point and nonpoint sources but about 60 percent of the total lead (Pb), 30 percent of the total zinc (Zn, the most from any one source), and nearly all of the total fecal coliform bacteria".[116] As urban areas grow, stormwater is also the state's fastest growing water quality problem.

Washington state has one of the most active, innovative and effective stormwater management programs in the nation. The state has thoughtfully developed both a regulatory initiative and a technical support program to assist municipalities in Washington in addressing stormwater quality. Stormwater is managed at the local county and municipal level since localities own and control the drainage systems that collect, convey and discharge stormwater. Thus the burden for operating and managing the complex drainage and water quality requirements rests primarily with the 39 counties and most of 281 incorporated municipalities in the state. There are a few exceptions to the local/municipal focus on stormwater management such as the Washington state Department of Transportation that manages their stormwater drainage system separate from counties and municipalities. The term "Secondary Permittees" means drainage, diking, flood control, or diking and drainage districts, ports (other than the Ports of Seattle and Tacoma), public colleges and universities, and any other owners or operators of municipal separate storm sewers located within the municipalities that are listed as permittees.

3.4.1 Regulatory Environment

Federal regulations adopted by EPA establish a permit requirement for stormwater discharges from all conveyances owned or operated by municipalities and public entities such as WSDOT, ports, and special districts that are located within municipalities. The

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115 According to the 2004 Municipal Stormwater NPDES Permit Program Report to Legislature, "Where water bodies are not healthy, salmon do not exist, shellfish beds are closed, and water-related recreational opportunities are limited. In areas with degraded water bodies, new stormwater and discharge permits can be difficult or impossible to issue. Businesses are more likely to be attracted to an area where getting a stormwater permit will not be so difficult and where the quality of life is enhanced by healthy waters that support salmon, shellfish, and various recreational opportunities. New businesses bring new families and new housing to communities, adding economic stability".

116 Municipal Stormwater NPDES Permit Program. Report to Washington State Legislature, January 2004. Publication Number 04-10-010. Accessible at http://fortress.wa.gov/ecy/publications/publications/0410010.pdf

permit requirement does not apply to privately-owned stormwater systems that discharge directly to waters of the state.[117]

Under Federal law, all states are required to address stormwater as a point source discharge. The first phase (Phase I) of the municipal stormwater program focused on large-sized municipalities. In 2000, Phase II of the federal municipal stormwater regulations imposed new requirements for smaller municipalities. There are now over one hundred municipalities in Washington state that require stormwater permit coverage under Phase I or II of the municipal NPDES stormwater permit program. These municipalities vary in size, existing stormwater programs, and funding ability. This diversity makes development and implementation of stormwater permits challenging.

Stormwater quality is managed in Washington state under the NPDES and state Waste Discharge General Permits that covers discharges from municipal separate storm sewer systems (MS4s). Permits are divided into two categories:

Phase I Municipal Stormwater Permits regulate the discharges from MS4s owned or operated by Clark, King, Pierce and Snohomish Counties; and the cities of Seattle and Tacoma (incorporated cities with a population over 100,000 and unincorporated counties with populations of more than 250,000 according to the 1990 census). The permit also applies to MS4s owned by public entities located in a Phase I city or county; including the Ports of Seattle and Tacoma.

The Phase II permit for Western Washington covers at least 80 cities and portions of five counties with an effective date of September 1, 2012. The updated 2013-2018 permit became effective on August 1, 2013. The Phase II permit for Eastern Washington applies to all regulated small municipal separate storm sewer systems in Eastern Washington. It covers 18 cities and portions of 6 counties.

3.4.2 Phase I Municipal Stormwater Permits for Washington

On August 1, 2012, Ecology issued an updated 2013-2018 Phase I Permit, effective on August 1, 2013.[118] The permit was first modified on December 17, 2014 effective on January 16, 2015. The permit was modified a second time on July 20, 2016 effective on August 19, 2016.

Under the updated permit, each Permittee is required to implement a Stormwater Management Program (SWMP) during the term of the permit. A SWMP is a set of actions and activities comprising the components listed in Section 5, and additional actions necessary, to meet the requirements of applicable total maximum daily load (TMDLs) pursuant to Section 7 "Compliance with TMDL Requirements," and Section 8 "Monitoring and Assessment" as specified in the permit.

Section 5 program elements include:

- Written description of the Permittee's Legal Authority

[117] Municipal Stormwater NPDES Permit Program. Report to Washington State Legislature, January 2004. Publication Number 04-10-010. Accessible at http://fortress.wa.gov/ecy/publications/publications/0410010.pdf

[118] Department of Ecology – Water Quality State Fiscal Year 2016 – Financial Assistance Summary. http://www.ecy.wa.gov/programs/wq/funding/cycles/FY2016/index.html.

- Municipal Separate Storm Sewer System Mapping and Documentation
- Coordination: The SWMP shall include coordination mechanisms among departments within each jurisdiction to eliminate barriers to compliance with the terms of this permit
- Public Involvement and Participation
- Controlling Runoff from New Development, Redevelopment, and Construction Sites
- Structural Stormwater Controls
- Source Control Program for Existing Development
- Illicit Connections and Illicit Discharges Detection and Elimination
- Operation and Maintenance Program
- Education and Outreach Program

3.4.3 Phase II Municipal Stormwater Permits

Phase II communities manage their stormwater discharges in a similar manner as Phase I communities, however, the regulatory requirements for each of the program elements are less stringent. Washington Department of Ecology has provided written guidance on how communities can address each of the required program elements such as control over construction runoff and post-development stormwater controls.

3.4.4 Low Impact Development (LID)

Low Impact Development (LID), or green infrastructure, is an alternative to traditional stormwater management that incorporates a consideration of a watershed's natural hydrological and ecological services into infrastructure decisions, to reduce the impact of the built environment on an ecosystem.[119] Incorporating LID allows for the rate and volume of stormwater reaching received waters to be the same pre and post stormwater infrastructure installation.[120] LID also reduces the cost of stormwater management and the buildup of pollutants in stormwater runoff. According to the EPA, LID "employs principles such as preserving and recreating natural landscape features, minimize effective imperviousness to create functional and appealing site drainage that treat stormwater as a resource rather than as a waste product".[121] Features incorporating the concept of LID include "bioretention facilities, rain gardens, vegetated rooftops, rain barrels, and permeable pavements".[122] The

[119] USEPA. Urban Runoff: Low Impact Development. Accessible at https://www.epa.gov/nps/urban-runoff-low-impact-development

[120] Minnesota Pollution Control Agency. Stormwater management: Low-impact development and green infrastructure. Accessible at https://www.pca.state.mn.us/water/stormwater-management-low-impact-development-and-green-infrastructure

[121] USEPA. Urban Runoff: Low Impact Development. Accessible at https://www.epa.gov/nps/urban-runoff-low-impact-development

[122] USEPA. Urban Runoff: Low Impact Development. Accessible at https://www.epa.gov/nps/urban-runoff-low-impact-development

DC Water and Sewer Authority argues that incorporating LID technologies into stormwater management promotes job creation, improves air quality, and protects wildlife habitat.[123]

The state of Washington's Department of Ecology requires that LID considerations must be incorporated into local codes, ordinances, and standards.[124] Several resources have been developed to assist government in integrating LID into stormwater management.[125] These resources include a collection of free trainings, funded by the Washington state Legislature.[126] Incorporating green infrastructure in replacement of existing grey infrastructure has the potential to provide additional benefits at lower costs to local governments.

3.4.5 Stormwater Utility Revenue Generation in Washington State

Washington state is fourth in the nation in terms of the number of communities with stormwater utilities. According to the latest annual survey conducted by the Western Kentucky University, as of 2016, there are currently 117 stormwater utilities in the state of Washington.

Washington state has some of the highest monthly residential stormwater utility fees in the nation. These fees range from approximately $2.00/month per household to more than $20.00/month. The national average cost per household per month for stormwater utilities is $4.00.[127]

3.4.6 Stormwater Funding Estimates

Using the Western Kentucky Stormwater Utility Survey from 2016[128] and estimates based on the average amount raised by communities in Washington state, close to one-half billion dollars per year is generated and primarily spent on stormwater drainage system maintenance and operation and stormwater water quality in the state of Washington. Most of these funds are spent on maintaining and improving drainage systems as well as support for the planning, design and construction of stormwater treatment facilities, including retrofits of existing infrastructure and new low-impact development or green infrastructure control measures. Funds are also used as matches for larger state and federal water quality grants including repayment of Revolving Fund Loans, Stormwater Financial Assistance Program funding, Centennial Clean Water Program grants and Section 319 Nonpoint source pollution control activities.

[123] DC Water and Sewer Authority. Low-Impact Development at DC Water. Accessible at https://www.dcwater.com/education/lowimpact.cfm

[124] Washington State Department of Ecology. Low Impact Development (LID) Resources. Accessible at http://www.ecy.wa.gov/programs/wq/stormwater/municipal/LID/Resources.html

[125] Washington State Department of Ecology. Low Impact Development (LID) Resources. Accessible at http://www.ecy.wa.gov/programs/wq/stormwater/municipal/LID/Resources.html

[126] Washington State Department of Ecology. Low Impact Development (LID) Trainings. Accessible at http://www.ecy.wa.gov/programs/wq/stormwater/municipal/LID/TRAINING/

[127] Western Kentucky University. Stormwater Utility Survey. 2016. Accessible at https://www.wku.edu/engineering/civil/fpm/swusurvey/swusurvey-2016draft11-7-2016hq.pdf

[128] Western Kentucky University. Stormwater Utility Survey. 2016. Accessible at https://www.wku.edu/engineering/civil/fpm/swusurvey/swusurvey-2016draft11-7-2016hq.pdf

Based on the Western Kentucky 2016 survey, there are 112 Washington communities with utilities that generate on average $1.5M/yr for a statewide total of $168,500,000. There are 4 communities with much higher annual stormwater revenue: Battleground, Bellingham, Seattle, and Tacoma. Their total revenue generation is equal to approximately $106,000,000/yr. When the two groups are totaled, that suggests an estimated total annual stormwater revenue of 274M statewide (total of 112 smaller utilities at $168M and the 4 larger utilities at $106M).

In addition, there are 281 incorporated municipalities, cities and towns in Washington state; 164 without stormwater utilities. Extrapolating from what is known about stormwater expenditures in areas with utilities, if they are each spending an average of $1M per year on stormwater, then the total stormwater annual budget for the state is somewhere in the vicinity of $438 M ($274M in communities with utilities + $164M stormwater spending by communities without a stormwater utility).

The question facing planners going forward is twofold: first-are these planned expenditures adequate to fund currently planned and projected investment needs and second- are these plans and projections adequate in the face of uncertain demand and climate change.

3.4.7 Challenges to Investing in Stormwater Management

Investing in stormwater infrastructure and management is essential, but actual investment often lags behind need.[129] According to the EPA, "The level of renewal and reinvestment in the water sector has not kept pace with the need. […] Historically, investment has not been enough to meet the ongoing need to maintain and renew these systems. Over the coming decades, this pattern of underinvestment needs to change and practices put in place to sustain the water services provided by water infrastructure and utilities. Doing so is vital to public, economic, and environmental health."

Nationwide, $271 billion is needed for capital wastewater and stormwater treatment and collection, including $198 billion for wastewater pipes and treatment facilities, $48 billion for CSO correction, $19 billion for stormwater management, and $6 billion for recycled water treatment and distribution.[130] For the state of Washington, $1.3 billion is needed for CSO correction, $745 million is needed for conveyance system repair, $738 million is required for secondary wastewater treatment, and $529 million for advanced wastewater treatment.[131] Other needs include new conveyance systems, improved stormwater management, and recycled water distribution. This results in estimated needs of $4.1 billion to improve Washington's water management by the year 2032, at which point these systems will have to provide for a population 40 percent larger than in 2012 (at the time of the study).

It is also difficult to assess the "need" for stormwater infrastructure investment. According to the CRS, "In the infrastructure context, funding needs estimates try to identify the level of investment that is required to meet a defined level of quality of service, but this depiction of

[129] EPA. Building Sustainable Water Infrastructure. Last Updated March 2016. Accessible at https://www.epa.gov/sustainable-water-infrastructure/building-sustainable-water-infrastructure

[130] EPA. Clean Watershed Needs Survey (CWNS) – 2012 Report and Data. Updated August 2016. Accessible at https://www.epa.gov/cwns/clean-watersheds-needs-survey-cwns-2012-report-and-data

[131] EPA. Clean Watershed Needs Survey (CWNS) – 2012 Report and Data – Washington State Fact Sheet. 2012. Accessible at https://www.epa.gov/sites/production/files/2015-10/documents/cwns_fs-wa.pdf

need is essentially an engineering concept. It differs from economists' conception that the appropriate level of new infrastructure investment, or the optimal stock of public capital (infrastructure) for society is determined by calculating the amount of infrastructure for which social marginal benefits just equal marginal costs".[132] In another report, CRS argues that, "In many cases, funding goes to projects that are presumed to be the most important, without a rigorous study of the costs and the benefits".[133] According to the GAO, "[The] federal budget structure does not prompt explicit debate about infrastructure spending that is intended to have long-term benefits".[134] The GAO also cautions that it is unclear whether cost-benefit analysis is useful in prioritizing infrastructure projects. Echoing this sentiment, the CBO states, "Many federal investments are motivated primarily by noneconomic policy goals (such as equality of opportunity, national security, and the advance of scientific knowledge). Others are influenced by political considerations. For those reasons, one cannot expect that federal funds will always be directed to the most cost-beneficial use, even within those classes of projects that have an economic rationale".[135]

EPA argues that it is imperative that both citizens and decision makers understand the value of water infrastructure, stating "systems should have an on-going collaborative process with all stakeholders to determine where and how water infrastructure investments are made in their communities."[136] It is often questioned whether costly action is worth the benefits, particularly given the high costs of water infrastructure.[137] Coupled with water infrastructure, are the often high costs of conforming to water quality standards. The EPA contends that the benefits of water quality legislation exceed the costs of compliance, and that investing in pollution control creates economic activity and jobs, increases economic competitiveness, and supports existing communities. EPA urges the pursuit of water infrastructure investments that are cost-effective, resource efficient, and contribute sustainably to the community.[138] EPA also urges these investments to consider the impacts of climate change.

3.4.8 Planning for Future Stormwater Management Investments

According to the Climate Impacts Group at the University of Washington, climate change and land use are expected to significantly impact infrastructure by damaging existing

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[132] Congressional Research Service. *Legislative Options for Financing Water Infrastructure*. June 2016. Accessible at http://www.fas.org/sgp/crs/misc/R42467.pdf

[133] Congressional Research Service. Report for Congress: *National Infrastructure Bank: Overview and Current Legislation*. December 2011. Accessible at http://www.fas.org/sgp/crs/misc/R42115.pdf

[134] United States General Accounting Office. Report to the Congress: *U.S. Infrastructure: Funding Trends and Opportunities to Improve Investment Decisions*. February 2000. Accessible at http://www.gao.gov/assets/590/588838.pdf

[135] Congressional Budget Office. The Economic Effects of Federal Spending on Infrastructure and Other Investments. June 1998. Accessible at http://www.cbo.gov/sites/default/files/105th-congress-1997-1998/reports/fedspend.pdf

[136] EPA. Clean Water and Drinking Water Infrastructure: Sustainability Policy. Accessible at https://www.epa.gov/sites/production/files/2016-01/documents/clean-water-and-drinking-water-infrastructure-sustability-policy.pdf

[137] Congressional Research Service. Water Quality Issues in the 114th Congress: An Overview. February 2016. Accessible at http://nationalaglawcenter.org/wp-content/uploads/assets/crs/R43867.pdf

[138] EPA. Clean Water and Drinking Water Infrastructure: Sustainability Policy. Accessible at https://www.epa.gov/sites/production/files/2016-01/documents/clean-water-and-drinking-water-infrastructure-sustability-policy.pdf

infrastructure and changing demand and needs for new infrastructure.[139] Trends in sea level rise, precipitation patterns, storm intensity, drought, population, water use, and agricultural production will be exacerbated by climate change and land use and directly affect stormwater infrastructure in Washington state.

Qualitatively, the state of Washington can expect more frequent heavy precipitation events (fivefold increase by the 2080s), and increasing flood risk, creating a demand for improved stormwater management.[140] Changing precipitation patterns will alter river flows, which will affect dams, reservoirs, power generation, and water supply, cause more intense droughts and flooding, and also affect stormwater infrastructure. Increased sedimentation due to decreased snow fall will also impact stormwater management. These factors combined will pressure stormwater and drainage systems, increasing the costs of managing and maintaining infrastructure and decreasing water quality. Failing to invest in stormwater infrastructure improvements to mitigate risk will result in damage of existing infrastructure and a failure to provide for future demand.

The July 2016 King County Hazard Mitigation Plan [141] identified priorities for mitigation, including increasing infrastructure resilience and better understanding key vulnerabilities and the necessary implementations to mitigate hazards. Other priorities include retrofitting and relocating structures in high hazard areas.

The mitigation actions that result in improvements in infrastructure will be necessary considering that climate change and natural disasters are already impacting infrastructure, including water resources and management. To quote the King County Hazard Mitigation Plan, natural resource managers already observe that:

- "Historical hydrologic patterns can no longer be solely relied upon to forecast the water future
- Precipitation and runoff patterns are changing, increasing the uncertainty for water supply and quality, flood management, and ecosystem functions
- Extreme climatic events will become more frequent, necessitating improvement in flood protection, drought preparedness, and emergency response"

The Mitigation Plan concludes that, "The changing hydrograph caused by climate change could have a significant impact on the intensity, duration, and frequency of storm events. […] The risk associated with the flood hazard overlaps the risk associated with other hazards, such as earthquake and landslide. This provides an opportunity to seek mitigation alternatives that can reduce risk for multiple hazards". The vulnerability associated with

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139 Mauger, G.S., J.H. Casola, H.A. Morgan, R.L. Stauch, B. Jones, B. Curry, T.M. Busch Isaksen, L. Whitely Binder, M.B. Krosby, and A.K. Snover, 2015. *State of Knowledge: Climate Change in Puget Sound*. Report prepared for the Puget Sound Partnership and the National Oceanic and Atmospheric Administration. Climate Impacts Group, University of Washington, Seattle. doi: 10.7915/CIG93777D. Accessible at https://cig.uw.edu/resources/special-reports/ps-sok

140 Ibid.

141 King County Office of Emergency Management. King County Regional Hazard Mitigation Plan Update. July 2015. Accessible at http://www.kingcounty.gov/depts/emergency-management/emergency-management-professionals/regional-hazard-mitigation-plan.aspx

increased risk of natural hazards can be reduced by improving infrastructure and reducing natural hazard exposure by creating and maintaining existing structures and infrastructure.

Stormwater infrastructure investment is necessary due to the multiple benefits it provides across water systems. Due to external stressors, stormwater systems face an increasing pressure to meet supply and demand changes.

3.5 Fisheries Resources in Washington

The fisheries in Washington are an important source of economic activity as well as cultural and community economic value. A brief description of the commercial and recreational fisheries is provided below, with a separate description of the shellfish industry. Habitat restoration investment is directly aimed at protecting and improving the value of fisheries, and nearly every other type of water resource investment (stormwater management, storage, flood damage reduction, etc.) will also affect the fisheries. This section is intended to briefly identify the economic resource that is at risk with any additional declines, and that may improve with additional support.

3.5.1 Commercial Fisheries

Commercial fishing in Washington in 2014 landed 126 million pounds, or $88 million in revenue from key non-shellfish species, primarily hake, halibut, sablefish, salmon, and albacore tuna.[142] The price of non-shellfish species is relatively low ($0.11/pound for hake, $5.44/pound for halibut, $3.08/pound for sablefish, $1.39/pound for salmon, and $1.17 for albacore) compared to the price per pound offered for shellfish. Within the Pacific region (Oregon, Washington, California), the landed volume of non-shellfish species has decreased by 24 percent since 2005, and decreased by 4 percent from 2013.

Multiple stocks and stock complexes were overfished in 2014, including canary rockfish, Pacific ocean perch, yelloweye rockfish, bigeye tuna, and Pacific Bluefin tuna.[143] Starting in the 2015 season, commercial fishing was closed for Pacific sardines after finding that the biomass had plummeted by over 90 percent from 2006 levels. Washington has the smallest commercial fishing landings (in terms of pounds) in the Pacific region, but the highest landings revenue, due to the large percentage of shellfish landings (low mass, but high value).

3.5.2 Recreational Fisheries

Licenses for recreational fishing are offered at multiple pricing tiers, dependent on if the sportsperson is a resident, non-resident, disabled, senior, or youth. These tiers are further split by type of license (saltwater, freshwater, shellfish/seaweed, combination, short-term, razor clam, PS crab endorsement, charter/guide, two-rod endorsement, and Columbia River

142 NOAA. NOAA Technical Memorandum NMFS-F/SPO-163. Fisheries Economics of the United States, 2014: Pacific Region. May 2016. Accessible at https://www.st.nmfs.noaa.gov/Assets/economics/publications/FEUS/FEUS-2014/Report-and-chapters/FEUS-2014-FINAL-04-Pac-V2.pdf

143 NOAA. NOAA Technical Memorandum NMFS-F/SPO-163. Fisheries Economics of the United States, 2014: Pacific Region. May 2016. Accessible at https://www.st.nmfs.noaa.gov/Assets/economics/publications/FEUS/FEUS-2014/Report-and-chapters/FEUS-2014-FINAL-04-Pac-V2.pdf

endorsement). A total of 1,507,472 licenses were sold in the 2014 fishing season across all license types, resulting in a revenue of $26,208,177.[144]

It is estimated there were 274,000 anglers who made 1.3 million recreational fishing trips in 2014.[145] The majority of the anglers are Washington Coastal residents (231,000), with 19,000 out-of-state residents and 24,000 non-coastal residents. A July 2016 Report from the Washington Department of Fish and Wildlife lists the sport catch report for the 2014-2015 fishing season.[146] In this year, 344,908 marine salmon and 346,446 freshwater salmon were caught (all species combined). One thousand sturgeon were caught, only on the Columbia and Snake Rivers. Since 1971, annual sport salmon catch has fallen. Throughout the 1970s, total sport salmon catch averaged well over 1 million annually. In 2014, the salmon catch was 698,126 and has averaged only 637,253 annually since 2000.[147]

3.5.3 Shellfish Resources

Shellfish are particularly sensitive to water quality, including changes in temperature, carbon dioxide, and concentrations of contaminants. Shellfish comprise 73 percent of commercial fishing value in Washington state.[148] It is therefore exceptionally important for the commercial fishing industry that improved stormwater management maintains water quality at a high enough level to support the shellfish industry.

Commercial Shellfish Industry

In 2014, over 65 million pounds of shellfish, for a total value of $238 million was landed by commercial fisheries of key shellfish species, including clams, crab, mussels, oysters, and shrimp.[149] The majority of the value is from clams and crab which account for $162 of the $238 million, but only 23 million of the 65 million pounds. This is due to the relatively high price of clams per pound ($18.87) obtained by commercial fisherman. Mussels are similarly expensive ($11.79/pound), while crab ($4.16/pound), oysters ($5.12/pound) and shrimp ($0.63/pound) are relatively less expensive. In the Pacific region (Oregon, Washington, and

144 Washington Department of Fish and Wildlife Fish Program Science Division. Washington State Sport Catch Report 2014. July 2016. Accessible at http://wdfw.wa.gov/publications/01835/wdfw01835.pdf

145 NOAA. NOAA Technical Memorandum NMFS-F/SPO-163. Fisheries Economics of the United States, 2014: Pacific Region. May 2016. Accessible at https://www.st.nmfs.noaa.gov/Assets/economics/publications/FEUS/FEUS-2014/Report-and-chapters/FEUS-2014-FINAL-04-Pac-V2.pdf

146 Washington Department of Fish and Wildlife Fish Program Science Division. Washington State Sport Catch Report 2014. July 2016. Accessible at http://wdfw.wa.gov/publications/01835/wdfw01835.pdf

147 Washington Department of Fish and Wildlife Fish Program Science Division. Washington State Sport Catch Report 2014. July 2016. Accessible at http://wdfw.wa.gov/publications/01835/wdfw01835.pdf

148 NOAA. NOAA Technical Memorandum NMFS-F/SPO-163. Fisheries Economics of the United States, 2014: Pacific Region. May 2016. Accessible at https://www.st.nmfs.noaa.gov/Assets/economics/publications/FEUS/FEUS-2014/Report-and-chapters/FEUS-2014-FINAL-04-Pac-V2.pdf

149 NOAA. NOAA Technical Memorandum NMFS-F/SPO-163. Fisheries Economics of the United States, 2014: Pacific Region. May 2016. Accessible at https://www.st.nmfs.noaa.gov/Assets/economics/publications/FEUS/FEUS-2014/Report-and-chapters/FEUS-2014-FINAL-04-Pac-V2.pdf

California), shellfish landing volume has increased by 69 percent since 2005, but declined by 6 percent from 2013.

Recreational Shellfishing

The 2014 Washington state Sport Catch Report finds that over 2 million razor clams were harvested over the course of 254,924 digging trips.[150] From monitored beaches, 409,555 pounds of clams and 601,183 oysters were harvested. Shrimpers caught 127,697 pounds of shrimp and crabbers retrieved 2,261,356 pounds of Dungeness crab.

3.5.4 Fisheries and Habitat

The fishery resources in Washington have long been a staple of the economy with values stemming from extensive commercial, recreational, and cultural fisheries. Fishing, both commercial and recreational, but particularly shellfish, is a vital part of the economy in some regions of Washington. Stocks of most key fish species have declined in the past decade, with some species suffering from overfishing or a near collapse in their total biomass. As discussed in Section 2.2.7, the limiting factor is one of the most important considerations in fish habitat investment decisions.

Approach to Identify the Subset of Projects that Potentially Improve the Carrying Capacity of the Various Basins

The most accurate approach towards identifying which projects would be beneficial would be to conduct a full limiting factors analysis for each basin. For instance, a habitat limiting factor analysis was conducted two times after the recovery plan was completed in Rock Creek, located in WRIA 31. Those analyses determined that flow is the limiting factor in the basin, that conditions are natural, and that the basin is likely a net "sink" for steelhead populations in that adult steelhead stray in the basin to spawn, but the juveniles are trapped in hot pools as the creek dries up in summer, and ultimately die (Glass 2008; Conley 2015). This suggests that the Rock Creek basin is likely a low priority for habitat restoration and the projects identified in the recovery plan for the Rock Creek basin are not necessary. Conducting a full limiting factor analysis in each of the basins would be costly and take considerable time to complete. There are several potential approaches that could be used to reduce the list of projects to focus on higher priority projects and to narrow the list of basins that would benefit from a full limiting factors analysis. These potential approaches are discussed below.

Basins with Extinct or Functionally Extirpated Populations

Several of the basins in Washington state are addressed in the recovery plans although the ESA listed species associated with those basins are extinct or functionally extirpated. In all of those basins, habitat is present and available for occupation. Until such time that the populations grow to a point where they fill or nearly fill the existing habitat (known as fully seeded), projects that increase the amount of available, yet unoccupied, habitat have little value in the near term. As the populations grow, habitat projects in those basins will become more important. Therefore, we can assume that habitat projects in basins with extinct or

[150] Washington Department of Fish and Wildlife Fish Program Science Division. Washington State Sport Catch Report 2014. July 2016. Accessible at http://wdfw.wa.gov/publications/01835/wdfw01835.pdf

functionally extirpated populations have negligible value unless those projects also address habitat for species that are currently present in those basins.

Carrying Capacity versus Population Size

The first potential avenue towards reducing the list of projects would be to look at the carrying capacity (the number of fish that the available habitat in a basin can support) of a basin and compare it with the population size that is supported in that basin. In basins where the population is substantially smaller than the carrying capacity, there is habitat present that is not being used. In these basins, the habitat is not fully seeded and habitat restoration projects are not likely to benefit the populations. However, we do not know the carrying capacity of many of the basins and, in some cases, do not know the population sizes of salmonids in the basins.

The Ecosystem Diagnosis and Treatment (EDT) model was developed by Mobrand Biometrics to help managers estimate the responses of anadromous fish populations to changes in habitat conditions (Lestelle et al. 1996; Lichatowich et al. 1995; Mobrand Biometrics 1999; Mobrand et al. 1997). The EDT model estimates the carrying capacity of a basin under current (and assumed historical) conditions. For those basins where the EDT model has been run, the estimated carrying capacity under current conditions can be compared to estimates of current run size to determine if the habitat is likely fully seeded. It is important to note that, in most cases, measured data regarding habitat conditions was not available to populate the input tables for the EDT models; therefore, the input tables were typically built based on best professional judgement of local biologists. Therefore, there is potential for considerable error in the model outputs. The following is a summary of some of the EDT models that have been run.

Habitat is not likely limiting in any of the basins listed on therefore projects that increase the available habitat are not likely to benefit the population in the near term. In addition to the basins listed in the table above, NMFS has indicated that Lower Columbia River Chinook have an abundance of available habitat that is not being utilized due to low population abundance. Their conclusion suggests that habitat is not limiting the Lower Columbia River Chinook. Where habitat is not currently limiting population size, the populations will eventually reach carrying capacity of the habitat, assuming that the non-habitat factor limiting the population is addressed. Once the populations reach a size that utilizes the available habitat, habitat restoration projects would increase the potential population size. More details regarding the EDT estimates are provided for a subset of the basins, below.

Table 3-2: EDT estimates of carrying capacity, current run size, and the likelihood that habitat is limiting production in the basins.

Basin	Population	Estimated Carrying Capacity	Run Size	Habitat Limiting?
Nooksack River[2]	Chinook	3938	348	Not likely
Stillaguamish River[3]	Chinook	6867	1000-1600 between the years of 2000 and 2003	Not likely
Hood Canal	Chinook	3052	267 between 1993 and 2004	Not likely
Yakima River[5]	Steelhead	7168	2269 (10-year average) 4491 (max in past 10 years)	Not likely
Wenatchee[6] River	Steelhead	2071	741+/- 1225 fish, lots of uncertainty in estimate	Not likely
	Spring Chinook	3372	2714	Possible

[1] Skagit River System Cooperative and Washington Department of Fish and Wildlife. 2005.
[2] Anon. 2005a.
[3] Stillaguamish Implementation Review Committee. 2005.
[4] Yakima Basin Fish & Wildlife Recovery Board, 2009
[5] Upper Columbia Salmon Recovery Board. 2007

Puget Sound Subbasin – Nooksack River Basin

An EDT model was run for the Nooksack basin (Anon. 2005). The modelling effort indicated that the carrying capacity under current conditions for Chinook in the North and Middle Forks of the Nooksack River is 2723 adults and the carrying capacity in the South Fork is 1,215 adults. The mean run size in the North and Middle Forks was 124 adults between 1998 and 2002. The mean run size in the South Fork was 224 adults between 1998 and 2002. In both cases, the current run size is well below the estimated carrying capacity of the basin under current conditions which suggests that freshwater habitat is not limiting fish production (assuming accuracy of the model, which has not been evaluated), which suggests that an evaluation of other factors potentially affecting the population size, such as harvest, disease, predation, and marine conditions, may be warranted. If the population is not limited by freshwater habitat, then projects that identify and address the limiting factor will be of greater benefit than projects that increase the already unoccupied habitat in the basin.

The EDT model uses estimated current conditions and estimated historical conditions to develop priority restoration actions for each reach in the basin. The priority actions are based on the factors where there is the largest difference between current and historical conditions. As with all models, the output is only as good as the input data. Since little to no data regarding habitat conditions in the state prior to development is available, the input data for historical conditions is, in most cases, based entirely on assumptions. The EDT model results are therefore highly dependent upon the assumptions made regarding historical conditions.

Puget Sound Subbasin – Stillaguamish River Basin

The current capacity for the South Fork Stillaguamish River is estimated at 3,028 under current conditions. The current capacity for the North Fork Stillaguamish River is estimated at 3,839. Current population estimates are far below carrying capacity.

Yakima Subbasin

The EDT model for the Yakima River basin indicates that the basin currently has a carrying capacity of 7,168 adult steelhead (Yakima Basin Fish & Wildlife Recovery Board, 2009). The 10-year average run size in the basin is 2,269 fish and the highest run size in the past 10 years was 4,491. Therefore, the habitat is not currently fully seeded (fully used), which would imply that the factor limiting the population is not habitat related, but rather the population is limited by some other factor such as predation, harvest, mortality in the mainstem, or ocean conditions. Further, the Middle Columbia River Recovery plan indicated target of 4,500 fish to support delisting. The EDT model indicates that under current conditions, there is sufficient habitat to exceed the delisting goal. Therefore, it would appear that instream habitat within the Yakima Basin is not limiting fish production for that basin, and that the limiting factor must lie outside of the basin.

3.6 Summary

This chapter provided an overview of investing in water infrastructure in the state of Washington. Without properly considered infrastructure investment in water supply, flood damage prevention, stormwater management, and fish habitat, Washington's economy could suffer. Given predicted changes in precipitation patterns and streamflow, flood damages are expected to increase. The EPA estimates that over $4 billion is needed for stormwater improvements alone in Washington over the next twenty years, given expected population changes. Due to the importance of commercial and recreational fishing to the Washington state economy, a careful consideration of fish habitat, population, and limiting factors must be considered in infrastructure investment decisions. A holistic approach to decision-making will consider the interplay between these water infrastructure types and the benefits provided across all sectors from investment in one type.

Water is essential to multiple sectors of Washington's economy, and proper investment is needed to manage flood prevention, stormwater, and fish habitat. By careful investment decisions, considering the impacts of climate change, land use change, and demographic changes on water supply and demand, damages can be avoided and economic benefits can be obtained.

4. APPROACH AND METHODOLOGY

Ramboll Environ has evaluated the existing water infrastructure assets of the state, and assessed how these assets will be affected by increased flooding, droughts, and other changes in water supply and demand. The assets will fall into different 'asset classes,' including a) Water Supply, b) Flood Protection, c) Stormwater Management, and d) Fisheries and Restoration. The ongoing pressures of population growth, land use change, economic development, and climate change have the potential to change the overall value of statewide assets by causing damages either by reducing the functionality of infrastructure such as roadways and railways, or through reduced access to water resources that support economic growth.

Ramboll Environ has attempted to evaluate changes in value to various statewide 'asset classes' over the next 20 years, through the year 2036, absent any additional water investment infrastructure. These estimates are used to benchmark conditions absent investment so that investments in water infrastructure may be explored throughout the state in terms of the benefits these projects will generate. Water infrastructure investment benefits are evaluated in terms of the regional economic impact potential each possesses (jobs, related industries, statewide GDP). This effort is supported and informed by reaching out to stakeholders throughout Washington including local governments, interested parties, and other state organizations.

The final results were compiled and the findings were developed in a manner intended to support political decision making at state and Federal levels.

A brief outline of our process follows:

1. Complete a scientific and technical review of water supply, floods and drought, storm water, planned infrastructure investment projects, and the benefits of those projects to the Washington state economy. This review will incorporate the existing data and reports relating to economic implications to the state.
2. Develop at least a 20-year forecast of infrastructure investment needs.
3. Work with multiple stakeholders, including the public and local governments to identify projects and need.
4. Conducting an economic assessment of the costs and benefits of investing in water infrastructure in the state of Washington

4.1 Assess Current Conditions

Through a comprehensive literature review and through stakeholder outreach, current conditions in each of the basins in regards to hydrology, the economy, and fisheries and habitat, are evaluated. By using a multi-disciplinary team of economists, water engineers and flood protection specialists, ecologists and environmental experts, and communications professionals to gather and interpret existing information, Ramboll Environ identified projects and developed assumptions about the water infrastructure investment that may be needed statewide.

For each of the basins, a summary of the hydrology, economy, and fisheries or other aquatic habitat were created based on the extensive literature review and information gathering process. These characteristics vary substantially between basins and are important to understand in order to evaluate the needs of water infrastructure in each basin.

As it is impractical to divide the economic data for the Washington state counties between basins when there is overlap, each full county has been assigned to a basin based on the location of the economic centers, which primarily correspond to the population centers as well. The Economy section for each basin provides a list of the counties included in that specific basin.

4.2 Stakeholder Outreach

Different types of water infrastructure investments are highest in priority for different interest groups. The goal of the stakeholder involvement was to initiate a conversation about investing in water and learn how different groups interpret the consequences of failing to invest in water infrastructure. The process involved informal interviews over the phone, face-to-face meetings, email communication, and stakeholder workshops. The process targeted groups and individuals knowledgeable and interested in the future of water infrastructure investment in the state, including irrigators, water purveyors, environmental groups, local governments, tribes and chambers of commerce across the state. Ramboll Environ was assisted in this effort by Lisa Dally Wilson from Dally Environmental who specializes in stakeholder outreach and water resource management.

Outreach with local government representatives involved in water infrastructure investment helped frame the current status of infrastructure need and funding. Informal interviews over the telephone expedited the research team's focus on key issues. The Ramboll Environ team conducted at least 20 such interviews with water infrastructure managers and planners such as representatives from the ACOE, the Washington state Department of Ecology, and the Department of Health, the Washington Water Utilities Council, as well as entities with proposals for significant water projects under consideration.

In late September, we held two workshops, one in eastern Washington and one in western Washington, which were open to interested parties. At the workshops, the research team provided an overview of the project and preliminary findings, and allowed groups to present their own perspectives through focused group discussions.

These workshops were organized as two back-to-back events each on two separate days and in two geographies, Yakima and Lynnwood. Fifty-one people attended the two back-to-back workshops in Yakima, while 67 people participated in the ones conducted in Lynnwood. As expected, there was a higher representation of farmers and irrigation districts in the Yakima workshops, while the Lynnwood workshops saw more participation from municipal water utilities. A complete list of workshop attendees is provided in Appendix B.

The primary goal was to understand the economic consequences of investing, and not investing, in water infrastructure and fisheries habitat across the state. Input was sought on two fundamental topics. First we gathered information on major water infrastructure and fisheries habitat restoration projects that are known to be proposed or likely to be proposed in the next 20 years. The second step was to learn how different stakeholders interpret the economic opportunities of these investments and the economic consequences of failing to invest in specific projects.

The format of each of these events included an overview presentation. The overview presentation provided an introduction to the project and the project team, the purpose of the workshop, the project schedule and activities, the framework for the analysis, examples of the types of information sought, type of input needed, and ways for the stakeholders to participate in the process. The overview presentation is provided in Appendix B. This was followed by a question and answer session and open house. Three stations were set up related to each type of investment, where participants could view exhibits in each of the subject matter areas during the open house. PowerPoint presentations similar to the overview presentation but more focused on the specific type of investment were set up at each station. In addition, sample project lists and other pertinent information regarding the project were available at the stations. Participants were asked to provide information through various means:

- Add to the Projects on Our List
  - Add to the Spreadsheets on the Table
  - Add to the Flip Charts
  - Provide URLs and/or Contact Information with Any Project Information
- Express Your Thoughts on Economics of Investing/Not Investing
  - On the Comment Sheets
  - On 3 X 5 Cards provided during Focus Group
  - Via Email after the Workshop

The highlight of these workshops was the focus groups, which were conducted separately for each subject area. The three focus groups in each workshop included:

- Flood and Habitat Restoration
- Storm water/Wastewater and Habitat Restoration
- Water Supply and Habitat Restoration

Each of these was facilitated with one main facilitator and a co-facilitator/note-taker. These resulted in lively discussions and information sharing. The facilitator notes and outcomes of these workshops are provided in Appendix XX.

4.3 Create Representative Forecast

The research team reviewed available information regarding water infrastructure investment that is planned and water infrastructure that is needed. Developing a 20 year forecast is challenging for a variety of reasons including a) collating inconsistent planning processes at different levels of jurisdiction, b) extrapolating a near-term plan from longer term (50 to 100 years) planning processes, and c) due to the inherent uncertainty of funding sources, For example, the Chehalis Basin has an extensive planning process underway for flood control investment and habitat restoration. In other basins, planning processes are less well defined.

The Ramboll Environ team developed a forecast for water resource infrastructure investments building on the results of the literature review (assessment of current conditions) and the stakeholder outreach and public comment process. The forecast includes investments for flood control, habitat restoration, water supply investment, and Low Impact Design (LID) investments (particularly stormwater improvement projects), and any other significant water supply investments scheduled, or identified as needed. The investment forecast is supported by an analysis of the trends in water infrastructure investment from state, federal, and private sources. To the extent possible, recent investment funding is described by type and by level 4 HUC basins.

Each infrastructure investment identified for the next 20 years (through the year 2036) is described using a common approach that identifies the project within the context of current and future conditions within the HUC Basin. Ramboll Environ reviewed the collection of investment projects and the estimates of cost where available.

This representative forecast results in a database describing all of the identified projects within each basin over the next two decades and provides estimates of funding needs in each basin by project type to meet these project goals.

The Ramboll Environ team built three databases related to the development of infrastructure needs projections for Washington state, by basin. The first is a database that includes all of the source data and literature reviewed and the type of information and data in each of the documents. This database is compiled and organized by basin when feasible. The second database consists of a listing of all of the information and data received through the stakeholder outreach and public comments processes. The data and associated information obtained from these two databases were used to develop the third database – the database of project costs, organized by basin and project type. These costs are the basis of the 20-year infrastructure investment needs projection by basin and project type. Data was obtained from a large number of sources, and as such were not uniformly organized. Some project costs were provided in total and others were provided by specific years which could then be summed up over the project years for a total cost. Where no more information was provided other than the total cost, the Ramboll Environ team was required to make assumptions as to how the total cost would be allocated through time. Under these circumstances, the total was divided equally among the 20 years in the forecast period. Other data that was provided by specific years or over a specified number of years we allocated accordingly. All projects were then summed by year and project type and then by basin. All basins were also summed by year and project type as well. The third database is an Excel workbook that houses the 20-year infrastructure needs projection in detail, which enables the Ramboll Environ team to report the projection by whichever aspect is of interest, including in total, by basin, by year, by project type, or in full detail. The final cost database is provided in Appendix C.

4.4 Evaluate Economic Consequences of Investment

In order to evaluate the economic consequences of an infrastructure investment decision, it is essential to evaluate the economic consequences of not investing in water infrastructure. Usually, infrastructure including habitat and natural infrastructure requires investment because either there is currently a problem with the functioning of the system, or else a problem has been identified in the coming years. Hence there is often a well identified scenario for future losses or economic and ecological challenges that have been studied and provide the basis for understanding what will happen in the absence of investment. However, because of the nature of investment – that infrastructure investment is a long run decision, these forecasts are inevitably incorrect. Instead, forecasts made using the best available information and incorporating alternatives or ranges of reasonable values are most effective.

The calculation of economic consequences that follows is divided into the economic stimulus and economic benefits. The quantification of economic benefits – following guidance from the PR&Gs and other recent documents on subsets of economic benefits – varies depending on the specific economic objective of an investment in infrastructure. There may be benefits of providing additional water supply (domestic, industrial, and agricultural benefits), in improving water quality and reducing damages associated with poor water quality, reducing damages from flooding, and so forth. Section 2.6 of this report provides an overview of these types of methods. In all cases, the economic benefits are compared with the economic and environmental costs associated with the investment through time. Both costs and benefits are evaluated on an annual basis throughout the life of the project using a discount rate for each year into the future that both costs and benefits will accrue. The discount rate reflects the social rate of time preference, allows for uncertainty, and accounts for the opportunity cost of the capital investment.

Benefits and costs of specific projects in the database were reviewed and analyzed in a manner consistent with the principles of benefit cost analysis as described in numerous texts (e.g. Boardman et al., 2011) and agency guidance documents such as the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&Gs), OMB Circular A-94, and the PR&Gs, where available. The approach should involve evaluating all the major costs and benefits associated with a proposed action through time. Benefits are defined in terms of gains from increased access to, or securing access to water, reduction in anticipated harm from water, plus any other ancillary benefits that might result from the investment project. Costs will be defined as financial costs required to bring about the project - capital costs as well as ongoing costs – plus any environmental costs or harm that occurs as a result of a project that is in addition to the baseline scenario.

Some but not all of the representative projects in the forecast have been evaluated for economic consequences. While a detailed evaluation of the benefits of each project is outside the scope of this effort, where economic analyses for identified projects have occurred, a description of the results is presented and evaluated. Elsewhere, as much detail as can be presented is provided for the impacts of investing in the projects, and a general discussion of the consequences of investment is also provided.

4.5 Regional Economic Impacts - Economic Resilience

This section provides a detailed description of the methodologies used to develop the economic activity estimates. An input-output model is a technique that quantifies the interactions between industries within an economy. Input-output models yield multipliers that are used to calculate the total direct, indirect, and induced impact on jobs, income and output resulting from a dollar of spending on goods and services in the study area. The model used to estimate economic impacts for this study is IMPLAN which is an input-output model developed by the United States (US) Government and the University of Minnesota (available from the Minnesota IMPLAN Group, Inc.[MIG]).

As with any economic analysis, assumptions are necessary and each model has its own limitations. Assumptions are needed to maintain a level of simplicity such that broad-based models can be used for several geographic areas and across various economic sectors. The general approach used in this analyses includes the following assumptions:

1. Full counties are assigned to one HUC basin based on location of greatest economic activity if a county is split by basin boundaries. The 39 counties are compiled into 8 HUC basin models, which are the starting point for socioeconomic analyses.
2. Multipliers are identified to measure the backward linkages to supporting industries (i.e., those who sell inputs to an affected sector). However, these multipliers do not provide information regarding forward linkages consisting of businesses that purchase goods from an affected sector for further processing. Multipliers do not capture forward linkages but each of the sectors analyzed fully account for all impacts to a region's economy.
3. Interpretations of direct and indirect/induced impacts must be prudent. Multipliers are based on "fixed-proportion production functions," which means that all inputs move together with changes in levels of output. In a scenario where output (i.e., sales) declines, losses in the immediate sector or supporting sectors could be much less than predicted by the IMPLAN model for several reasons. For one, businesses will likely continue operating so they can maintain spending on inputs for future use; or they may be under contractual obligations to purchase inputs for an extended period regardless of external conditions. Further, employers may not lay-off workers if skilled personnel are not readily available when needed. Third, people who do lose jobs might find other employment within the region. As a result, direct impacts to employment and indirect/induced impacts to sales and employment should be considered an upper bound.
4. Models and associated multipliers are based upon the structure of the U.S. and regional economies in 2014. However, water infrastructure investments are projected to occur several years into the future. Therefore, the analysis assumes that the overall structure of the Washington state economy remains the same over the planning horizon. This assumption becomes less robust the further the analysis is projected.
5. Impacts are annual estimates and employment is measured in Full Time Equivalent (FTE) jobs
6. Values are reported in constant 2014 dollars.

4.6 Decision Making with Uncertainty

As discussed above, risk and uncertainty are important considerations in infrastructure investment decisions. The goal of this research is to inform decision making about water infrastructure investment. Based on the research and review of information conducted as part of this study, some recommendations were developed regarding appropriate uses of the information compiled and suggestions for how more fully developed information about a particular investment might be explored in light of the many uncertain or probabilistic factors that will affect the decision to invest.

5. STAKEHOLDER OUTREACH FINDINGS

As discussed in previous sections, especially Section 4.2, connecting with stakeholders was a key part of the data collection effort. The team was able to gather pertinent information and insights from relevant stakeholders, which helped develop an understanding of the economic consequences of investing and not investing in water infrastructure and fisheries habitat across the state, in addition to an understanding of the plans and needs for water infrastructure over the next twenty years. The process included workshops in Yakima and Lynnwood, telephone interviews, in-person meetings, and email exchanges. Close to 120 individuals were contacted through workshops in Yakima and Lynnwood, while over twenty interviews were conducted with water infrastructure managers and planners from organizations including the ACOE, the Washington state Department of Ecology, the Department of Health, and he Washington Water Utilities Council. This information was collated into an identified projects database, with costs and needs organized by basin and project type (see Appendix C).

This section presents the key findings and insights gained from the stakeholder outreach process. These are presented separately below for each of the four topic areas. Also, within the outreach process and especially through the focus groups, questions were asked about the economic consequences of both investing, and failing to invest in the several types of infrastructure.

5.1 Key Findings and Insights Related to Water Infrastructure

The following provide the key findings related to water supply infrastructure based on the stakeholder outreach process:

- There are many benefits to building storage projects, but also "true" costs associated with some of the larger projects, both during drought and non-drought years. In the context of agriculture, the benefits relate to, for example, water being available for irrigation and avoidance of crop loss during drought conditions, especially for higher value crops, such as cherries, apples, blueberries, and raspberries. While in the context of municipal water supply, an example related to excess supply of water due to available storage that can be provided to basins where water has already been over appropriated (basin closures).
- Given the changing hydrograph resulting from climate change (too much early in the year, not enough later in the year), there is a need for storage. In addition to big dam projects, this can be done through natural systems, aquifer recharge, and wetlands and flood plains, forest management, large scale land treatment, water reuse (rainfall harvesting for potable re-use). Storage capacity should be built in as an infrastructure investment and as part of everyday land use management.
- Recreational and commercial fisheries would decline, including later returning years. These are not typically considered in economic analysis. Also, these are not just a single year occurrence, for example, in the cases of coho, steelhead, and sockeye.
- The trout guiding services would lose of business.
- It would lead to low instream flows, resulting in curtailment of junior water right holders, loss of annual crops, and in case multiple year curtailment occurs, loss of

orchards and other perennial crops (multiple year losses can be significant). Absent the development of additional storage, water reliability for junior water rights holders would be less than 70 percent in any given year. For junior water rights holders, two to three years of back to back curtailment will drive them to bankruptcy ("Water is Life" for the agricultural community).

- There would be significant production losses for all farmers, and some may need to shut down early.
- This would lead to farmers installing wells, resulting in higher cost of water to farmers and, hence, crop.
- The price of crops would increase to cover these additional costs and losses, leading to food prices going up. This could ultimately result in food insecurity for all.
- There would be impacts on farming jobs due to the reduced crops because of, for example, less double cropping, more valuable crops but lesser people employed (farmgate). Farmers may switch to another crop that is more valuable but requires less water. However, that would result in a loss of jobs. Economic analyses should include year-by-year effects and look into the long-term economic impact on production and quality of crops.
- Not investing in storage could lead to hoarding of water, and turning irrigation districts against each other.
- Back to back droughts can impact groundwater over time if additional storage is not put in place.
- There would be crop loss for both junior and senior water right holders (for example, 28,000 acres of high density orchards could be lost)
- Could lead to economic decline of the community
- Storage would ensure water supply in back to back droughts – this will become more and more important with climate change impacts.
- Additional consequences on not building storage could include, during high flow – early in hydrograph: Flood costs, home loss, soil loss and erosion, decline in land and home values. During low flow – late in hydrograph, these would include: Loss of jobs, loss of fish habitat, loss of exports, loss of recreation, less tourism, and fire danger.
- Additional storage would help during both drought and non-drought situations.
- During non-drought years, additional storage would provide more water for everyone. For example, if there is storage available and you have all the water you need to meet the needs during a particular year, the additional water can be put in the ground for long-term benefits. More water in more places also benefits wildlife.
- During drought years, additional storage would ensures water supply (especially if there are back-to-back droughts). If snowpack changes to rainfall (climate change), there is a way to store that additional water. There will be significant fish and irrigation benefits.

- There would be less effect of drought on commercial fisheries if there is additional storage available. Commercial fisheries suffered during the 2015 drought, and the ramifications go beyond 2015.
- There would be less effect of drought on trout guiding services if there is additional storage available.
- Additional storage would help junior water rights holders during drought. They were particularly affected during the 2015 drought.
- More water for everyone avoids conflicts. During the 2015 drought, cherry growers suffered more as there were three-week shut-offs of water supply, while the apple growers were favored. It resulted in setting everybody against everybody, small farmers against corporate farmers, and irrigation districts against each other.
- More water for everyone results in less hoarding and avoids conflict, leading to less negative impacts to society.
- Additional storage in the right locations would provide water to shape the hydrograph with saturation of groundwater. This can have huge benefits for fish and agriculture (Drought years – instream fish benefits (upstream), Agricultural benefits (downstream)). There would be more water for crops and soil water storage for the next year.
- These would keep groundwater table static in the longer term.
- There is a need to account for the “true” cost of building water storage projects:
    - Aside from the monetary cost associated with building storage projects, we need to take into account the “true” cost of building large water infrastructure projects, such as storage projects. Some of these could include (using Bumping Lake from the YBIP as an example) recreational impacts, old growth impacts, wildlife and endangered species impacts.
    - There is an economic consequence (overspending) in overdesigning dam capacity.
    - Need to take into account the liability associated with additional water storage.
- Water delivery infrastructure can help put water to its highest and best use. For example, in Skagit Basin, water is being trucked to some areas at a very high cost. Better infrastructure to transport/deliver water from other areas can help bring that cost down. Home values go down if water is too expensive.
- Statewide, there are Water Districts that will have needs over the next 20 years, but they either do not know it or have not projected it yet. These include the smaller municipal and domestic water supplies (Group B Water systems and smaller Group A’s). Future infrastructure investment (for both growth and O&M) are not well forecasted or not forecasted at all for these systems, and these may not be able to shoulder the future costs given that their rate payer base is small and these do not have the resources to invest in mega projects or larger system expansion infrastructure. In such cases, the counties take on these projects but the home-owners ultimately pay for these (water system acquisition and rehabilitation). The issue is that the counties can only take over after four to five years, and by then it is too expensive to fix the

problems and the home-owners end up paying two to three times more. The trickle down here eventually results with the county placing Liens on the customers' homes if they cannot reimburse the water entity (note that the Public Works Trust Fund that used to provide funding for infrastructure has been greatly diminished). Also need to consider costs of salt water intrusion on smaller water systems.

- Need to look into and address the issue of aging Army Corp of Engineers infrastructure (for example, locks, dams, etc.) and potential infrastructure failures. This would be a huge expense and need to look into who will be impacted and who will pay.
- Irrigation Efficiency investments – note that there have been a lot of investments in conservation through Irrigation Efficiency Program, but the "low hanging fruit" is gone. Generally, the dollar returns on agricultural conservation are not very high at this point. The effects of 1992-1994 were huge, and precipitated many changes in irrigation infrastructure and operation after that. Unintended consequences of irrigation efficiencies need to be considered (piping water to avoid leakage).
- Decline in wetlands, wildlife impacts, problems with groundwater infiltration and re-timing of groundwater delivery to streams, natural recreation need to considered
- Need to ensure that healthy ecosystems are accurately accounted for.
- Investments in water infrastructure and availability of water can lead to an overall vibrant economy.
- Water users invest a lot of money, and it can take two to three years for them to recover from a lack of water during drought years or other low water supply years. That might be too long for some and they may not recover economically. Storage options can help. Economic studies typically do not account for the number of years that it takes for crops/soil to recover from drought on drought conditions.
- Water Infrastructure needs for Whatcom County (driven by Tribes settlement agreement to address instream flows) trying to move agriculture off of tributary water and onto mainstem water. This threatens the livelihood of agriculture (e.g., 11 to 14 million pounds of raspberries per year), and can result in threat of urban development of farmlands with many negative impacts to the water budget and to agriculture.
- Culvert benefits should be identified and considered. These have multiple benefits both to fish and drainage, but also to transportation infrastructure.
- Washington Needs a Statewide Water Plan!
- As an example of a multiple benefit project, the Dungeness off-channel reservoir could provide the following benefits,
  - Streamflow restoration for ESA listed species
  - Aquifer recharge for small stream/tributary benefits and stable drinking water supply
  - Avoid water table declines and unwanted changes to hydrogeology – enable surface water/groundwater recharge and hydraulic connectivity

  - Provides water for growth additional demand
  - Provides public recreation (300-acre park)
  - Helps with drought resiliency/climate resiliency
  - Flood protection – capturing surface water prevents downstream flooding and prevents water quality impacts (saves large amounts of money on infrastructure because we do not need as much surface water infrastructure for larger storms)
  - Water supply for Agriculture – agriculture is no longer as liable for ESA related losses
- Benefits are for children, education, things like the locks are integral to this part of the world
- Salmon recovery
- Impacts to agriculture
- Reduces risks of flood
- Reduces damages to home
- Fisheries for food sources and tribal value
- Sediment needs to be managed otherwise this aggravates flooding
- Upland watersheds need to be managed to reduce sediment
- There will be less water in summers and more in winter and this will aggravate sediment by 100%
- Levees exacerbate conditions of sediment
- Risks to railways
- Sea level rise a concern
- Benefits include avoiding litigation
- Drinking water quality improves
- Health of population
- Maritime and navigation safety
- Savings in emergency costs
- Long term food security issues with losses to agriculture

5.2 Key Findings and Insights Related to Fisheries and Restoration Infrastructure

- Fish habitat projects can lead to not only environmental benefits, but also many benefits to the Federal Government, as well as state and local economies. Fish passage projects, such as that proposed above the Chief Joseph Dam, can help the Federal Government meet its obligations under the Tribal Treaty rights – Colville Nation – if these are not met, it is a huge lawsuit waiting to happen and can end up with substantial cost to the government. While our analyses will factor in the typical economic consequences of not investing in such infrastructure projects, we need to make sure we take into account such legal costs (avoided litigation).

- Benefits of investing in habitat restoration
  - Avoid liability
  - ESA de-listings Avoid legal $$, avoid curtailment of development
- Consider the cost to fish and <u>all wildlife</u> of NOT investing in habitat improvements
- Cost of not investing in fish habitat projects:
  - rivers and pools dry out
  - wildlife suffers
  - salmon can go instinct – salmon is essential to Washington residents – "What it means to be a Washingtonian" will change
  - effects recreation
  - effects on tourism
  - effects commercial fisheries
  - effects Tribal treaty rights
  - irrigation is affected
  - cultural issues – this goes beyond livelihood – spiritual, religious, time immemorial
  - ecological issues
  - loss of investment from large companies – recreation/scenic opportunities also drive economic investment from companies such as Microsoft and Google – people want to move here because of the scenic beauty and recreational opportunities
  - "What it means to be a Washingtonian" will change if investments are not made in fish habitat projects.
- Additional ESA listings
  - Legal investments
  - Federal investments
  - Curtailment of development
  - Huge costs to state and feds re. ESA listings
- Tribal Cultural values impacted severely
- Wild salmon stocks will go extinct
- Impact tourism
- Recreation impacts – no fishing
- Commercial fishing impacts

- Tribal Treaty Rights – litigation
- What it means to be a Washingtonian will change.
- Impact to Recreational scenic identity that attracts businesses to WA (Google, Amazon)
- Benefit to fish of investments in water infrastructure – increased streamflow leads to additional water in streams, which provides fish passage and also cools the water
- Potential Future projects with BIG implications – Open Fish passage above Chief Joseph Dam – Colville Tribe currently negotiating between Bonneville Power Authority (BPA) and other Federal Agencies ('FRCPS') – Federal Responsible Columbia Parties??
- Culvert Benefits – multiple benefits both to fish and drainage, but also to transportation infrastructure.
- Benefits Associated with Opening Fish passage above Chief Joseph Dam (from Okanogan River to Lake Roosevelt)– Negotiation between Colville Tribe and Federal Agencies
  - Negative for some property owners, now there will be ESA regulations and implications
  - Positive - tourism
  - Helps secure long term power supply
  - Tribal benefits – treaty rights to fish, food, cultural
- Benefits of Salmon Recovery/Avoiding ESA related litigation
  - Save on costs of federal oversight
  - Passive value of fish
  - Save on mitigation costs
  - Economic viability
  - Tourism
  - Tribal/cultural values
  - Quality of life
  - Human health

6. CURRENT CONDITIONS AND IDENTIFICATION OF NEEDS THROUGH 2036

This chapter provides and overview of the essential hydrologic, economic, and ecologic information needed to assess water infrastructure investment need at the watershed level. For each of the eight HUC-4 boundary basins, information about basin hydrology including trends, recent drought and flood information, impacts of climate change and existing infrastructure is summarized. Next, the economy is described showing population growth, income and sectoral employment in the basin. Following the presentation of economic information, an analysis of the fisheries and habitat needs and conditions including trends and changes is provided. These summaries are intended to set the stage for understanding the representative investment project needs that were identified during the project literature reviews and stakeholder outreach efforts. An overview of the hydrology and economy at the state level is provides context for the subsequent basin-level information.

6.1 State Overview

General information relevant to water infrastructure investment in Washington state includes the following hydrologic and economic overviews.

6.1.1 Hydrology

Observed variations in climate have been shown to effect hydrologic extremes (including floods and droughts) in the Pacific Northwest, including Washington state[151]. There has been a state-wide trend to higher extreme precipitation events associated with higher peak river flows, and especially in the areas of Western Washington. For example, of the five most extreme flooding events in the state, four have occurred in the past two decades. However, Hamlet (2012) argues that these changes are not necessarily related to the changing climate, but are combination of many other factors including urbanization. The author notes that two of the wettest years (precipitation-wide) in the 20th century (water years 1974 and 1997) were matched or exceeded five times in the last 40 years of the 19th century according to the sporadic data.

Variations of flood and droughts in the state has been mostly influenced by decadal and inter-annual variations in the climate associated with the Pacific Decadal Oscillation (PDO) and with the El Nino Southern Oscillation (ENSO). Analysis of the 20th century records showed that hydrologic extremes in the 20th century were entirely correlated with variations in PDO and ENSO occurrences, and decadal oscillations in the climate with the[152]:

- Highest historical floods occurring in ENSO neutral and (temperature) cool ENSO years;
- Higher flooding in cooler PDO periods;
- Lower flood risks in warmer PDO periods;

[151] Hamlet, Alan, 2012. Impacts on Climate Variability and Climate Change on Transportation Systems and Infrastructure in Washington State

[152] Hamlet, A.F., and Lettenmaier, D.P., 2007. Effects of 20th Century Warming and Climate Variability on Flood Risk in Western US, Water Resources Research, Vol. 43, W06427.

Changes in variability in cool season precipitation have also been obvious in Washington State (and other western states) with statistically significant shifts in variance of the cool season precipitation, that in turn has been always associated with higher flood risk.

Changes in temperatures have caused changes in other hydrologic variables, including timing of the snowmelt and associated increase in flooding and decrease in the base streamflow and drier than average streamflow (in some years).

Local sea level has been also strongly influenced by variability in ENSO – to such extent, that in some years the impact of a relatively strong warm ENSO event coinciding with "king tides" resulted in tides 2-feet higher than the normal tides, and thus, had stronger flooding impact on the Washington coastline than one would expect with any projected sea level rise (SLR).

Global climate change is projected to bring warmer temperatures and changes in the seasonality of precipitation in Washington state. These changes are projected to lead to increased extreme high temperatures and decreased the extreme low temperatures, wetter conditions in winter, spring, and fall, and drier summers. These changes are also projected to decrease mountain snowpack (especially at moderate elevations) and the frequency of low elevation snow storms. Hydrologic extremes such as flooding are projected to increase or decrease in different ways in different parts of the state, depending in part on variations in mid-winter temperatures and the spatial distribution of precipitation change. Loss of snowpack may decrease avalanche risks at moderate elevations (such as mountain passes) while raising the risk of landslides, debris flows, and scour due to an increase in exposed soils. It may also prolong periods with drier (and below normal streamflows). Uncertain changes in precipitation extremes may affect the performance of stormwater systems, the frequency of infrastructure damage, and public safety. SLR is projected to threaten coastal transportation infrastructure such as roads in low-lying areas, roadways on dikes and levies, or in coastal areas subject to beach erosion. SLR may also create drainage problems in low gradient areas.

6.1.2 Economy

Washington state comprises 39 counties, with King County making up the largest population share. Seattle is the largest city in the state, followed by Tacoma, Spokane, and Vancouver. The primary industries, based on employment, of the state include health care and social assistance, retail trade, local government, manufacturing, and accommodation and food services. The current (2015) population from census estimates and the most recent county population forecast from OFM are presented in Table 6-1 for the state and the eight basins that are the subject of this report. The total state population is expected to grow from 7.17 billion in 2015 to 8.55 million in 2036, representing a 0.8 percent average annual rate of growth (AARG), which is slightly higher than the national annual growth rate of 0.7 percent for the same period.[153] The Puget Sound basin, which is by far the most populous also shows a 0.8 percent AARG, consistent with statewide growth. However, faster growing basins are the Yakima, which is expected to grow at an AARG of 1.1 percent, the Lower Columbia, also expected to grow at an AARG of 1.1 percent, and the Upper Columbia River basin, expected to grow at 1.4 percent per year over the next 20

[153] U.S. Census Bureau, Population Division, Table 1. Projections of the Population and Components of Change for the United States: 2015 to 2060 (NP2014-T1)

years. Slower growing basins include the Lower Snake basin, forecast to grow at 0.2 percent per year, the Middle Columbia basin, and the Washington Coastal basin, expected to grow at 0.4 and 0.5 percent per year respectively.

Table 6-1: OFM Population Projections for Washington State (millions)

	2015	2017	2018	2019	2020	2025	2030	2035	2036	AARG*
Washington	7.17	7.18	7.26	7.33	7.41	7.79	8.15	8.48	8.55	0.8%
Yakima	0.48	0.50	0.50	0.51	0.51	0.54	0.57	0.60	0.60	1.1%
Lower Snake	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.2%
Puget Sound	4.85	4.82	4.88	4.93	4.98	5.24	5.48	5.69	5.74	0.8%
Washington Coastal	0.17	0.17	0.17	0.18	0.18	0.18	0.18	0.19	0.19	0.5%
Kootenai P - O - S	0.50	0.51	0.52	0.52	0.53	0.55	0.57	0.59	0.59	0.8%
Lower Columbia	0.55	0.57	0.58	0.58	0.59	0.62	0.65	0.68	0.69	1.1%
Middle Columbia	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.4%
Upper Columbia	0.42	0.44	0.44	0.45	0.46	0.49	0.52	0.55	0.56	1.4%

*Average Annual Rate of Growth

The economic sector breakdown by employment for the largest industry sectors in the state counties is provided in Table 6-2. Healthcare and social assistance accounts for nearly 390,000 jobs within the state, and retail trade accounts for just under 350,000. Local governments provide close to 330,000 jobs, with manufacturing and Accommodation and food services sectors including more than 250,000 jobs as of 2015. .

Table 6-2: 2015 County Employment by Largest Economic Sectors

Washington State	Number of jobs
1. Health care and social assistance	389,735
2. Retail Trade	349,640
3. Local government	329,746
4. Manufacturing	287,595
5. Accommodation and food services	257,320

Total employment, wage, and number of firms for the state in 2015 are displayed in Table 6-3, in total. Washington state had an average of nearly 223,000 firms, providing nearly $177 billion in wages, for 3.12 million jobs. Average annual wages throughout the state are just under $42,000. Unemployment figures by basin are shown in Table 6-3. With a state total unemployment rate of 5.3 percent. Table 6-4 shows the unemployment rates for each basin, demonstrating that the Washington Coastal basin, Yakima, and Upper Columbia basins each have much higher unemployment rates, with 8.1 percent, 7.3 percent, and 7 percent respectively. The Puget Sound basin has an unemployment rate that is lower than the state average, with Puget Sound showing unemployment at 4.8 percent.

Table 6-3: 2015 State Industry Employment, Wages, and Firms

	Avg. Firms	Total 2015 wages paid (million $)	Average annual employment (million)	Average annual wage
Total State	222,946	$176,932	3.12	$41,865

Table 6-4: 2016 Basin Unemployment Rates

Basin	Unemployment Rate (November 2016)
Washington Coastal	8.1%
Lower Columbia	5.9%
Middle Columbia	5.9%
Upper Columbia	7.0%
Puget Sound	4.8%
Lower Snake	4.4%
Kootenai-Pend Oreille-Spokane	5.7%
Yakima	7.3%
Total State	**5.3%**

6.2 Upper Columbia River Basin

The Upper Columbia River Basin (UCRB) covers much of central Washington, north of the confluence of the Yakima and Columbia Rivers, and east of the Cascade crest. The Wenatchee National Forest is located within the basin, and the basin contains the cities of Wenatchee, Leavenworth, Moses Lake, Chelan, and Richland. Major tributaries to the Columbia River within the subbasin include the Methow, Wenatchee, Entiat, Lake Chelan, Okanogan, and Spokane Rivers. Interstate 90 and Highways 2 run cross the basin. A map of the UCRB is shown in Figure 6-1 below.

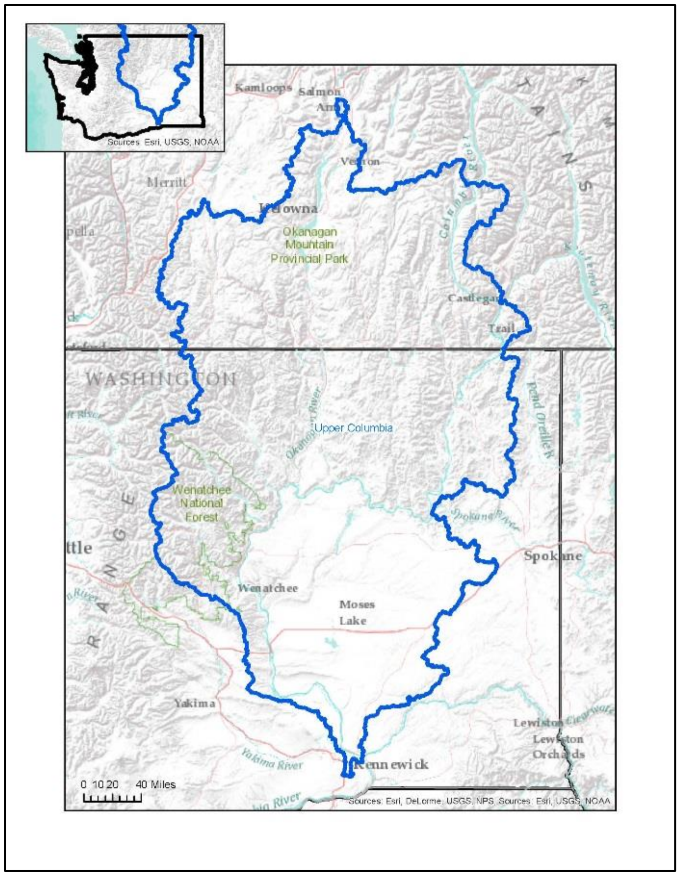

Figure 6-1: Map of Upper Columbia River Basin.

6.2.1 Hydrology

The Columbia River Basin is the fourth largest watershed in North America in terms of average annual flow. Significant parts of the basin lie in Oregon, Idaho, Montana, and British Columbia. Climate varies considerably across the basin, both spatially and temporarily. The north-south Cascade Mountains in Washington slow the flow of rainfall into eastern Washington, resulting in drier and warmer climate than in western Washington. The variation in precipitation and temperature from year to year, combined with the geographic complexity of the basin, results in highly variable river flows. Surface water flows are highly dominated by the cycle of snow accumulation and melting, with peak river flows occurring in late spring and early summer (coinciding with the peak of the snowmelt).

Existing Water Infrastructure

The basin has roughly 60 dams in the US and Canada that provide hydroelectricity, irrigation, flood control, stream flow regulation, and storage and delivery of water. There is additional supporting infrastructure, including irrigation canals, and navigation locks. The major water infrastructure in the UCRB includes river dams at: Grand Coulee (primarily used for hydropower and irrigation, can be used for flood control due to large storage), Chief Joseph (run-of-the-river dam - it cannot be used for water storage, but can generate power in coordination with Wells dam downstream), Wells (used for hydropower and some flood storage), Rocky Reach, (used for hydropower, some flood storage and fish passage), Chelan River/Lake (used historically for hydropower and water supply storage, also provides flood protection), Rock Island (hydropower and some flood protection), Wanapum and Priest Rapids dams (hydropower and some flood protection). The majority of these reservoirs are also used for recreation. Grand Coulee Dam is the only dam that provides major flood protection, while the others coordinate in regulating water releases during a major flood.

Despite its huge annual runoff, the Columbia River does not have a history of catastrophic flooding (compared to other large rivers like the Mississippi), so the major purpose of all the dams constructed on the Columbia was hydropower, and not flood protection. Before the dams were constructed, the river rose in the early spring and summer and flooded low-lying areas not protected by levees. Usually this was considered more of an inconvenience than a disaster, and the ACOE originally recommended using levees and not dams for flood protection. During the historic floods of 1948 and 1956, regulators had to release flows through the dams downstream once the water level exceeded the maximum design water level at each dam.

Flood History

Historic floods in the UCRB are summarized:

- **June 1894 Flood**, when heavy precipitation throughout the basin led to heavy snowpack. This was followed by a dry, warm spring resulting in massive snowmelt.
- **May 1948 Flood**, when heavy precipitation throughout the basin led to heavy snowpack. The early spring had little precipitation and few warm days. May brought warm temperatures and heavy rainfall, resulting in heavy snowmelt causing flooding throughout the basin.
- **June 1956 Flood**, - persistent heavy precipitation started in October of 1955 through February of 1956, Heavy rainfall in the UCRB continued through March. Snowpack started accumulating before the end of October and by springtime was much more than usual. Warmer temperatures in the late spring augmented the snowmelt.

Although there has been no recent major floods in the UCRB, there has been an increasing trend towards more extreme rainfall events occurring during the winter.

Drought History

The UCRB has been subjected to numerous historic droughts. The following historic droughts were identified (using tree-ring methodology[154]):

- Multi-year drought: 1840 – 1855 – most severe and persistent drought on record,
- Multi-year droughts 1790-1800, 1840s, 1870s,
- 1-year droughts in 1775, 1805, and 1925,
- 1890s and 1930s – periods of extremely low flows in the river.

Drought conditions in the basin are summarized weekly in the U.S. Drought Monitor, a collaborative effort between Federal and academic partners, including the University of

[154] Gedalof, Peterson, and Mantua, Columbia River Flow and Drought since 1750, in Journal of the American Water Resources Association, December 2004, Paper No. 03073, pp. 1- 14.

Nebraska-Lincoln, the United States Department of Agriculture (USDA), and NOAA[155]. Some of the more recent droughts include:

- Shorter droughts 1976-78, and 2000-2004[156]
- Single year drought 2014- 2015

There has not been any significant trend/pattern in the frequency of droughts during the 20th century. However, there has been a possible increasing trend towards drier summers with lower streamflows. The droughts in 1840s and 1930s coincide with recorded and recognized drought on the Great Plains, indicating that the drought was widespread across the United States. In general, the 20th century had fewer droughts in the UCRB than in earlier centuries. The most recent drought in the basin (and throughout Eastern Washington) occurred in 2014-15. At the peak of the drought (mid-summer 2015), Columbia River flows were 50 to 60 percent below normal. A statewide drought was declared May 15, 2015.

Hydrologic Trends

The following trends in hydrology have been documented from the late 19th century through today[157]:

- There has been a steady increase in the basin-wide mean annual temperature from the 1890s to 1930s, and then again from the 1980s through 2000s;
- Mean annual precipitation in the basin has remained unchanged (no trend to increase or decrease); however, there has been a regional trend of increasing precipitation during the wet season and an increase in extreme precipitation events;
- There has been a general decline in spring snowmelt (mostly as a result of increases in temperature, and more precipitation falling as rain than snow in winter)[158];
- There is a possible trend of reduced annual streamflow during dry years[159].

Statistical analysis of these trends conducted by the Bureau of Reclamation and others could not determine whether the trends are caused by natural climate variability or by anthropogenic influence.

6.2.2 Economy

The counties that are included in the economic analysis for the UCRB are Adams, Chelan, Douglas, Ferry, Franklin, Grant, Lincoln, Okanogan, and Stevens counties. Within these

155 http://www.usda.gov/oce/weather/Drought/

156 Xiao, M., Nijsenn, B., and Lettenmaier, Drought in the Pacific Northwest, 1920-2013, Journal of Hydrometeorology, American Meteorological Society, Volume 17, No. 12, September 2016, http://journals.ametsoc.org/doi/full/10.1175/JHM-D-15-0142.1.

157 US Dept. of Interior, Bureau of Reclamation, Managing Water in the West, Secure Water Act Section 9503(c), Reclamation, Climate Change and Water, 2011.

158 Knowles, N., Dettinger, M., and Cayan, D., 2007. Trends in Snowfall versus Rainfall for the Western United States 1949-2001. Prepared for California Energy Commission Public Interest Research Program, Project Report CEC-500-2007-032.

159 Luce, C. H, and Holden, Z.A., 2009. Declining Annual Streamflow Distribution in the Pacific Northwest United States, 1948-2006. Geophysical Research Letters, Vol 36, L16401, doi:10.1029/2009GL039407.

counties, the largest notable cities are Wenatchee, East Wenatchee, Othello, Pasco, Moses Lake, Omak, and Colville. The primary industries, based on employment, of the counties within the basin include agriculture, forestry and fishing, healthcare and social assistance, local government, and retail trade.

The current (2015) population from census estimates and the most recent county population forecast from OFM are presented in Table 6-5 by county and for the total basin. The total basin population is expected to grow from 420,708 (5.9 percent of Washington's population) in 2015 to 560,704 (6.8 percent of the state population) in 2036. Currently, over 60 percent of that population is in Chelan (75,644), Franklin (88,807), and Grant counties (93,259). By 2036, that share is expected to grow to over 65 percent (87,603, 149,357, and 131,481 respectively).

Table 6-5: OFM Population Projections for Upper Columbia Basin

	2015	2017	2018	2019	2020	2025	2030	2035	2036
Washington	7,170,351	7,178,675	7,256,835	7,334,646	7,411,977	7,793,173	8,154,193	8,483,628	8,546,278
Adams	19,254	20,794	21,082	21,364	21,640	22,964	24,289	25,690	25,993
Chelan	75,644	76,550	77,238	77,918	78,586	81,885	84,778	87,168	87,603
Douglas	40,534	41,812	42,411	43,014	43,619	46,662	49,583	52,256	52,762
Ferry	7,582	7,655	7,674	7,691	7,706	7,751	7,754	7,740	7,732
Franklin	88,807	92,902	95,511	98,185	100,926	115,142	130,284	146,103	149,357
Grant	93,259	99,090	100,744	102,408	104,078	112,525	121,204	129,779	131,481
Lincoln	10,321	10,654	10,674	10,692	10,707	10,800	10,865	10,862	10,856
Okanogan	41,516	42,597	42,799	42,989	43,163	43,978	44,619	45,127	45,254
Stevens	43,791	44,636	44,834	45,026	45,212	46,447	47,834	49,340	49,666
Total Basin	420,708	436,690	442,967	449,287	455,637	488,154	521,210	554,065	560,704

The economic sector breakdown by employment for the largest industry sectors in the basin's counties is provided in Table 6-2. Agriculture, forestry and fishing is significantly the largest employment sector for six of the nine counties in the basin (Adams, Chelan, Douglas, Grant, Franklin, and Okanogan), providing nearly twice as many jobs as the second largest sector for each of those counties. Local government, retail trade, and healthcare and social assistance are also key employment industry sectors for all of the counties within the basin, as they are all within the top five industries for all of the basin counties.

Table 6-6: 2015 County Employment by Largest Economic Sectors

County	Number of Jobs
Adams County	
1. Agriculture, forestry and fishing	2,214
2. Local government	1,502
3. Manufacturing	1,074
4. Healthcare and social assistance	688
5. Retail trade	622
Chelan County	
1. Agriculture, forestry and fishing	10,267
2. Healthcare and social assistance	5,763
3. Local government	4,959
4. Retail trade	4,505
5. Accommodation and food services	4,310
Douglas County	
1. Agriculture, forestry and fishing	3,030
2. Local government	1,766
3. Retail trade	1,493
4. Accommodation and food services	847
5. Healthcare and social assistance	715
Grant County	
1. Agriculture, forestry and fishing	10,512
2. Local government	6,509
3. Manufacturing	5,085
4. Retail trade	3,285
5. Healthcare and social assistance	2,572
Okanogan County	
1. Agriculture, forestry and fishing	6,124
2. Local government	3,988
3. Retail trade	1,844
4. Healthcare and social assistance	1,472
5. Accommodation and food services	1,155
Franklin County	
1. Agriculture, forestry and fishing	6,730
2. Local government	4,072
3. Manufacturing	3,802
4. Retail trade	3,124
5. Healthcare and social assistance	2,586
Ferry County	
1. Local government	702
2. Retail trade	122
3. Accommodation and food services	112
4. Healthcare and social assistance	85
5. Construction	83

County	Number of Jobs
Lincoln County	
1. Local government	1,161
2. Agriculture, forestry and fishing	294
3. Wholesale trade	284
4. Retail trade	210
5. Healthcare and social assistance	128
Stevens County	
1. Local government	2,279
2. Healthcare and social assistance	1,681
3. Manufacturing	1,218
4. Retail trade	1,154
5. Accommodation and food services	598

Total employment, wage, and number of firms for the basin in 2015 are displayed in **Error! Reference source not found.**, in total and by county. The UCRB had an average of nearly 15,000 firms, providing over $6 billion in wages, for over 167,000 jobs. Average annual wages by county range between $30,000 and $37,000.

Table 6-7: 2015 Basin Industry Employment, Wages, and Firms by County

Area	Avg. Firms	Total 2015 wages paid	Average annual employment	Average annual wage
Adams County	834	$286,003,943	7,838	$36,489
Chelan County	3,339	$1,574,771,696	42,834	$36,765
Douglas County	1,230	$391,785,753	11,527	$33,989
Ferry County	272	$65,633,727	1,754	$37,419
Franklin County	2,619	$1,223,528,965	33,190	$36,864
Grant County	3,138	$1,454,820,537	38,979	$37,323
Lincoln County	535	$95,439,913	2,777	$34,368
Okanogan County	1,829	$552,829,855	18,373	$30,089
Stevens County	1,125	$360,689,375	9,933	$36,312
Total	14,921	$6,005,503,764	167,205	

6.2.3 Fisheries and Habitat

Anadromous species in the UCRB are present in the Okanogan, Methow, Wenatchee, Entiat, and Lake Chelan River basins, and other smaller basins downstream of Grand Coulee Dam. Grand Coulee Dam blocks fish passage into upstream waters. As a result, no anadromous fish populations are found in Northeast Washington upstream of the dam.

Fishery populations

Bull trout, which are listed as threatened under the ESA, are present in the Pend Oreille, Wenatchee, Entiat, and Methow Rivers[160]. The upper Columbia stock of steelhead, also listed as threatened under the ESA, are present in the Methow, Wenatchee, Entiat, and Okanogan River basins and are also found in several smaller tributary streams[161]. The upper Columbia stock of Spring Chinook, listed as Endangered, is present in the Wenatchee, Methow and Entiat River basins[2]. Upper Columbia sockeye, which are not listed under the ESA, are present in the Wenatchee and Okanogan River basins[162]. Upper Columbia summer Chinook, which are also not listed under the ESA, are present in the Methow, Entiat, Okanogan, Lake Chelan, and Wenatchee River basins[163](see Table 6-8). Most of the basins in the UCRB also contain rainbow trout and a variety of other native and, in many cases, non-native fish species.

Table 6-8: Bull trout, salmon, and steelhead presence in the basins within the UCRB

	Bull Trout (threatened)	Steelhead (threatened)	Spring Chinook (endangered)	Summer Chinook (not listed)	Sockeye (not listed)
Pend Oreille	X				
Okanogan		X		X	X
Wenatchee	X	X	X	X	X
Entiat	X	X	X	X	
Methow	X	X	X	X	
Lake Chelan				X	

Harvest rates of bull trout are limited to accidental by catch in local fisheries. Harvest rates of spring Chinook are believed to be less than 10 percent and harvest rates of steelhead are thought to be in the range of 5 to 7 percent[164].

Condition of habitat

Human activities acting in concert with natural occurrences (e.g., floods, drought, fires, wind, etc.) within the UCRB have impacted habitat conditions, primarily on the lower

160 U.S. Fish and Wildlife Service. 2015. Recovery plan for the coterminous United States population of bull trout (Salvelinus confluentus). Portland, Oregon. xii + 179 pages.

161 Upper Columbia Recovery Board. 2007. Upper Columbia spring Chinook and steelhead Recovery Plan NMFS. Portland Oregon. http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/interior_columbia/upper_columbia/uc_plan.pdf.

162 Washington Department of Fish and Wildlife fish inventory maps. https://fortress.wa.gov/dfw/score/score/maps/map_wria.jsp.

163 Washington Department of Fish and Wildlife fish inventory maps. https://fortress.wa.gov/dfw/score/score/maps/map_wria.jsp.

164 NMFS. 2016. 2016 5-year review: Summary & evaluation of upper Columbia River steelhead upper Columbia River spring-run Chinook salmon. NMFS. Portland, OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_upper-columbia.pdf.

reaches of the basins. Habitat within many of the upper reaches of most subbasins is in relatively pristine condition. Water quality and quantity have also been affected by land-use and management activities. Loss of large woody debris and floodplain connectivity have reduced overwinter habitat for salmon, steelhead, and bull trout in the larger rivers (i.e., Wenatchee, Entiat, Methow, and Okanogan rivers). Fish management, including introductions and persistence of non-native species continues to affect habitat in some locations (e.g., presence of brook trout in bull trout habitat)[165]. Significant habitat restoration and protection actions have been implemented to improve degraded habitat conditions and restore fish passage. These efforts are expected to benefit the survival and productivity of the targeted populations, however, evidence demonstrating that improvements in habitat conditions have led to improvements in population abundance and/or productivity is lacking[166].

NMFS' most recent 5-year review[167] identified the following as specific areas of concern:

Wenatchee River:

- Passage conditions and upstream passage delays for adult Chinook salmon and steelhead in the Wenatchee River at Tumwater Dam and for steelhead in Icicle Creek at both the Leavenworth Fish Hatchery and the boulder field.
- Reduced flow levels and/or elevated water temperatures, particularly in Icicle River, Peshastin Creek, Chumstick Creek, and Mission Creek.
- Juvenile rearing habitat in lower tributaries and in the mainstem Wenatchee River that provide complex channel structure, floodplain connectivity, and forage.
- Impairment of tributary habitat-forming processes and functions from upland actions that influence channel structure, complexity, connectivity, and vegetation. Particularly the United States Forest Service (USFS) road network in the Little Wenatchee, Nason, Chiwawa, Icicle, Peshastin, Chumstick, and Mission watersheds.

Entiat:

- Juvenile rearing habitat in lower tributaries and in the mainstem Entiat River that provide complex channel structure, floodplain connectivity, and forage.
- Reduced flow levels and/or elevated water temperatures, particularly in Roaring Creek.

[165] Upper Columbia Recovery Board. 2007. Upper Columbia spring Chinook and steelhead Recovery Plan NMFS. Portland Oregon. http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/interior_columbia/upper_columbia/uc_plan.pdf.

[166] NMFS. 2016. 2016 5-year review: Summary & evaluation of upper Columbia River steelhead upper Columbia River spring-run Chinook salmon. NMFS. Portland, OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_upper-columbia.pdf.

[167] NMFS. 2016. 2016 5-year review: Summary & evaluation of upper Columbia River steelhead upper Columbia River spring-run Chinook salmon. NMFS. Portland, OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_upper-columbia.pdf.

- Impairment of tributary habitat-forming processes and functions from upland actions that influence channel structure, complexity, connectivity, and vegetation. Particularly the USFS road network in the Upper Entiat and Mad River watersheds.

Methow:

- Juvenile rearing habitat in lower tributaries and in the mainstem Methow River that provide complex channel structure, floodplain connectivity, and forage.
- Reduced flow levels and/or elevated water temperatures, particularly in theUpper Methow, Chewuch, Beaver Creek, Early Winters Creek, and Lower Twisp River.
- Impairment of tributary habitat-forming processes and functions from upland actions that influence channel structure, complexity, connectivity, and vegetation. Particularly the USFS road network in the Chewuch River, Twisp River, and Beaver Creeks.
- Livestock related impacts to riparian areas and redd trampling of ESA-listed species in the Chewuch and Twisp watersheds.

Okanogan:

- Reduced flow levels and/or elevated water temperatures, particularly in Salmon Creek, Omak Creek, Johnson Creek, and others.
- Impairment of tributary habitat-forming processes and functions from upland actions that influence channel structure, complexity, connectivity, and vegetation. Particularly the road network in Omak Creek and Salmon Creek watersheds.
- Juvenile rearing habitat in lower tributaries and in the mainstem Okanogan River that provide complex channel structure, floodplain connectivity, and forage.
- The road created passage barrier at river mile 1.7 on Eightmile Creek.

Additional recommended actions identified in the 5-year review include:

- Fisheries co-managers further evaluating the impacts of other hatchery releases (both anadromous and resident) on spring-run Chinook salmon and steelhead.
- Federal and private dam operators further investigating causes of adult losses between hydro facilities by reach (particularly the Columbia River Estuary to Bonneville Dam; Bonneville Dam to McNary Dam; and, McNary Dam to Wells Dam).
- Federal and state management agencies estimating sea lion population (and predation rates on salmonids) in the lower Columbia River.
- Fisheries co-managers improving estimates of catch and release harvest impacts.
- State and Tribal fisheries co-managers using pit tag detection on all harvested fish to better understand the sources of losses in conversion rates and improve the sophistication in harvest management.
- Federal, state, tribal and private entities improving estimates of research, monitoring, and evaluation handling (electrofishing, weirs, catch and release, tagging, marking, trapping, sorting) impacts.

- Federal, state, tribal and private entities identifying contributing factors for lower or greater hatchery fish reproductive success.
- Federal, state, tribal and private entities continuing focus and prioritization of recovery actions on limiting factors.
- Federal, state, tribal and private entities implementing Research Monitoring and Evaluation (RME) actions to address critical uncertainties
- Assess options for restoring access to UCRB steelhead in the Similkameen River above Enloe Dam.
- Improve passage in Icicle Creek for UCRB steelhead past the boulder field in Icicle Creek and the Leavenworth Fish Hatchery
- Assess options for improving passage for steelhead and spring-run Chinook salmon at Tumwater Dam.
- Finalize and implement the Okanogan and Wenatchee National Forest Procedures for Watershed and Aquatic Resource Assessment, Analysis and Proposal Development.
- Manage the proliferation of overwater structures and alteration of mainstem Columbia River shallow water nearshore habitat.
- Through the Hatchery and Genetic Management Plan (HGMP) consultation process, continue implementation of actions to reduce productivity and diversity risk from hatchery programs.
- Implement additional RM&E designed to increase understanding of productivity and diversity risk from hatchery programs.

The majority of these additional recommendations are focused on research, evaluation, and monitoring, reflecting a high degree of uncertainty regarding population size and productivity, harvest rates, hatchery effects, and predation rates.

Trends

In their latest 5-year review, NMFS found that current estimates of natural origin spring Chinook spawner abundance increased relative to the levels observed in the prior review for all three extant populations, and productivities were higher for the Wenatchee and Entiat and unchanged for the Methow[168]. However, abundance and productivity remained well below the viable thresholds called for in the Upper Columbia Recovery Plan for all three populations.

UCRB steelhead populations have increased relative to the low levels observed in the 1990s, but natural origin abundance and productivity remain well below viability thresholds for three out of the four populations[169].

[168] NMFS. 2016. 2016 5-year review: Summary & evaluation of upper Columbia River steelhead upper Columbia River spring-run Chinook salmon. NMFS. Portland, OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_upper-columbia.pdf.

[169] NMFS. 2016. 2016 5-year review: Summary & evaluation of upper Columbia River steelhead upper Columbia River spring-run Chinook salmon. NMFS. Portland, OR.

Climate Change

Climate change in the Pacific Northwest includes rising air temperature, changes in the timing of streamflow related to changing snowmelt, increases in extreme precipitation events, lower summer stream flows, and other changes. Issues include the effects of rising air temperatures and lower summer flows on range reductions; changing stream temperatures, threats to redds and juvenile habitat from stream scouring caused by increased winter precipitation extreme events and increased rain in lower elevations (rather than snow); lower summer flows inhibiting movement between populations and from spawning and rearing habitat to foraging habitat; and increased frequency and extent of wildfires resulting in loss and fragmentation of habitat.[170] Fish populations currently occupying areas of the subbasin with cool water and good streamflow may not be significantly affected, at least in the near term, by climate change. However, populations occupying habitats that are already relatively warm and/or dry (such as the Okanogan River) are likely to have the availability of suitable habitat reduced over time. Projects that help to reduce stream temperature (increased stream shading or, where flows are low, increased stream flow) in these warmer habitats may help to offset the effects of climate change.

6.2.4 Projects and Needs

A list of infrastructure investment projects and needs are grouped into the different investment categories and summarized below. Other projects are likely to exist within each the basin, but the list included in this report is intended to be representative of basin projects.

Water Supply

The UCRB is part of the larger Columbia River Basin, which includes the Snake River, Upper, Middle, and Lower Columbia River Basins. While parts of the Columbia River Basin fall in other states, as well as in Canada, the focus of this discussion is only on the portions located in the State of Washington. The water supply systems in the Columbia River Basin were built to reliably deliver water under historical conditions. However, changes in water supply and demand due to population growth and climate change have the potential to stress the system.

About $34.5 Million of ongoing, planned, and proposed water supply infrastructure projects are identified in the UCRB through research and interviews conducted for this study. Over $17.7 million worth of these are projects related to the Icicle Working Group Integrated Base Package (September 9, 2016) developed for the Icicle Creek Water Resource Management Strategy, of which $7.5 million are proposed for updating Irrigation Comprehensive Plans and funding irrigation efficiency projects. At present, the Icicle Working Group is evaluating project feasibility and conducting environmental review on these projects.

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http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_upper-columbia.pdf.

[170] NMFS. 2016. 2016 5-year review: Summary & evaluation of upper Columbia River steelhead upper Columbia River spring-run Chinook salmon. NMFS. Portland, OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_upper-columbia.pdf.

Another example of a larger proposed project investment in the UCRB is the $10 million for the Little Spokane Water Bank,[171] which is in the state funded appraisal or environmental review stage. Over $4.8 million is also allocated to various projects under the Water System Plans and Capital Improvement Plans (CIPs) of utilities in the Basin, including $2.2 million for the Murray Reservoir extension under the City of Okanogan's Comprehensive Water System Plan.[172]

Flood Protection

No projects or needs identified. There is evidence of some recent flooding in the UCRB, although no infrastructure investment projects have been identified. In 2014, flash floods caused mudslides to cover state Highways 153 and 20 in Okanogan County.

Stormwater Management

In the UCRB, multiple projects are ongoing to address improved stormwater management. The twenty-seven identified in this project total to $8 million in 2017. The largest of these is a $5 million wastewater improvement project in Peshastin/Dryden. Jessica Schwing, the Stormwater Grants Program Coordinator at the Washington Department of Ecology identified 18 projects, predominantly at the county level, to address water quality improvement, TMDLs, non-point source pollution response, and stormwater plan developments. Corina Hayes, the Source Water Protection Manager at the Washington Department of Health identified nine projects, mostly city-level grants to improve water systems, in Okanogan, Oakesdale, Chewelah, Chelan, Oroville, and Moses Lake.

Fisheries and Restoration

Considerable effort has been extended towards addressing uncertainties and improving habitat. As of 2011, the estimated cost for recovery of listed species was estimated at $898 million for the UCRB. The majority of the projects funded are listed on the Habitat Work Schedule website (http://hws.ekosystem.us/home) and the Columbia fish and Wildlife website (https://www.cbfish.org/). Since 2011, $53 million has been expended on projects, leaving an estimated cost for recovery of $845 million over the next 20 years (Table 6-9). Projects are likely to be implemented as funding becomes available.

Generally, the estimated costs of implementing projects summarized in recovery plans did not include an accurate estimate of the costs of replacing culverts to meet current passage standards. Therefore, the costs listed below likely do not include Washington state Department of Transportation's costs of replacing culverts and upgrading passage at stream crossings. The estimated costs below include only those projects listed at the Habitat Work Schedule and the Columbia Fish and Wildlife websites. Other projects likely have been implemented through funding sources that are not tracked by those sites, including projects implemented by the U.S. Forest Service, BLM, and private individuals. Additionally, the recovery plan listed numerous projects for which cost estimates were not available. Therefore, the total estimated cost listed below is likely an underestimate. We also note that

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171 Personal communication with Wendy Valdez, Project Assistant, Aspect Consulting LLC. Email dated October 11, 2016.

172 Personal communication with Jon K. Culp, Water Resources Programs Manager, WA State Conservation Commission, Okanogan WA. Email dated October 13, 2016.

estimates of project costs developed during the recovery planning process were frequently "ball park" estimates and are subject to change once projects go into detailed planning.

Table 6-9 includes estimated costs for recovery as of 2011, funds allocated since 2011, and estimated remaining cost for recovery of upper Columbia steelhead and spring-run Chinook.

Table 6-9: Remaining Fishery and Habitat Need in the UCRB in Millions of Dollars

Project type	Estimated Remaining Costs in 2011[173]	Funds Allocated between 2011 and Present[174]	Estimated Remaining Costs as of the end of 2016
Habitat Restoration	520	45	475
Land and Easement Acquisition	144	6	138
Passage Barrier Retrofits	70	2	68
Total Capital Projects	734	53	682
Non-Capital Projects	164	1	163
Total	898	54	844

6.2.5 Summary of Basin Water Infrastructure and Fisheries and Habitat Needs

The UCRB water infrastructure investment needs by type in total and projected through time is presented in Table 6-10. Total estimated costs in current (2016) dollars is $886 million, with the largest shares for Fisheries and Habitat projects, with $844 million. Nearly one-third of the water supply needs ($35 million) are for one project, Little Spokane Water Bank ($10 million), and more than one-half of the Stormwater needs ($8 million) are for the Peshastin/Dryden Wastewater Improvement Project ($5 million).

- The basin is growing fast in terms of population.
- Water supply is the biggest issue. Dams helped with water supply and irrigation and secondarily there will be longer drier summers. With climate change, the water supply issue is expected to increase.
- Generally, the projects identified to improve fish habitat were not based on a true limiting factors analysis, but rather an evaluation of all the potential pathways that anthropogenic activities could be affecting fish habitat.
- The identified list of fish projects was intended to bring the habitat quality back to historical conditions. No attempt has been made to identify which projects are needed to meet recovery goals. An analysis of the true limiting factor(s) for each basin and

[173] Cantry. 2011. Funding for salmon recovery in Washington state. For the Governor's Salmon Recovery Office and the Council of Regional Salmon Recovery Organizations.

[174] Habitat Work Schedule. Washington State Recreation and Conservation Office and Washington State Governor's Salmon Recovery Office. http://hws.ekosystem.us/home. Columbia Basin Fish and Wildlife Program. https://www.cbfish.org/.

identification of the subset of projects that address the true limiting factors will likely result in a significant reduction in overall expected costs.

- If the limiting factor in a basin is not related to freshwater habitat, none of the projects identified for a particular basin should be considered priority projects. If the limiting factor is related to freshwater habitat, the priority projects would include those that address that limiting factor.

Table 6-10: UCRB Water Infrastructure Investment Needs Projection by Type

	Millions of Dollars								
Investment Type	**Total**	**2017**	**2018**	**2019**	**2020**	**2025**	**2030**	**2035**	**2036**
Water supply	$35	$18	$1	$1	$1	$1	$1	$1	$1
Stormwater	$8	$8	-	-	-	-	-	-	-
Flooding	-	-	-	-	-	-	-	-	-
Fish & habitat	$844	$42	$42	$42	$42	$42	$42	$42	$42
Multiple	-	-	-	-	-	-	-	-	-
Total	$886	$68	$43	$43	$43	$43	$43	$43	$43

6.3 Middle Columbia River Basin

The Middle Columbia River Basin (MCRB) is located in southern Washington along the border with Oregon. There are no large cities within the basin, though the basin runs close to the city of Kennewick (counted as part of the UCRB for the purpose of this report due to the Franklin County boundary) to the north and Hermiston (Oregon) to the south.

The predominant rivers include the Columbia, the Klickitat River, the White Salmon River, and the Walla Walla River. Highway 97 in Washington runs adjacent to the Columbia River. A map of the MCRB is provided in Figure 6-2 below. This analysis includes just the Washington state portion of the MCRB, and not the Oregon portion.

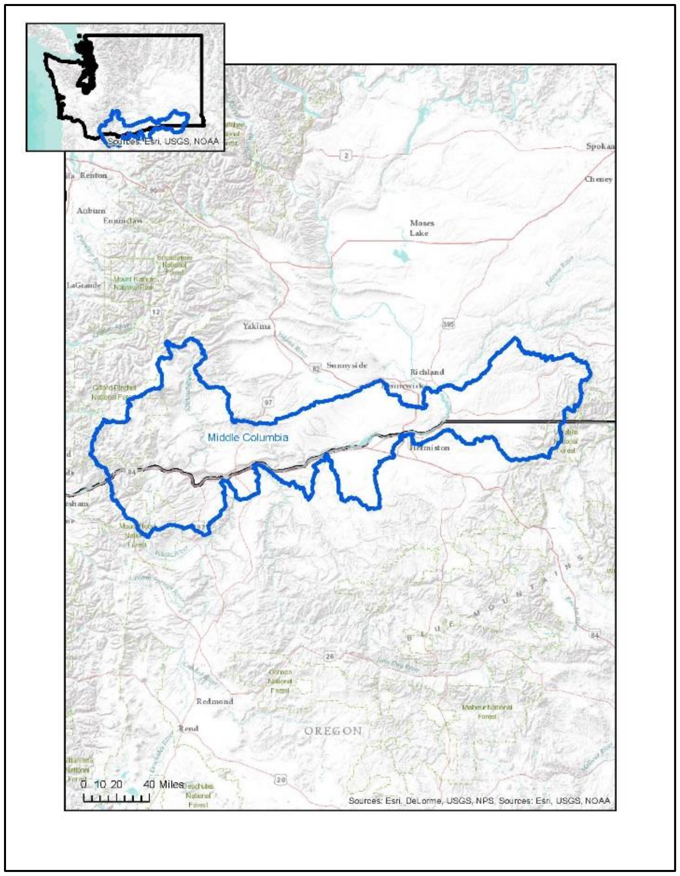

Figure 6-2: Map of Middle Columbia River Basin.

6.3.2 Hydrology

The Columbia River Basin is the fourth largest watershed in North America in terms of average annual flow. Significant parts of the basin lie in Oregon, Idaho, Montana, and British Columbia. The MCRB portion of the Columbia River Basin lies in southern Washington, downstream of the confluence with the Yakima River and upstream of Bonneville Dam, along the border with Oregon. The variation of precipitation and temperature from year to year, combined with geographic complexity of the basin, results in highly variable river flows. This is a low-lying basin and the river flow is mostly affected by rain runoff and Columbia River flow regulation at major dams in the area. However, the majority of the runoff is influenced by Columbia River inflows from the UCRB. The western side of the subbasin supports ponderosa pine and Oregon oak forests. The eastern portion of the subbasin is drier and supports only scattered trees.

Existing Water Infrastructure

The major infrastructure in the MCRB are Columbia River dams at Dalles (run-of-the river dam use for hydropower with minimum water storage), John Day (run-of-the-river dam built for hydropower with minimum water storage) and McNary (also built for hydropower with incidental use for recreation and irrigation), and Mill Creek water storage reservoir on the Walla Walla River. The Mill Creek dam and adjacent Bennington Lake water storage, constructed and maintained by the Corp of Engineers, is the only off-channel flood mitigation project, as it uses Bennington Lake to divert flood during major flood events. The lake has been also used for recreation. Additional supporting infrastructure includes irrigation canals (and features supporting orchards and plantations immediately adjacent to the River), navigation locks, and river port facilities. Other infrastructure includes wastewater treatment plants, storm-drain/sewage systems, water distribution networks, and several water supply reservoirs.

Flood History

The historic floods in the MCRB are summarized:

- **June 1894 Flood**, when heavy precipitation throughout the basin led to heavy snowpack. This was followed by a dry, warm spring resulting in massive snowmelt.
- **May 1948 Flood**, when heavy precipitation throughout the basin led to heavy snowpack. Early spring had little precipitation and few warm days. May brought warm temperatures and heavy rainfall, resulting in heavy snowmelt causing flooding throughout the basin.
- **June 1956 Flood**, - persistent heavy precipitation started in October of 1955 through February of 1956, Heavy rainfall in the MCRB continued through March. Snowpack started accumulating before the end of October and by springtime was much more than usual. Warmer temperatures in late spring augmented the snowmelt.
- During the historic floods of 1948 and 1956 regulators had to release flows through the dams downstream once the water level exceeded the maximum design water level at each dam.

Although there have been no recent major floods in the MCRB, there has been an increasing trend towards more extreme rainfall events occurring during the winter.

Drought History

The Columbia River Basin has been subjected to numerous historic droughts. The following historic droughts were identified (using tree-ring methodology[175]):

- Multi-year drought: 1840 – 1855 – most severe and persistent drought on the record,
- Multi-year droughts 1790-1800, 1840s, 1870s,
- 1-year droughts in 1775, 1805, and 1925,
- 1890s and 1930s – periods of extremely low flows in the river.
- Shorter droughts 1976-78, and 2000-2004[176]
- Single year drought 2014- 2015

[175] Gedalof, Peterson, and Mantua, Columbia River Flow and Drought since 1750, in Journal of the American Water Resources Association, December 2004, Paper No. 03073, pp. 1- 14.

[176] Xiao, M., Nijsenn, B., and Lettenmaier, Drought in the Pacific Northwest, 1920-2013, Journal of Hydrometeorology, American Meteorological Society, Volume 17, No. 12, September 2016, http://journals.ametsoc.org/doi/full/10.1175/JHM-D-15-0142.1.

There has not been any significant trend/pattern towards droughts during the 20th century (see below). However, there has been possible increasing trend towards drier summers with lower streamflows.

The droughts in 1840s and 1930s coincide with recorded and recognized drought on the Great Plains indicating that the drought was widespread in and out of the basin. In general, the 20th century had fewer droughts in the basin than in earlier centuries. The most recent drought in the basin (and throughout Eastern Washington) occurred in 2014-15. At the peak of the drought (mid-summer 2015), Columbia River flows were 50 to 60 percent below normal. A statewide drought was declared May 15, 2015. Drought conditions in the basin are summarized weekly in the *U.S. Drought Monitor*, a collaborative effort between Federal and academic partners, including the University of Nebraska-Lincoln, the USDA, and NOAA[177].

Hydrologic Trends

The following trends in hydrology have been documented from the late 19th century through today[178]:

- There has been a steady increase in the basin-wide mean annual temperature from the 1890s to 1930s, and then again from the 1980s through 2000s;
- Mean annual precipitation in the basin has remained unchanged (no trend to increase or decrease); however, there has been a regional trend of increasing precipitation during the wet season and, specifically, increases in extreme precipitation events;
- There has been general decline in spring snowmelt (mostly as a result of increases in temperature, and more precipitation falling as rain than snow in winter)[179];
- There is a possible trend of reduced annual streamflow during dry years[180].

Statistical analysis of these trends conducted by the Bureau of Reclamation and others could not determine whether the trends are caused by natural climate variability or by anthropogenic influence.

Climate Change

The US Department of interior Bureau of Reclamation[181] has identified the following climate challenges:

- Temperatures in the basin may increase by 6-7 degrees throughout the 21st century. The greatest temperature increase is projected to occur in the summer.

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177 http://www.usda.gov/oce/weather/Drought/

178 US Dept. of Interior, Bureau of Reclamation, Managing Water in the West, Secure Water Act Section 9503(c), Reclamation, Climate Change and Water, 2011.

179 Knowles, N., Dettinger, M., and Cayan, D., 2007. Trends in Snowfall versus Rainfall for the Western United States 1949-2001. Prepared for California Energy Commission Public Interest Research Program, Project Report CEC-500-2007-032.

180 Luce, C. H, and Holden, Z.A., 2009. Declining Annual Streamflow Distribution in the Pacific Northwest United States, 1948-2006. Geophysical Research Letters, Vol 36, L16401, doi:10.1029/2009GL039407.

181 Reclamation, Managing Water in the West, Secure Water Act Section 9503(c), Reclamation, Climate Change and Water, 2011.

- Precipitation projections are less certain, but all models agree about potentially drier summers and wetter fall and winters. The average annual precipitation may increase 6.9 to 7.2 percent by 2050.
- Decreased snowpack could result in decreased groundwater infiltration, runoff, and lower river baseflows in summer. Rising temperatures will also cause earlier snowmelt in many sub-basins resulting in lack of water during spring and summer seasons.
- Mean annual runoff is projected to increase by 1.2 to 3.7 percent by 2050.
- Moisture falling as rain instead of snow at lower elevations will increase winter runoff and decrease summer runoff.
- Frequency of reduced annual streamflows could double by 2045, resulting in longer and drier summers (which could result in an accompanying drought).

6.3.3 Economy

The counties that are included in the economic analysis for the Middle Columbia basin are Columbia, Klickitat, Skamania, and Walla Walla counties. Within these counties, the largest notable cities are Dayton and Walla Walla. The primary industries, based on employment, of the counties within the basin include agriculture, forestry and fishing, health and social services, government, and manufacturing.

The current (2015) population from census estimates and the most recent county population forecast from OFM are presented in Table 6-11 by county and for the total basin. The total basin population is expected to grow from 95,939 (1.3 percent of Washington's population) in 2015 to 104,788 (1.2 percent of the state population) in 2036. Currently, over 60 percent of that population is in Walla Walla County alone (60,338). That share is expected to remain constant over the projection period.

Table 6-11: OFM Population Projections for MCRB

	2015	2017	2018	2019	2020	2025	2030	2035	2036
Washington	7,170,351	7,178,675	7,256,835	7,334,646	7,411,977	7,793,173	8,154,193	8,483,628	8,546,278
Columbia	3,944	4,034	4,028	4,021	4,013	3,968	3,895	3,800	3,781
Klickitat	20,318	20,743	20,815	20,881	20,943	21,225	21,430	21,492	21,487
Skamania	11,339	11,383	11,438	11,493	11,548	12,014	12,447	12,816	12,872
Walla Walla	60,338	60,690	61,031	61,363	61,685	63,368	64,978	66,378	66,648
Total Basin	95,939	96,850	97,312	97,758	98,189	100,575	102,750	104,486	104,788

The economic sector breakdown by employment for the largest industry sectors in the basin's counties is provided in Table 6-12. Manufacturing and healthcare and social assistance are the largest industry sectors in terms of employment within the basin, each providing nearly 5,000 jobs. Local government and agriculture, forestry, fishing, and hunting are also strong employment industries within the basin, providing 4,634 and 3,636 jobs respectively, the majority of them in Walla Walla County (2,407 and 3,520 respectively).

Table 6-12: County Employment by Largest Economic Sectors

County	Number of Jobs
Columbia County	
1. Local government	382
2. Ag., forestry, fishing and hunting	147
3. Construction	100
4. Accommodation and food services	100
5. Retail trade	87
Skamania	
1. Accommodation and food services	561
2. Local government	451
3. Manufacturing	277
4. Healthcare and social assistance	157
5. Retail trade	131
Walla Walla County	
1. Healthcare and social assistance	4,380
2. Manufacturing	3,520
3. Ag., forestry, fishing and hunting	3,489
4. Local government	2,407
5. Retail trade	2,310
Klickitat County	
1. Local government	1,394
2. Manufacturing	1,142
3. Retail trade	351
4. Healthcare and social assistance	334
5. Accommodation and food services	315

Total employment, wage, and number of firms for the basin in 2015 are displayed in Table 6-13, in total and by county. The Middle Columbia Basin had an average of nearly 3,400 firms, providing over $1.5 billion in wages, for over 37,000 jobs. Average annual wages by county range between $34,000 and $44,000.

Table 6-13: 2015 Basin Industry Employment, Wages, and Firms by County

Area	Avg. Firms	Total 2015 wages paid	Average annual employment	Average annual wage
Columbia County	240	$47,797,513	1,268	$37,695
Klickitat County	753	$307,817,448	6,964	$44,201
Skamania County	257	$74,249,848	2,134	$34,794
Walla Walla County	2,121	$1,077,731,108	26,795	$40,221
Total Basin	3,371	$ 1,507,595,917	37,161	

6.3.4 Fisheries and Habitat

The MCRB includes the Esquatzel Coulee, Rock-Glade, Klickitat, Lower and Upper Crab, and Wind-White Salmon WRIAs. No salmon or steelhead are present in the Lower and Upper Crab WRIAs[182]. Condit Dam formerly blocked passage into the White Salmon River basin. As a result, coho and chum salmon were extirpated from the basin. Chinook were present in the White Salmon, but were limited to the reach downstream of the dam in the lower river. Removal of Condit Dam was completed in 2012 providing access to 16.9 miles of habitat for salmon and steelhead that had been blocked for over 100 years. Recolonization of extirpated species is relying upon natural straying of area stocks into the White Salmon. Coho and Steelhead have been documented in the river since the dam was removed[183]. Note, recovery of the White Salmon population of steelhead is not required to attain ESA recovery.

Fishery populations

ESA listed species in the MCRB include bull trout, the Middle Columbia River stock of steelhead, the lower Columbia River stock of spring Chinook salmon, the Columbia River stock of coho salmon, and the Columbia River stock of chum salmon (Table 6-14). The Middle Columbia stocks of spring and fall Chinook are also present in some of the basins. Middle Columbia Chinook are not listed under the ESA.

Harvest rates of bull trout are limited to accidental by catch in local fisheries. Harvest rates of middle Columbia River steelhead are believed to be less than 10 percent[184].

Condition of habitat

Human activities acting in concert with natural occurrences (e.g., floods, drought, fires, wind, etc.) within the MCRB have impacted habitat conditions, primarily on the lower reaches of some of the basins. Habitat within many of the upper and middle reaches of most subbasins is in relatively pristine condition. Habitat within the Rock-Glade basin has been determined to be near pristine; the low flows and high water temperatures that affect survival of steelhead are apparently naturally occurring. The Rock-Glade basin may be a net "sink" for steelhead. Steelhead spawn within the river, but the offspring are stranded in warm pools in most summers, where they eventually die. Therefore, the basin does not appear to contribute to the overall productivity of the Middle Columbia River steelhead population. The primary anthropogenic factor affecting the Klickitat is likely sediment introduced by roads; however, fine sediments are not a significant problem in the basin. As was mentioned earlier, Condit Dam in the White Salmon basin was removed in 2012. The habitat upstream of the former dam location will recover over time, but it will take decades for that habitat to become fully restored. Within the Walla Walla/Umatilla basin, the

182 Washington Department of Fish and Wildlife fish distribution webpage. https://fortress.wa.gov/dfw/score/score/maps/map_wria.jsp.

183 NMFS. 2016. 2016 5-year review: summary and evaluation of middle Columbia River steelhead. NMFS. Portland, OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_middle-columbia.pdf.

184 NMFS. 2016. 2016 5-year review: summary and evaluation of middle Columbia River steelhead. NMFS. Portland, OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_middle-columbia.pdf.

Table 6-14: Bull trout, salmon, and steelhead presence in the basins within the MCRB[185].

	Bull Trout (threatened)	Middle Columbia Steelhead (threatened)	Middle Columbia Spring Chinook (not listed)	Lower Columbia Spring Chinook (threatened)	Columbia River Coho (threatened)	Middle Columbia Fall Chinook (not listed)	Lower Columbia Fall Chinook (threatened)	Columbia River Chum (threatened)
Esquatzel Coulee						X		
Walla Walla	X	X						
Rock-Glade		X						
Klickitat	X	X	X		X (hatchery origin – not included in listing)	X		
Wind-White Salmon	X	X (extinct, recolonizing)	X (extinct)	X (extinct)	X (extinct, recolonizing)	X	X	X (functionally extinct)

highest priorities are passage at major barriers (Bennington Dam, Mill Creek flood control channel, and Nursery Bridge), low flow, and water temperature.

Significant habitat restoration and protection actions have been implemented to improve degraded habitat conditions and restore fish passage. These efforts expected to benefit the survival and productivity of the targeted populations, however, evidence demonstrating that improvements in habitat conditions have led to improvements in population abundance and/or productivity is lacking.

NMFS' most recent 5-year reviews[186] identified the following as specific areas of concern:

- Walla Walla/Umatilla: The highest priorities are passage at major barriers
- (Bennington Dam, Mill Creek flood control channel, and Nursery Bridge), low flow and water temperature.
- Rock Glade: None.

[185] Washington Department of Fish and Wildlife fish distribution webpage. https://fortress.wa.gov/dfw/score/score/maps/map_wria.jsp.

NMFS. 2016. 2016 5-year review: summary and evaluation of middle Columbia River steelhead. NMFS. Portland, OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_middle-columbia.pdf.

[186] NMFS. 2016. 2016 5-year review: summary and evaluation of middle Columbia River steelhead. NMFS. Portland, OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_middle-columbia.pdf. NMFS. 2016. 5-year review: lower Columbia River Chinook salmon, Columbia River chum salmon, lower Columbia River coho salmon, lower Columbia River steelhead. NMFS. Portland OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_lower-columbia.pdf,

- Klickitat: None.
- White Salmon: None.

Other recommendations provided by NMFS in their 5-year reviews include:

- Continue ACOE and fisheries co-managers' implementation of flow and passage improvements in the Umatilla, Walla Walla and Touchet Rivers – specifically Bennington Dam, Mill Creek channel, and Nursery Bridge.
- Implement priority actions identified in the recovery plan (NMFS 2009b) that will reduce water temperature.
- Implement key habitat status/trends and habitat restoration effectiveness monitoring to address key habitat status and trends and habitat restoration effectiveness.
- Implement a comprehensive research and monitoring program to address population abundance and survival, success of implemented recovery actions, and basic understandings of the factors limiting fish production in the subbasin.
- Continue to implement projects/programs aimed at upgrading irrigation intakes and conserving water to increase flows for fish in the Umatilla/Walla Walla basin.
- Continue to work with the ACOE and fisheries co-managers in the implementation of flow and passage improvements in the Umatilla, Walla Walla and Touchet Rivers.
- Encourage management of forests to restore natural species and tree density toward reducing the intensity and frequency of wildfires and subsequent impacts of fire on fish habitat.
- Encourage state and tribal fisheries co-managers evaluate MCRB overshoot phenomenon (fish overshooting their natal stream and moving upstream of dams) and develop management actions to address the issue.

Trends

Steelhead abundance has generally increased over the last 5 years in the Walla Walla basin[187] but does not meet the targeted abundance for recovery. Only seven years of data are available for the Klickitat River steelhead abundance. The Klickitat steelhead population abundance has been near or above the targeted abundance. The lower Columbia Chinook, chum, and coho salmon are only present in the White Salmon basin and all but the Chinook are functionally extinct in that basin. See the discussion under the Lower Columbia Subbasin for further discussion of trends in those populations.

Climate Change

Trends in warming and ocean acidification are highly likely to continue during the next century. In winter across the west, the highest elevations will shift from consistent longer (>5 months) snow-dominated winters to a shorter period (3-4 months) of reliable

[187] Northwest Fisheries Science Center. 2015. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest.

snowfall[188]. Watersheds will experience more intense precipitation events with possible shifts in the timing of the most intense rainfall. Warmer summer air temperatures will increase both evaporation and direct heading. When combined with reduced winter water storage, warmer summer air temperatures will lead to lower minimum flows in many basins.

Studies examining the effects of long term climate change to salmon populations have identified a number of ways that climate change is likely to influence salmon sustainability. These include direct effects of temperature such as mortality from heat stress, changes in growth and development rates, reduced habitat availability due to lower flows and higher water temperatures, reduced disease resistance, and shifts in seasonal timing of important life history events, such as the adult migration, spawn timing, fry emergence timing, and the juvenile migration. Fish populations currently occupying areas of the subbasin with cool water and good streamflow, such as the headwaters of the Klickitat River, may not be significantly affected, at least in the near term, by climate change. However, populations occupying habitats that are already relatively warm and/or dry (such as the Walla Walla River) are likely to have the availability of suitable habitat reduced over time. Projects that help to reduce stream temperature (increased stream shading or, where flows are low, increased stream flow) in these warmer habitats may help to offset the effects of climate change.

6.3.5 Projects and Needs

A list of infrastructure investment projects and needs are grouped into the different investment categories and summarized below. Other projects are likely to exist within each the basin, but the list included in this report is intended to be representative of basin projects.

Water Supply

Close to $1 Billion worth of ongoing, planned, and proposed projects are identified in the MCRB through research done as part of this effort. About $309 Million are associated with three proposed water storage projects being considered by Klickitat County.[189] The Legislature put funding in the 2016/17 capital budget for continued work on $280 Million[190] proposed Switzler Canyon water storage project, and Klickitat County is working with the Office of Columbia River on the necessary grant amendment. This project is one of 3 storage projects that comprise the preferred option for developing water supplies in WRIA 31. Another one of these storage projects, Spring Creek project, is a $3.5 Million[191]

188 NMFS. 2016. 2016 5-year review: summary and evaluation of middle Columbia River steelhead. NMFS. Portland, OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_middle-columbia.pdf. NMFS. 2016. 5-year review: lower Columbia River Chinook salmon, Columbia River chum salmon, lower Columbia River coho salmon, lower Columbia River steelhead. NMFS. Portland OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_lower-columbia.pdf.

189 Personal communication with Dave McClure, Director, Klickitat County Natural Resources Department. Emails dated September 28, 2016.

190 Personal communication with Wendy Valdez, Project Assistant, Aspect Consulting LLC. Email dated October 11, 2016.

191 Personal communication with Wendy Valdez, Project Assistant, Aspect Consulting LLC. Email dated October 11, 2016.

proposed water storage project in an ephemeral tributary basin to Spring Creek. Klickitat County considers the project worth pursuing, but is studying further a couple of subbasins in the upper portion of the Little Klickitat that have greater capacity.[192]

Other major projects identified in the MCRB is the $400 Million Walla Walla Integrated Flow Study and the $10 Million White Salmon Source Improvement Project.[193] The MCRB had a long history of land use and agriculture. Desk research and stakeholder outreach efforts conducted for this study identified a little over $73.1 Million in other ongoing, planned, and proposed projects in the MCRB over the next 14 years. These include about $54.6 Million worth of projects under the CIPs in the area, including the City of Kennewick CIP. In addition, about $9 Million are for the proposed Othello Treatment Plant and ASR, while another $5 Million for the proposed Mission Creek Improvement Project.[194] Both of these projects are in the state funded appraisal or environmental review stage.

Flood Protection

No projects or needs identified.

Stormwater Management

In the MCRB, only two project costs were identified for 2017: a $79,567 stormwater system plan for College Place, and a $92,546 water quality implementation project for WRIA 29. Five other stormwater improvement planning projects were identified for the MCRB, but no costs were estimated.

Fisheries and Restoration

Considerable effort has been extended towards addressing uncertainties and improving habitat. As of 2011, the estimated cost for recovery of listed species was estimated at $524 million for the MCRB and Yakima Subbasins[195]. The overwhelming majority of these costs are associated with projects within the Yakima Subbasin. The majority of the projects funded are listed on the Habitat Work Schedule website (http://hws.ekosystem.us/home) and the Columbia fish and Wildlife website (https://www.cbfish.org/). Since 2011, $8.3 million has been expended on projects in the MCRB (excludes the Yakima Subbasin). Cantry (2011) included the Yakima Subbasin in the estimates for the Middle Columbia Subbasin. We were not able to separate the total expected costs as of 2011 for the Yakima and MCRB, therefore, an estimated cost for recovery for the MCRB without the Yakima Subbasin could not be developed.

6.3.6 Summary of Basin Water Infrastructure and Fisheries and Habitat Needs

MCRB water infrastructure investment needs by type in total and projected through time is presented in Table 6-15. Total estimated costs in current (2016) dollars is $771 million, with

192 Personal communication with Dave McClure, Director, Klickitat County Natural Resources Department. Emails dated September 28, 2016.

193 Personal communication with Wendy Valdez, Project Assistant, Aspect Consulting LLC. Email dated October 11, 2016.

194 Personal communication with Wendy Valdez, Project Assistant, Aspect Consulting LLC. Email dated October 11, 2016.

195 Cantry. 2011. Funding for salmon recovery in Washington state. for the Governor's Salmon Recovery Office and the Council of Regional Salmon Recovery Organizations.

the majority of the costs ($766) allocated to water supply projects. The MCRB does have fisheries and habitat projects, but they are consolidated with the Yakima basin fisheries projects, and as such are included in the Yakima basin discussion and presentation.

- See Yakima for some of the fisheries numbers
- Water supply biggest issue – impacts from drought (longer periods of low flow in summer) Klickitat has 3-4 supply projects.

Table 6-15: MCRB Water Infrastructure Investment Needs Projection by Type

	Millions of Dollars								
Investment Type	**Total**	**2017**	**2018**	**2019**	**2020**	**2025**	**2030**	**2035**	**2036**
Water supply	$766	$736	$4	$4	$4	$2	-	-	-
Stormwater	-	-	-	-	-	-	-	-	-
Flooding	-	-	-	-	-	-	-	-	-
Fish & habitat	-	-	-	-	-	-	-	-	-
Multiple	$5	$5	-	-	-	-	-	-	-
Total	$771	$741	$4	$4	$4	$2	-	-	-

6.4 Lower Columbia River Basin

The Lower Columbia River Basin (LCRB) is located in southwest Washington, extending from the Bonneville Dam to the Pacific Coast. Although the subbasin extends into Oregon, only the areas within the state of Washington are included in this analysis. Within Washington, the Gifford-Pinchot National forest lies within the basin, as do the cities of Longview, Battle Ground, and Vancouver. The predominant river in the basin is the Columbia River. The larger tributaries in the basin include the Cowlitz, Toutle, Lewis, and Washougal Rivers. Major highways include Interstate 5 and Highway 97 which borders the Columbia River in southern Washington. The basin is shown in Figure 6-3.

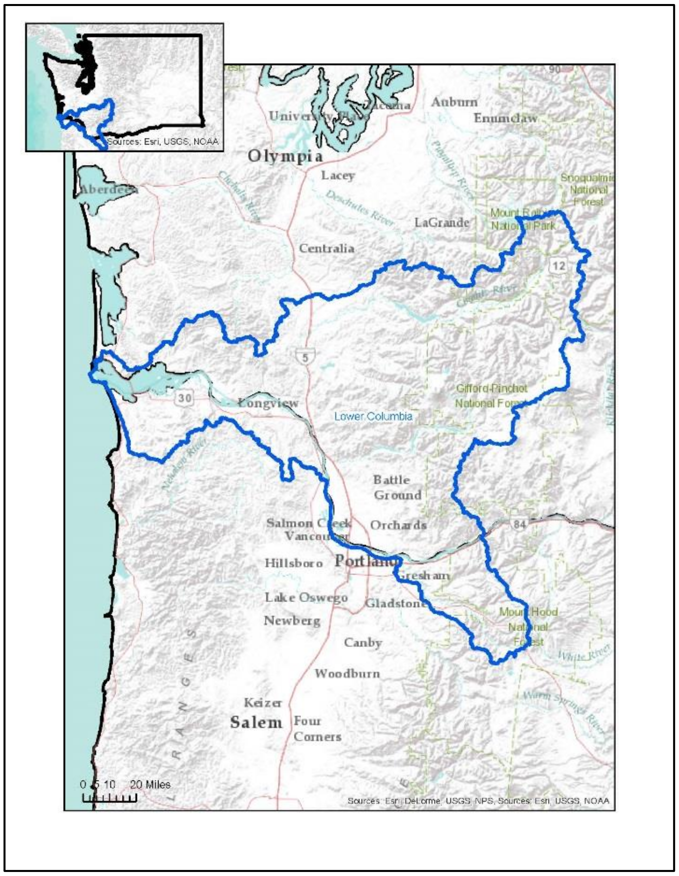

Figure 6-3: Map of Lower Columbia River Basin

6.4.2 Hydrology

The Columbia River Basin is the fourth largest watershed in North America in terms of average annual flow. Significant parts of the basin lie in Oregon, Idaho, Montana, and British Columbia. The LCRB part of the Columbia River Basin contains tributary watersheds in Oregon and Washington downstream of Bonneville Dam. The variation of precipitation and temperature from year to year, combined with the geographic complexity of the basin, results in highly variable river flows. Surface water flows are highly dominated by the cycle of snow accumulation and melting, with peak river flows occurring in late spring and early summer (coinciding with the peak of snowmelt) or with rain-on-snow flood events as documented by several major historic floods in the basin.

Existing Water Infrastructure

The major infrastructure in the LCRB includes Bonneville Dam, which was built to provide hydropower (and its water storage potential for hydropower, recreation, and occasional irrigation water supply). The Bonneville Dam consists of two run-of-the-river dam structures and a navigation lock. Additional supporting infrastructure includes irrigation canals, navigation locks, and river port facilities. Other infrastructure in the basin includes wastewater treatment plants, storm-drain/sewage systems, water distribution networks, several water supply reservoirs, and a sediment retention dam on the North Fork of the Toutle River.

Flood History

In addition to the 1894, 1948, and 1956 flood events, the LCRB experienced additional floods caused by snowmelt/flooding in the Willamette Valley watershed:

- **February 1890 Flood**, when heavy precipitation was followed by heavy snowmelt in the Willamette Valley.
- **May/June 1948 - Greatest Spring Snowmelt Flooding.** This flood lasted 45 days, causing widespread flooding in northern Idaho, eastern Washington and along the Columbia River to the Pacific Ocean. Columbia River below Priest Rapids reached the Flood of Record 458.65 FT (FS 432.0 FT). May 30th 1948 is also known as the Vanport Flood, when America's largest war-time housing project was wiped out in less than one hour as dikes along the Columbia River near Portland gave way. Vanport was not rebuilt and is now the Delta Park area of north Portland. Ports of Vancouver, Camas, Kalama, Kelso and Longview also suffered from flooding.
- **December 1964 Flood,** when unusually cold weather in early December was followed by heavy snowfall. This was flowed by persistent heavy rains later in the month, causing "rain on snow floods" throughout Oregon, southern Washington and throughout the LCRB.
- **February 1996 Flood** – this season had heavy precipitation and warmer temperatures earlier throughout the region, causing heavy rainfall and snowmelt, and massive flooding in the region.
- During the historic floods of 1948, 1956, 1964, and 1996, regulators had to release flows through Bonneville Dam and other upstream dams once the water level exceeded the maximum design water level at each dam.

Drought History

The Columbia River Basin has been subjected to numerous historic droughts. The following historic droughts were identified (using tree-ring methodology[196]):

- Multi-year drought: 1840 – 1855 – most severe and persistent drought on the record,
- Multi-year droughts 1790-1800, 1840s, 1870s,
- 1-year droughts in 1775, 1805, and 1925,
- 1890s and 1930s – periods of extremely low flows in the river.
- Shorter droughts 1976-78, and 2000-2004[197]
- Single year drought 2014- 2015

The droughts in 1840s and 1930s coincide with recorded and recognized drought on the Great Plains indicating that the drought was widespread across the United States. In

[196] Gedalof, Peterson, and Mantua, Columbia River Flow and Drought since 1750, in Journal of the American Water Resources Association, December 2004, Paper No. 03073, pp. 1- 14.

[197] Xiao, M., Nijsenn, B., and Lettenmaier, Drought in the Pacific Northwest, 1920-2013, Journal of Hydrometeorology, American Meteorological Society, Volume 17, No. 12, September 2016, http://journals.ametsoc.org/doi/full/10.1175/JHM-D-15-0142.1.

general, the 20th century had fewer droughts in the LCRB than in earlier centuries. The most recent drought in the basin (and throughout eastern Washington as well) occurred in 2014-15. At the peak of the drought (mid-summer 2015), Columbia River flows were 50 to 60 percent below normal. A statewide drought was declared May 15, 2015. Drought conditions in the basin are summarized weekly in the *U.S. Drought Monitor*, a collaborative effort between Federal and academic partners, including the University of Nebraska-Lincoln, the USDA, and NOAA[198].

Hydrologic Trends

The following trends in hydrology have been documented from the late 19th century through today[199]:

- There has been a steady increase in the basin-wide mean annual temperature from the 1890s to 1930s, and then again from the 1980s through 2000s;
- Mean annual precipitation in the basin has remained unchanged (no trend to increase or decrease); however, there has been a regional trend of increasing precipitation during the wet season and, specifically, an increase in extreme precipitation events;
- There has been general decline in spring snowmelt (mostly as a result of increases in temperature, and more precipitation falling as rain than snow in the winter)[200];
- There is a possible trend of reduced annual streamflow during dry years[201].

Statistical analysis of these trends conducted by the Bureau of Reclamation and others could not determine whether the trends are caused by natural climate variability or by anthropogenic influence.

Climate Change

The US Dept. of interior Bureau of Reclamation[202] has identified the following climate challenges:

- Temperatures in the basin may increase by 6-7 degrees throughout the 21st century. The greatest temperature increase is projected to occur in the summer.
- Precipitation projections are less certain, but all models agree about potentially drier summers and wetter fall and winters. The average annual precipitation may increase 6.9 to 7.2 percent by 2050.

198 http://www.usda.gov/oce/weather/Drought/ and http://droughtmonitor.unl.edu/Home/StateDroughtMonitor.aspx?WA

199 US Dept. of Interior, Bureau of Reclamation, Managing Water in the West, Secure Water Act Section 9503(c), Reclamation, Climate Change and Water, 2011.

200 Knowles, N., Dettinger, M., and Cayan, D., 2007. Trends in Snowfall versus Rainfall for the Western United States 1949-2001. Prepared for California Energy Commission Public Interest Research Program, Project Report CEC-500-2007-032.

201 Luce, C. H, and Holden, Z.A., 2009. Declining Annual Streamflow Distribution in the Pacific Northwest United States, 1948-2006. Geophysical Research Letters, Vol 36, L16401, doi:10.1029/2009GL039407.

202 Reclamation, Managing Water in the West, Secure Water Act Section 9503(c), Reclamation, Climate Change and Water, 2011.

- Decreased snowpack could result in decreased groundwater infiltration, runoff, and lower river baseflows in summer. Rising temperatures will also cause earlier snowmelt in many subbasins resulting in lack of water during spring and summer seasons.
- Mean annual runoff is projected to increase by 1.2 to 3.7 percent by 2050.
- Moisture falling as rain instead of snow at lower elevations will increase winter runoff and decrease summer runoff.
- Frequency of low flows (and droughts) could double by 2045.

6.4.3 Economy

The counties that are included in the economic analysis for the LCRB are Clark, Cowlitz, Wahkiakum counties. Within these counties, the largest notable cities are Vancouver and Longview. The primary industries, based on employment, of the counties within the basin include Healthcare and social assistance, Professional & Business Services, local government, manufacturing and logging.

The current (2015) population from census estimates and the most recent county population forecast from OFM are presented in Table 6-16 by county and for the total basin. The total basin population is expected to grow from 551,122 (7.8 percent of Washington's population) in 2015 to 686,620 (8.3 percent of the state population) in 2036. Currently, over 80 percent of that population is in Clark County alone (442,800). That share is expected to increase to 83 percent (566,865) by 2036.

Table 6-16: OFM Population Projections for the LCRB

	2015	2017	2018	2019	2020	2025	2030	2035	2036
Washington	7,170,351	7,178,675	7,256,835	7,334,646	7,411,977	7,793,173	8,154,193	8,483,628	8,546,278
Clark	442,800	459,548	465,638	471,753	477,884	508,124	536,717	562,207	566,865
Cowlitz	104,280	106,534	107,239	107,924	108,588	111,706	114,158	115,798	116,047
Wahkiakum	4,042	3,909	3,899	3,889	3,877	3,830	3,772	3,716	3,708
Total Basin	551,122	569,991	576,776	583,566	590,349	623,660	654,647	681,721	686,620

The economic sector breakdown by employment for the largest industry sectors in the basin's counties is provided in Table 6-17. Healthcare and social assistance is significantly the largest employment sector for the three counties, although it is only in the top five industries in Clark and Cowlitz counties (24,500 and 2,300 respectively). Manufacturing is significant in all three counties (13,100, 6,500, and 50 for Clark, Cowlitz, and Wahkiakum counties respectively). Professional and business services is the second largest sector in Clark County, providing 18,300 jobs.

Table 6-17: 2015 County Employment by Largest Economic Sectors

County	Number of Jobs
Clark County	
1. Healthcare and social assistance	24,500
2. Professional & Business Services	18,300
3. Retail trade	17,200
4. Leisure & Hospitality	14,200
5. Manufacturing	13,100
Cowlitz County	
1. Manufacturing	6,500
2. Leisure & Hospitality	3,800
3. Construction	2,400
4. Healthcare and social assistance	2,300
5. Financial Services	1,400
Wahkiakum County	
1. Local government	260
2. Logging	100
3. Construction	60
4. Trade, Transportation & utilities	60
5. Manufacturing	50

Total employment, wage, and number of firms for the basin in 2015 are displayed in Table 6-18, in total and by county. The LCRB has an average of over 16,000 firms, providing over $8.6 billion in wages, for over 182,000 jobs. Average annual wages by county range between $34,000 in Wahkiakum County and $47,000 in Clark County.

Table 6-18: 2015 Basin Industry Employment, Wages, and Firms by County

Area	Avg. Firms	Total 2015 wages paid	Average annual employment	Average annual wage
Clark County	13,331	$6,898,008,882	144,553	$47,720
Cowlitz County	2,869	$1,693,106,104	37,381	$45,293
Wahkiakum County	133	$24,307,720	712	$34,140
Total Basin	16,333	$ 8,615,422,706	182,646	

6.4.4 Fisheries and Habitat

The LCRB includes the Grays/Elochoman, Cowlitz, Lewis, and Salmon/Washougal WRIAs.

Fishery populations

ESA listed species in the LCRB include bull trout, the lower Columbia River stock of steelhead, the lower Columbia River stock of spring Chinook salmon, the lower Columbia River stock of fall Chinook salmon, the lower Columbia River stock of coho salmon, and the lower Columbia River stock of chum salmon (Table 6-19). All Columbia basins also contain populations of coastal cutthroat, which are not listed under the ESA.

Table 6-19: Bull trout, salmon, and steelhead presence in the basins within the LCRB[203].

	Bull Trout (threatened)	Lower Columbia Spring Chinook (threatened)	Lower Columbia Fall Chinook (threatened)	Lower Columbia Coho (threatened)	Columbia River Chum (threatened)	Lower Columbia Steelhead (threatened)	Coastal Cutthroat (not listed)
Grays/ Elochoman			X	X	X	X	X
Cowlitz		X	X	X	X	X	X
Lewis	X	X	X	X	X	X	X
Salmon/ Washougal			X	X	X	X	X

Harvest rates of lower Columbia fall Chinook have ranged from 30 to 65 percent in recent years and harvest rates of lower Columbia spring Chinook have ranged from 30 to 40 percent[204]. These higher exploitation rates were identified as a concern in NMFS' most recent 5-year review[205]. Harvest rates of coho in recent years have ranged from 11 to 18 percent. Steelhead harvest rates have been approximately 4.2 percent in recent years and the harvest rate for chum salmon has been less the 1 percent.

Condition of habitat

Human activities acting in concert with natural occurrences (e.g., floods, drought, fires, wind, etc.) within the LCRB have impacted habitat conditions. In their latest 5-year review, NMFS identified the following specific areas of concern:

- Reduced or loss of habitat complexity, connectivity, quantity, and quality in the lower tributaries and tributary/Columbia River mainstem interface, the mainstem Columbia River and the Columbia River estuary. Lack of access into historically accessible floodplain habitats affects all lower Columbia River listed stocks.
- Toxic pollution in the estuary.

203 Washington Department of Fish and Wildlife fish distribution webpage. https://fortress.wa.gov/dfw/score/score/maps/map_wria.jsp.

204 Northwest Fisheries Science Center. 2015. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest.

205 NMFS. 2016. 5-year review: lower Columbia River Chinook salmon, Columbia River chum salmon, lower Columbia River coho salmon, lower Columbia River steelhead. NMFS. Portland OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_lower-columbia.pdf.

- Dam blocking or impeding passage including the Cowlitz Basin (affects Chinook salmon), the North Fork Toutle River basin (affects steelhead and coho salmon), and the North Fork Lewis Basin (affects steelhead).
- Predation by birds, pinnipeds, and non-native fish species.

The 5-year review for the LCRB species included.[206]

- Continue implementation of priority habitat actions in accordance with the NMFS 2013 recovery plan.
- Systematically review and analyze the amount of habitat protected/restored against those high priority lower Columbia River mainstem and tributary areas identified in the NMFS 2013 Recovery Plan.
- Analyze and document the effectiveness of existing land-use regulatory mechanisms, land-use management plans, and fisheries harvest management regulations.
- Incorporate mechanisms of salmonid density dependent growth, dispersal, and survival when selecting habitat restoration actions as an approach to opening up new habitat and/or restoring degraded habitat.
- Expand research efforts in the Columbia River estuary on survival and run timing for adult salmonids migrating through the lower Columbia River to Bonneville Dam.
- Continue to implement long-term settlement agreements at Federal Energy Regulatory Commission (FERC) licensed dams in the lower Columbia River tributaries.
- Continue monitoring efforts and reducing predation risk in the lower Columbia River between pinnipeds, birds, and fish predators and ESA-listed species.
- Continue research efforts in the Columbia River estuary on survival and run timing for adult salmonid migration.
- Reevaluating the allowable harvest rates for Lower Columbia River Chinook and coho salmon.
- Completing ESA section 7 consultations on hatchery and harvest biological opinions and hatchery genetic management plans.
- Expanding reintroduction efforts to include programs for Columbia River chum salmon.
- Continuing to analyze the impact of hatchery-produced salmon upon natural-origin lower Columbia River salmon and steelhead.

Many of the above recommendations involve research, monitoring and evaluation aimed at addressing critical uncertainties.

[206] NMFS. 2016. 2016 5-year review: summary and evaluation of middle Columbia River steelhead. NMFS. Portland, OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_middle-columbia.pdf. NMFS. 2016. 5-year review: lower Columbia River Chinook salmon, Columbia River chum salmon, lower Columbia River coho salmon, lower Columbia River steelhead. NMFS. Portland OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_lower-columbia.pdf.

Significant habitat restoration and protection actions have been implemented to improve degraded habitat conditions and restore fish passage. These efforts expected to benefit the survival and productivity of the targeted populations, however, evidence demonstrating that improvements in habitat conditions have led to improvements in population abundance and/or productivity is lacking.

Trends

NMFS[207] noted that the fall-run populations had increases in abundance and decreases in hatchery contribution relative to baseline levels identified in the Recovery Plan[208]. NMFS indicated that there has been an overall improvement in the status of a number of fall-run Chinook populations, although most are still far from the recovery plan goals. For the remainder of this section, if not otherwise stated, the information was developed from the above-cited document.

The abundance of spring-run Chinook populations in this ESU has not changed appreciably since the species was listed under the ESA. Most of the populations are at a high or very risk of extinction due to low abundances and the high proportion of hatchery origin fish spawning naturally. The presence of spring-run Chinook salmon remaining in the Toutle River Basin is uncertain. The removal of Condit Dam on the White Salmon River provides an opportunity to re-establish a spring-run population in that basin.

The majority of the Columbia River chum salmon populations are at high to very high risk of extinction, with very low abundances. One population, Grays River, is at low risk of extinction; spawner abundances in the basin are in the thousands. The Washougal River and Lower Gorge populations appear to be relatively stable. Continued land development in the low gradient reaches that chum salmon prefer may pose a threat to most chum salmon populations.

Trends in coho salmon in the Lower Columbia River Washington streams are not well documented. When the species was listed under the ESA, little was known about naturally spawning coho populations in the Washington state basins of the Lower Columbia River. Subsequent monitoring has indicated that the species is more wide-spread than previously thought. Nonetheless, population abundances are low and the population remains at moderate risk of extinction. Land development and increasing human population pressures may continue to degrade habitat if not adequately controlled.

The abundance of the majority of winter-run steelhead populations in the LCRB is low. Summer-run steelhead population abundances appear to be low but stable. The abundance of winter-run steelhead has improved in recent years, but do not yet meet the targeted population size for viability.

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[207] NMFS. 2016. 5-year review: lower Columbia River Chinook salmon, Columbia River chum salmon, lower Columbia River coho salmon, lower Columbia River steelhead. NMFS. Portland OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_lower-columbia.pdf.

[208] NMFS. 2013. ESA recovery plan for lower Columbia River coho salmon, lower Columbia River Chinook salmon, Columbia River chum salmon, lower Columbia River steelhead. NMFS. Portland, OR. http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/willamette_lowercol/lower_columbia/final_plan_documents/final_lcr_plan_june_2013_-corrected.pdf.

Climate Change

Trends in warming and ocean acidification are highly likely to continue during the next century. In winter across the west, the highest elevations will shift from consistent longer (>5 months) snow-dominated winters to a shorter period (3-4 months) of reliable snowfall[209]. Watersheds will experience more intense precipitation events with possible shifts in the timing of the most intense rainfall. Warmer summer air temperatures will increase both evaporation and direct heading. When combined with reduced winter water storage, warmer summer air temperatures will lead to lower minimum flows in many basins.

Studies examining the effects of long term climate change to salmon populations have identified a number of ways that climate change is likely to influence salmon sustainability. These include direct effects of temperature such as mortality from heat stress, changes in growth and development rates, reduced habitat availability due to lower flows and higher water temperatures, reduced disease resistance, and shifts in seasonal timing of important life history events, such as the adult migration, spawn timing, fry emergence timing, and the juvenile migration.

Fish populations currently occupying areas of the subbasin with cool water and good streamflow may not be significantly affected, at least in the near term, by climate change. However, populations occupying habitats that are aready relatively warm and/or dry are likely to have the availability of suitable habitat reduced over time. Projects that help to reduce stream temperature (increased stream shading or, where flows are low, increased stream flow) in these warmer habitats may help to offset the effects of climate change.

6.4.5 Projects and Needs

A list of infrastructure investment projects and needs are grouped into the different investment categories and summarized below. Other projects are likely to exist within each the basin, but the list included in this report is intended to be representative of basin projects.

Water Supply

Nearly $180 million worth of water infrastructure investments are associated with CIPs in the basin. These include CIPs for the cities of Vancouver and Camas.

Flood Protection

No projects or needs identified. There is evidence of some recent flooding in the LCRB, although no infrastructure investment projects have been identified. The Columbia River has a long history of flooding in and near Vancouver. In 1996 the river rose over 27 feet, well above the 16 foot flood stage (measured at the Port of Vancouver), resulting in extensive flooding of agricultural lands and other low lying lands and islands. River traffic

[209] NMFS. 2016. 2016 5-year review: summary and evaluation of middle Columbia River steelhead. NMFS. Portland, OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_middle-columbia.pdf. NMFS. 2016. 5-year review: lower Columbia River Chinook salmon, Columbia River chum salmon, lower Columbia River coho salmon, lower Columbia River steelhead. NMFS. Portland OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_lower-columbia.pdf.

was halted temporarily to prevent overtopping the lowest dykes along the river. Less extensive flooding occurred in the same area in 1995 and 1997.

Stormwater Management

In the LCRB, multiple stormwater system improvement projects are identified for 2017, costing a total of $7.3 million. The largest of these is a $6 million SR-501/I-5 stormwater management project at the Port of Vancouver. Smaller projects include a $601,300 Clark County Peterson channel residential low impact development study for stormwater, a $249,696 East Fork Lewis Knotweed control project, a $170,399 East Fork Lewis River side channel restoration project, pervious concrete sidewalk retrofits for stormwater improvement in Cowlitz County costing $125,300, and a $100,000 plan for Kalama general sewer and wastewater facilities.

Fisheries and Restoration

As of 2011, the estimated cost for recovery of listed species was estimated at $1,258 million for the LCRB[210]. The majority of the projects funded since 2011 are listed on the Habitat Work Schedule website (http://hws.ekosystem.us/home) and the Columbia fish and Wildlife website (https://www.cbfish.org/). Since 2011, $10.3 million has been expended on projects in the LCRB, leaving an estimated cost for recovery of $1,248 million over the next 20 years (Table 6-20). Projects are likely to be implemented as funding becomes available.

Generally, the estimated costs of implementing projects summarized in recovery plans did not include an accurate estimate of the costs of replacing culverts to meet current passage standards. Therefore, the costs listed below likely do not include Washington state Department of Transportation's costs of replacing culverts and upgrading passage at stream crossings. The estimated costs below include only those projects listed at the Habitat Work Schedule and the Columbia Fish and Wildlife websites. Other projects likely have been implemented through funding sources that are not tracked by those sites, including projects implemented by the U.S. Forest Service, BLM, and private individuals. Additionally, the recovery plan listed numerous projects for which cost estimates were not available. Therefore, the total estimated cost listed below is likely an underestimate. We also note that estimates of project costs developed during the recovery planning process were frequently "ball park" estimates and are subject to change once projects go into detailed planning.

[210] Cantry. 2011. Funding for salmon recovery in Washington state. for the Governor's Salmon Recovery Office and the Council of Regional Salmon Recovery Organizations.

Table 6-20: Remaining Fishery and Habitat Need in the LCRB in Millions of Dollars

Project type	Estimated Remaining Costs in 2011[211]	Funds Allocated between 2011 and Present[212]	Estimated Remaining Costs as of the end of 2016
Habitat Restoration	857	10	847
Land and Easement Acquisition	167	0	167
Passage Barrier Retrofits	116	0	116
Total Capital Projects	1,140	10	1,,130
Non-Capital Projects (Operations, RM&E, Outreach)	118	0	118
Total	1,258	10.3	1,248

6.4.6 Summary of Basin Water Infrastructure and Fisheries and Habitat Needs

LCRB water infrastructure investment needs by type in total and projected through time is presented in Table 6-21. Total estimated costs in current (2016) dollars is $1.4 billion, with the largest shares for Fish and habitat and water supply projects, with $1.3 billion and $179 million respectively.

Table 6-21: LCRB Water Infrastructure Investment Needs Projection by Type

	Millions of Dollars								
Investment Type	Total	2017	2018	2019	2020	2025	2030	2035	2036
Water supply	$179	$14	$14	$14	$14	$7	$6	-	-
Stormwater	$7	$7	-	-	-	-	-	-	-
Flooding	-	-	-	-	-	-	-	-	-
Fish & habitat	$1,252	$66	$62	$62	$62	$62	$62	$62	$62
Multiple	-	-	-	-	-	-	-	-	-
Total	$1,439	$88	$76	$76	$76	$70	$68	$62	$62

211 Cantry. 2011. Funding for salmon recovery in Washington state. for the Governor's Salmon Recovery Office and the Council of Regional Salmon Recovery Organizations.

212 Habitat Work Schedule. Washington State Recreation and Conservation Office and Washington State Governor's Salmon Recovery Office. http://hws.ekosystem.us/home. Columbia Basin Fish and Wildlife Program. https://www.cbfish.org/.

- Basin has a tendency toward flood/drought, and being downstream of all upper basins that are flooding or in drought, therefore is affected by these forces more profoundly than the others;
- Generally, the projects identified to improve fish habitat were not based on a true limiting factors analysis, but rather an evaluation of all the potential pathways that anthropogenic activities could be affecting fish habitat.
- NMFS has indicated that freshwater habitat is not likely limiting the abundance of Chinook salmon in the lower river and has also indicated that the harvest rates for that species may merit reconsideration. Therefore, habitat enhancement projects in the freshwater environment are not likely to improve Chinook salmon populations. This may also be true for other lower Columbia River species. In the absence of a true limiting factors analysis, it is impossible to estimate the reduction in fish habitat costs that are possible, but the costs of addressing only the limiting factors is likely to range between zero (0) to fifty (50) percent of the current total estimated costs for fish habitat projects.

6.5 Kootenai-Pend Oreille – Spokane Basin

The Kootenai-Pend Oreille-Spokane Basin (KPOS) intersects parts of Canada, Idaho, and eastern Washington. Within Washington, the major city in the basin is Spokane. The basin includes portions of Spokane and Pend Oreille Counties. The Priest River and Kootenai River are larger tributaries to the Columbia River within the basin. The larger lakes of the basin (Coeur d'Alene, Lake Pend Oreille, and Priest Lake) are in Idaho. Interstate 90 intersects the region, passing through the larger cities of Spokane (Washington), and Post Falls (Idaho). Smaller highways on the Washington side of the basin include Highways 2 and 395. The basin is depicted in Figure 6-4. This analysis includes only the portion of the basin that lies within the boundaries of the state of Washington.

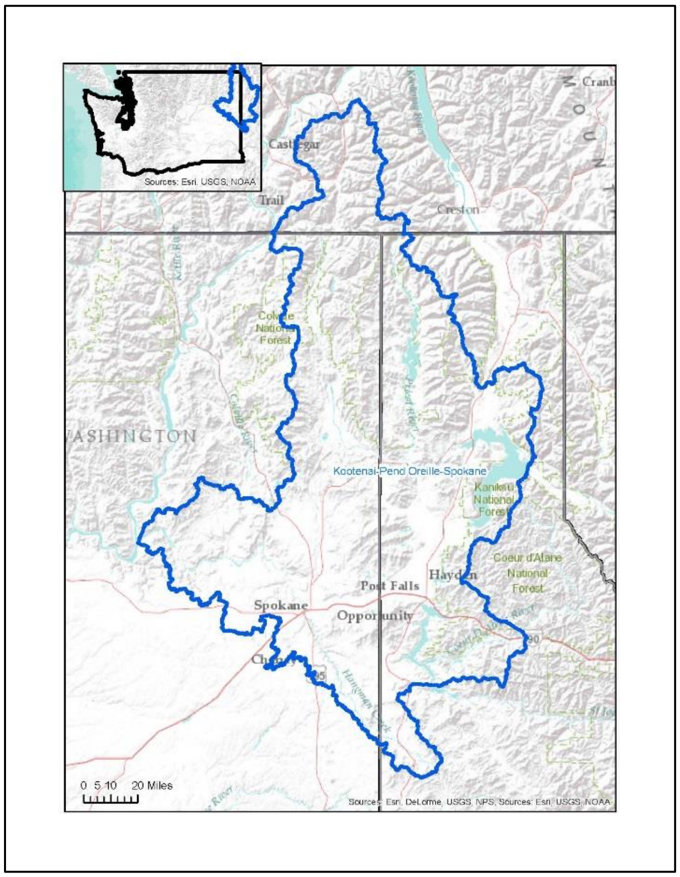

Figure 6-4: Map of Kootenai-Pend Oreille-Spokane Basin

6.5.2 Hydrology

Annual precipitation in WRIAs 55 and 57 varies from 15 inches in low elevations to 45 inches in the mountains[213]. Seventy (70) percent of precipitation falls between October and March, and 25 to 40 percent falls as snow depending on elevation. Evapotranspiration is also an important water balance component and can reach up to 0.5 inches per day during a hot summer day. Eight major groundwater aquifers have been identified in the basin, the majority of which are used for water supply.

Existing Water Infrastructure

The Kootenay and Spokane rivers are both major tributaries to Columbia River. As recently as the mid-1960s, the upper Columbia and Kootenay rivers in British Columbia were still free-flowing and unaffected by dams and reservoirs. The uncontrolled discharge past the Canada-U.S. border created problems for electricity generation in the US, and Canada also wanted to utilize the Columbia River for the production of hydroelectric power. Negotiated in 1961 between the governments of the two countries, the Columbia River Treaty attempted to ratify these problems. Construction of the first three of the four dams authorized by the treaty—Mica, Keenleyside and Duncan—was implemented in 1964. Of the four dams, the first two are on the Columbia, the third is on the Duncan River, a tributary of the Kootenay, and the fourth, Libby, on the Kootenay River proper. Today, there are 17 major river dams in the KPOS, out of which only two dams (Box Canyon and Boundary dams) are located in Washington state; however, there are an additional five run-of-the-river dams on the Spokane River (Upper Falls, Monroe, Nine Mile, Long Lake, Little Falls), in addition to other supporting infrastructure.

Box Canyon and Boundary dams are both hydroelectric dams, but the long elongated lakes above each dam are regularly used for recreation. Dams help in flood reduction, but were not built to contain major floods. Dam regulators release flood waters downstream into the Kootenay River when flood waters reach the maximum design water level (in order to prevent dam failure).

The Spokane River dams are all run-of-the-river dams. With the exception of Long Lake, formed behind the Long Lake dam, the Spokane River dams generally do not store much water. The primary purpose of the Spokane River dams is power generation; however, flood control has been included as an important element in the operation of these dams (in addition to recreation and fisheries). Generally, operation of the dams (mostly operated by Avista Power Company) are based upon snow pack, precipitation, and temperature forecasts. Forecasts are highly variable due to the relatively low elevation of the KPOS.

Other flood mitigation mechanisms are being considered to control flooding in the basin.

Flood history

Numerous historic floods have been recorded in the basin; the largest floods occurred in 1997, 1933, and 1974. More recent floods occurred in 2011 and 2012 (NOAA stream-gage, Spokane River in Spokane[214]).

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213 Watershed Management Plan, Water Resources Inventory Area 55 – Little Spokane River and Water Resources Inventory Area 57 – Middle Spokane River, Spokane County, January 2006.

214 http://water.weather.gov/ahps2/hydrograph.php?gage=spow1&wfo=otx

Drought history

This basin was subjected to the same major droughts as the rest of the Columbia River Basin, including the 1840 – 1955 multi-year drought, droughts during the late 1790s, 1840s, 1870s, and 1930s, single year droughts in 1775, 1805, 1925, and most recent droughts in 1976-78, 2000-2004, and in 2015.

Hydrologic Trends

The KPOS is part of the Columbia River Basin, and as such is subject to the general hydrologic trends common throughout the Columbia River region:

- There has been a steady increase in the basin-wide mean annual temperature from the 1890s to 1930s, and then again from the 1980s through 2000s;
- Mean annual precipitation in the basin has remained unchanged (no trend to increase or decrease); however, there has been a regional trend of increasing precipitation during the wet season and an increase in extreme precipitation events;
- There has been general decline in spring snowmelt (mostly as a result of increases in temperature, and more precipitation falling as rain than snow in the winter)[215];
- There is a possible trend of reduced annual streamflow during dry years[216].

Statistical analysis of these trends conducted by the Bureau of Reclamation and others could not determine whether the trends are caused by natural climate variability or by anthropogenic influence.

Climate Change

In general, the warming climate in Washington state tends to produce lengthened growing seasons, declining snowpack, and earlier timing of spring runoff. Several recent studies investigated the impacts of climate change in the basin: [217]

Temperature could increase from 0.1 to 3.5 degrees Celsius; precipitation could decrease by 7 percent or increase by 18 percent (depending on the climate impact scenario); and corresponding peak river runoff could either decrease by 58 m^3/sec or increase by 106 m^3/sec.

6.5.3 Economy

The counties that are included in the economic analysis for KPOS are Spokane and Pend Oreille counties. Within these counties, the largest notable city is Spokane. Some of the other larger communities in the basin include Cheney, Colville, Chewelah, Deer Park and Newport. The primary industries, based on employment, of the counties within the basin

[215] Knowles, N., Dettinger, M., and Cayan, D., 2007. Trends in Snowfall versus Rainfall for the Western United States 1949-2001. Prepared for California Energy Commission Public Interest Research Program, Project Report CEC-500-2007-032.

[216] Luce, C. H, and Holden, Z.A., 2009. Declining Annual Streamflow Distribution in the Pacific Northwest United States, 1948-2006. Geophysical Research Letters, Vol 36, L16401, doi:10.1029/2009GL039407.

[217] Jin, X. and Sridhar, V. Impacts of Climate Change on Hydrology and Water Resources in the Boise and Spokane River Basins, in Journal of American Water Resources Association (JAWRA), Vol. 48, April 2012, pp. 197-210.

include healthcare and social assistance, retail trade, local government, accommodation and food services, and manufacturing.

The current (2015) population from census estimates and the most recent county population forecast from OFM are presented in Table 6-22 by county and for the total basin. The total basin population is expected to grow from 504,033 (7.0 percent of Washington's population) in 2015 to 594,263 (7.0 percent of the state population) in 2036. Currently, over 97 percent of that population is in Spokane County alone (490,945). That share is expected to remain constant over the projection period.

Table 6-22: OFM Population Projections for KPOS Basin

	2015	2017	2018	2019	2020	2025	2030	2035	2036
Washington	7,170,351	7,178,675	7,256,835	7,334,646	7,411,977	7,793,173	8,154,193	8,483,628	8,546,278
Pend Oreille	13,088	13,457	13,538	13,616	13,692	13,977	14,129	14,149	14,146
Spokane	490,945	499,348	504,243	509,100	513,910	537,428	558,614	576,763	580,117
Total Basin	504,033	512,805	517,781	522,716	527,602	551,405	572,743	590,912	594,263

The economic sector breakdown by employment for the largest industry sectors in the basin's counties is provided in Table 6-23. Healthcare and social assistance is significantly the largest employment sector for the two counties (38,926 and 195 respectively). Retail trade and local government are also strong industries, each providing over 20,000 jobs in the basin.

Table 6-23: 2015 County Employment by Largest Economic Sectors

Spokane	Number of jobs
1. Healthcare and social assistance	38,926
2. Retail trade	25,584
3. Local government	20,413
4. Accommodation and food services	17,822
5. Manufacturing	15,247
Pend Oreille	
1. Local government	1,314
2. Retail trade	231
3. Manufacturing	225
4. Healthcare and social assistance	195
5. Accommodation and food services	166

Total employment, wage, and number of firms for the basin in 2015 are displayed in Table 6-24 , in total and by county. KPOS Basin had an average of nearly 15,000 firms, providing over $9.3 billion in wages, for over 212,000 jobs. Average annual wages by county range between $44,000 in Spokane County and $45,000 in Pend Oreille County.

Table 6-24: 2015 Basin Industry Employment, Wages, and Firms by County

Area	Avg. Firms	Total 2015 wages paid	Average annual employment	Average annual wage
Pend Oreille County	398	$133,718,838	2,960	$45,175
Spokane County	14,345	$9,226,786,457	209,532	$44,035
Total Basin	14,743	$ 9,360,505,295	212,492	

6.5.4 Fisheries and Habitat

Grand Coulee Dam blocks all upstream migration of anadromous fish. As a result, there are no anadromous fish in this subbasin. Bull trout are also thought to be absent[218]. Trout and numerous other small native and non-native species are present in the basin.

6.5.5 Projects and Needs

A list of infrastructure investment projects and needs are grouped into the different investment categories and summarized below. Other projects are likely to exist within each the basin, but the list included in this report is intended to be representative of basin projects.

Water Supply

No projects or needs identified. There is evidence of some recent water supply concerns in the KPOS although no infrastructure investment projects have been identified. In 2013 there was concern that private wells were unable to address increased demand, with several households in rural Spokane County unable to meet basic water needs, much less water for lawns or other "luxury" uses.

Flood Protection

No projects or needs identified. There is evidence of some recent flooding in the KPOS, although no infrastructure investment projects have been identified. In 2016, Spokane experienced flooding of highways and streets due to flooding of several creeks and streams. Similar flooding also occurred in 2011. The Spangle Creek flooded in 2014, rendering several homes uninhabitable in Spangle, WA.

Stormwater Management

In KPOS, there are twenty stormwater improvement projects for 2017, totaling $11 million. The largest of these is a $4.2 million riverside interceptor for protecting water quality. Spokane County is investing an additional $3 million in CSOs, high drive stormwater improvements, and river infiltration reduction. Close to $2.5 million will be spent on stormwater retrofits on major roads (Hawthorne Road, Monroe Street, and Hastings Road). Another $1 million will be spent on a Rebecca Control facility for CSO Basin 41. These projects will improve the stormwater system's ability to manage uneven flow and reduce local water pollution.

218 Washington Department of Fish and Wildlife fish distribution webpage. https://fortress.wa.gov/dfw/score/score/maps/map_wria.jsp.

Fisheries and Restoration

No projects or needs identified.

6.5.6 Summary of Basin Water Infrastructure and Fisheries and Habitat Needs

KPOS water infrastructure investment needs by type in total and projected through time is presented in Table 6-25. There is limited water infrastructure project needs information available for this basin. Based on information available to the team, the total estimated costs in current (2016) dollars is $11 million, with all costs allocated to stormwater projects. There are no fish and habitat projects in this basin.

Table 6-25: KPOS Water Infrastructure Investment Needs Projection by Type

	Millions of Dollars								
Investment Type	**Total**	**2017**	**2018**	**2019**	**2020**	**2025**	**2030**	**2035**	**2036**
Water supply	-	-	-	-	-	-	-	-	-
Stormwater	$11	$11	-	-	-	-	-	-	-
Flooding	-	-	-	-	-	-	-	-	-
Fish & habitat	-	-	-	-	-	-	-	-	-
Multiple	-	-	-	-	-	-	-	-	-
Total	$11	$11	-	-	-	-	-	-	-

- Fish populations in the basin are limited to resident fish; Grand Coulee dam blocks upstream migration of anadromous fish into the basin
- The smaller streams in this basin are typically more sensitive to drought

6.6 Washington Coastal Basin

The Washington Coastal Basin (WCB) covers the length of the Washington coastline on the Pacific Ocean. Olympic National Park falls within the basin, as do the cities of Centralia and Aberdeen. Overlapping counties include Pacific, Grays Harbor, Jefferson, and Clallam. Multiple rivers flow through the basin, including the Hoh, Quinault, and the Chehalis. The major lake within the basin is Lake Quinault. Predominant highways intersecting the basin include Highway 101 along the Coast, and Interstate 5 near Centralia. The basin is shown in Figure 6-5.

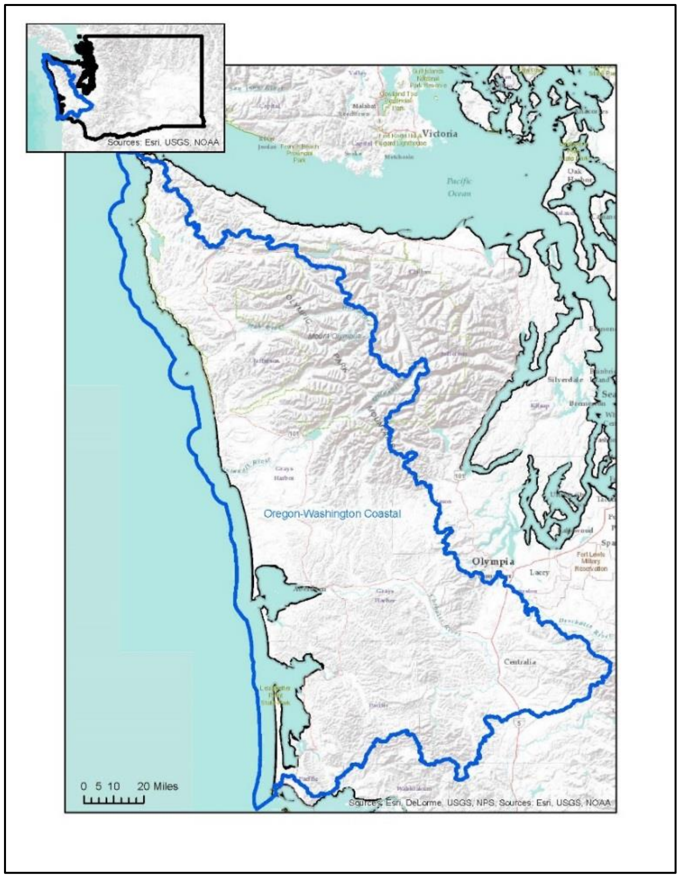

Figure 6-5: Map of Washington Coastal Basin

6.6.2 Hydrology

The WCB is hydrologically diverse. The basin includes the Pacific coastline and the western part of the Olympic peninsula – the area that receives the highest precipitation in the state. Average annual precipitation ranges from 80 to 100 inches along the coastline; over 250 inches (mostly snow) along the Olympic mountains; and only 40 to 50 inches in the southeastern part of the basin (Lewis County). An average annual temperature along the coastline is about 51 degrees, and weather tends to be mild and humid throughout the year with frequent cloud cover, considerable fog, and long-lasting drizzles. All the rivers in this basin drain to the Pacific, and the Chehalis Basin is the largest subbasin.

Existing Water Infrastructure

The major water infrastructure in this basin include several water supply reservoirs in the Chehalis River basin, ACOE of Engineers Wynoochee reservoir on the Olympic Peninsula, several waste-water treatment facilities, and numerous stormwater and water supply distribution systems, facilities supporting vessel navigation and port operations on rivers and the coastline (Aberdeen, Raymond, Long Beach), and shoreline protection structures along the Washington coastline.

Flood history

This basin has been subjected to persistent flooding. In the Chehalis River Subbasin, for example, the first major flood was recorded in 1887[219], then in 1933, 1990, and 1996, and more recently in December 2007 and in January 2009. The two most recent floods had devastating effects on transportation, including the state closing Interstate I-5 and interrupting train service for several days. The Washington state Governor's Office funded a comprehensive study of different flood mitigation alternatives in the basin[220].

Drought history

Drought history in this basin coincides with estimated or recorded droughts in Washington state and Western Washington.

Climate Change

Global climate change is projected to bring warmer temperatures and changes in the seasonality of precipitation, that in turn may increase extreme high temperatures and decrease extreme low temperatures, result in wetter conditions in the fall, spring, and winter, and drier summers. These changes are projected to decrease mountain snowpack (that will significantly affect mountains with lower to moderate elevations in the WCB) and the frequency of lower elevation snow storms[221]. Flooding could increase or decrease in the WCB, depending on variations in mid-winter temperatures, and the spatial distribution of precipitation change. The coastal areas of the WCB will be affected by SLR that may significantly increase flooding (along the coastline and inland), and may affect coastal infrastructure. As indicated earlier, SLR predictions range from 4 to 56 inches for the basin, depending on the climate change forecast scenarios.

6.6.3 Economy

The counties that are included in the economic analysis for the WCB are Grays Harbor, Lewis, and Pacific counties. Within these counties, the largest notable cities are Centralia, Aberdeen, Hoquiam, and Raymond. The primary industries, based on employment, of the counties within the basin include local government, retail trade, health care and social assistance, and accommodation and food services.

The current (2015) population from census estimates and the most recent county population forecast from OFM are presented in Table 6-26 by county and for the total basin. The total basin population is expected to grow from 167,852 (2.3 percent of Washington's population) in 2015 to 186,248 (2.1 percent of the state population) in 2036. Currently, over 87 percent of that population is in Grays Harbor and Lewis counties (147,004). That share is expected to increase only slightly to 88.3 percent (164,445) over the projection period.

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[219] Scott, R., Zerbe, R, and Scott, T. "Benefit-Cost Analysis in the Chehalis Basin" in Regulation, summer 2013, pp. 20-25.

[220] William Ruckelshaus Center, University of Washington, Chehalis Basin Flood Hazard Mitigation Report, December 2012.

[221] Impact of Climate Variability and Climate Change on Transportation Systems and Infrastructure in Pacific Northwest, Alan Hamlet, March 2012.

Table 6-26: OFM Population Projections for WCB

	2015	2017	2018	2019	2020	2025	2030	2035	2036
Washington	7,170,351	7,178,675	7,256,835	7,334,646	7,411,977	7,793,173	8,154,193	8,483,628	8,546,278
Grays Harbor	71,122	73,898	74,083	74,253	74,408	75,529	76,428	76,905	76,958
Lewis	75,882	78,741	79,302	79,852	80,385	82,924	85,165	87,092	87,487
Pacific	20,848	20,913	20,940	20,966	20,990	21,261	21,495	21,736	21,803
Total Basin	167,852	173,552	174,325	175,071	175,783	179,714	183,088	185,733	186,248

The economic sector breakdown by employment for the largest industry sectors in the basin's counties is provided in Table 6-27. Local government is the largest employment sector for the three counties, and is a significant employer in all three counties (4,842, 3,600, and 1,480 for Grays Harbor, Lewis and Pacific respectively). Health care and social assistance is also significant in all three counties (2,855, 3,600, and 592 respectively).

Table 6-27: 2015 County Employment by Largest Economic Sectors

County	Number of jobs
Grays Harbor County	
1. Local government	4,842
2. Health care and social assistance	2,855
3. Retail Trade	2,605
4. Manufacturing	2,438
5. Accommodation and food services	2,071
Lewis County	
1. Retail Trade	3,617
2. Health care and social assistance	3,602
3. Local government	3,600
4. Manufacturing	3,196
5. Accommodation and food services	2,109
Pacific County	
1. Local government	1,480
2. Accommodation and food services	840
3. Ag, forestry, fishing, and hunting	654
4. Health care and social assistance	592
5. Retail Trade	585

Total employment, wage, and number of firms for the basin in 2015 are displayed in Table 6-28, in total and by county. The WCB had an average of nearly 5,600 firms, providing over $1.9 billion in wages, for nearly 52,000 jobs. Average annual wages by county range between $33,000 in Pacific County and $38,000 in Grays Harbor County.

Table 6-28: 2015 Basin Industry Employment, Wages, and Firms by County

Area	Avg. Firms	Total 2015 wages paid	Average annual employment	Average annual wage
Grays Harbor County	2,397	$822,439,627	21,792	$37,740
Lewis County	2,340	$919,461,403	23,971	$38,357
Pacific County	855	$204,199,897	6,185	$33,015
Total Basin	5,592	$ 1,946,100,927	51,948	

6.6.4 Fisheries and Habitat

The WCB includes the Solduc, Queets/Quinalt, Lower Chehalis, Upper Chehalis, and Willapa WRIAs. The Solduc and Queets/Quinalt basins support ESA listed population of bull trout and the Solduc basin supports the Ozette Lake population of sockeye which are listed under the ESA as threatened (Table 6-29). None of the other salmonid populations in the Coastal Subbasin are listed under the ESA.

Table 6-29: Bull trout, salmon, and steelhead presence in the basins within the WCB[222].

Basin	Bull Trout (threatened)	Sockeye (not listed except in Solduc)	Spring/Summer Chinook (not listed)	Fall Chinook (not listed)	Coho (not listed)	Chum (not listed)	Steelhead (not listed)	Cutthroat (not listed)
Solduc	X	X	X	X	X	X	X	X
Queets/Quinalt	X	X	X	X	X	X	X	X
Lower Chehalis			X	X	X		X	
Upper Chehalis				X			X	
Willapa				X	X		X	X

Condition of habitat

The Solduc basin lies primarily in the Olympic National Forest and the Olympic National Park. Commercial timberlands are also present in the basin. Smaller communities lie along the coast. Legacy logging (prior to the adoption of the current forest practices regulations), development along the coast, and Highway 101, which parallels the river for many miles, are the primary land uses affecting fish habitat. Predation is a primary factor affecting

[222] Washington Department of Fish and Wildlife fish inventory maps. https://fortress.wa.gov/dfw/score/score/maps/map_wria.jsp.

Ozette Lake sockeye[223]. Predators include cutthroat trout (native), northern pikeminnow (native), otters and seals (native) and the introduced largemouth bass. Water quality is also a concern. The lake has high levels of mercury and PCBs[224]. Stream flow, stream temperature, sediment and ocean conditions may also be a factor affecting survival of sockeye.

Trends

NMFS' 5-year review of the listing status of the Ozette Lake sockeye salmon indicated that the population abundance is highly variably and also indicated a need to improve assessment methods in order to gain a better understanding of population size and productivity. Habitat restoration and protection actions at the Federal, state, and local levels have been implemented to improve degraded habitat conditions and restore fish passage. While these efforts are expected to improve the survival and productivity of the sockeye population, sufficient evidence documenting the population effects of those improvements is not available. Improvements in monitoring, evaluation, and reporting of habitat conditions and fish population response are needed. The NMFS 5-year review suggested the following as priorities for Ozette Lake:

- Improve estimates of population size and estimates of the proportion of hatchery fish present
- Address ongoing water quality issues
- Continue/increase programs that reduce predation
- Implement RM&E listed in the Recovery Plan
- Improve habitat for beach spawning sockeye

Climate Change

Trends in warming and ocean acidification are highly likely to continue during the next century. Both freshwater and marine productivity tend to be lower in warmer years for most salmonid populations. These trends suggest that the population might decline as mean temperature rises. However, the population may have some resilience to climate change provided that water temperatures remain within a range that is suitable for rearing of young sockeye salmon.

6.6.5 Projects and Needs

A list of infrastructure investment projects and needs are grouped into the different investment categories and summarized below. Other projects are likely to exist within each the basin, but the list included in this report is intended to be representative of basin projects.

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[223] NMFS 2009. Recovery plan for Ozette Lake sockeye salmon (*Oncorhynchus nerka*). NMFS, Seattle, WA. http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/puget_sound/lake_ozette/lakeozetterecoveryplan.pdf.

[224] NMFS 2016. 5-year review: summary and evaluation of Ozette Lake sockeye. NMFS, Portland, OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_lake_ozette.pdf.

Water Supply

Nearly $3.0 million for one ongoing, future, and proposed project is identified in the WCB through research and interviews with stakeholders. This investment project is related to the Department of Natural Resources (DNR) water infrastructure investment capital projects.

Flood Protection

Within the WCB, there is immediate need for investment in projects that mitigate the impacts of flooding within the basin. According to OFM Funding Data for 2015 to 2017, $34 million has been pledged for immediate catastrophic flood relief.[225] This includes projects in Aberdeen, Chehalis, Oakville, Elma, and Napavine, and Thurston and Lewis Counties. Over $3 million was pledged to the town of Bucoda to regrade the Main Street to mitigate the impact of floods, and Cosmopolis received $3.4 million for projects to mitigate flooding from Mill Creek. Aberdeen will receive $1 million for the construction of levees. Of the $34 million, nearly $14 million will be spent on flood strategy within the basin, and over $6 million will fund EIS and technical studies for flood mitigation projects.

Since Interstate-5, the main north-south thoroughfare in the state, crosses the WCB flooding is of particular concern due to the economic consequences. In 2007, severe flooding on I-5 shut the interstate for days, causing delays and damage, costing millions.[226] A 2016 EIS for the Chehalis Basin Strategy analyzes the costs of four alternatives, in addition to the No Action Alternative, to reduce flood damages and protect aquatic species habitat. The Governor's Workgroup Recommendation Alternative (Alternative No. 1) would provide flood damage reduction (including a flood retention facility) over a large geographic area, localized benefits through local flood damage reduction actions, and restore aquatic species habitat through "low" or "high" restoration actions. The project cost for the Workgroup Recommendation totals between $601 million and $929 million for actions with a net positive benefit, depending on the specific actions taken. According to the current economic analysis, the highest benefit-cost ratio is achieved through a Flood Retention Only facility (no flood retention flow augmentation) and low restoration activities. This combination of actions costs $601 million and provides $929 million in flood damage reduction benefits and $15 million in fishery use value benefits for salmon. No decision has been made and an ecosystem services analysis will change the benefit cost ratios, perhaps making Alternative 4 (restorative flood protection, currently estimated to cost up to $1.7 million, depending on low or high aquatic species habitat restoration actions) a feasible option.

Stormwater Management

In the WCB, close to $12 million will be spent in 2017 improving stormwater management. The largest of these are work along two highways to reduce sedimentation within the stormwater system. Along SR-109, the Moclips River bridge will be replaced ($6.1 million) and along US-101 at a Hoh River site, the slopes will be stabilized ($4.9 million). Within the City of Sequim, projects will repair inflow and infiltration to Centennial Place, fix

[225] OFM Funding Data, Bien 2015-2017, Catastrophic Flood Relief (Ver 3)

[226] The Seattle Times. "Flood-damaged I-5 to stay closed until this weekend". Published December 5, 2007. Accessible at http://www.seattletimes.com/seattle-news/flood-damaged-i-5-to-stay-closed-until-this-weekend/

stormwater storage at River Road, improve drainage at South 3rd Avenue, and develop a floodplain plan for the middle reach of Bell Creek, among others.

Future projects were identified in the City of Sequim Stormwater Master Plan's CIP Project Implementation schedule, including a twenty-year stormwater system rehabilitation for Sequim (costing $300,000 annually), close to $1.5 million in upgrades to Bell Creek culverts, and the development of a $742,000 Sequim Area Stormwater-Watershed plan. In total, $15 million will need to be invested in stormwater management in the WCB over the next two decades.

These projects will positively affect flood prevention efforts within the basin; as stormwater management improves, floods become less likely and less severe.

Fisheries and Restoration

As of 2011, the estimated cost for recovery of listed species was estimated at $622 million for the WCB[227]. The majority of the projects funded since 2011 are listed on the Habitat Work Schedule website (http://hws.ekosystem.us/home). Since 2011, $24 million has been expended on projects in the Subbasin, leaving an estimated cost for recovery of $598 million over the next 20 years (Table 6-30). Projects are likely to be implemented as funding becomes available.

Generally, the estimated costs of implementing projects summarized in recovery plans did not include an accurate estimate of the costs of replacing culverts to meet current passage standards. Therefore, the costs listed below likely do not include Washington state Department of Transportation's costs of replacing culverts and upgrading passage at stream crossings. The estimated costs below include only those projects listed at the Habitat Work Schedule. Other projects likely have been implemented through funding sources that are not tracked by those sites, including projects implemented by the U.S. Forest Service, BLM, and private individuals. Additionally, the recovery plan listed numerous projects for which cost estimates were not available. Therefore, the total estimated cost listed below is likely an underestimate. We also note that estimates of project costs developed during the recovery planning process were frequently "ball park" estimates and are subject to change once projects go into detailed planning.

[227] Cantry. 2011. Funding for salmon recovery in Washington state. for the Governor's Salmon Recovery Office and the Council of Regional Salmon Recovery Organizations.

Table 6-30: Estimated costs in $millions for recovery as of 2011, funds allocated since 2011, and estimated remaining cost for recovery of the WCB listed Ozette Lake sockeye.

Project type	Estimated Remaining Costs in 2011[228]	Funds Allocated between 2011 and Present[229]	Estimated Remaining Costs as of the end of 2016
Habitat Restoration	364	18	346
Land and Easement Acquisition	123	5	118
Passage Barrier Retrofits	40	0	40
Total Capital Projects	527	23	504
Non-Capital Projects (Operations, RM&E, Outreach)	95	1	94
Total	622	24	598

6.6.6 Summary of Basin Water Infrastructure and Fisheries and Habitat Needs

WCB water infrastructure investment needs by type in total and projected through time is presented in Table 6-31. Total estimated costs in current (2016) dollars is $5.5 billion, with the largest shares for fish and habitat and flooding projects, with $598 million and $4.9 billion respectively. This basin includes the Chehalis basin, and the majority of the flooding project costs are attributable to the Chehalis basin and surrounding areas.

Table 6-31: WCB Water Infrastructure Investment Needs Projection by Type

	Millions of Dollars								
Investment Type	Total	2017	2018	2019	2020	2025	2030	2035	2036
Water supply	$3	$3	-	-	-	-	-	-	-
Stormwater	$19	$12	-	-	-	-	-	-	-
Flooding	$1,181	$91	$57	$57	$57	$57	$57	$57	$57
Fish & habitat	$598	$30	$30	$30	$30	$30	$30	$30	$30
Multiple	-	-	-	-	-	-	-	-	-
Total	$1,802	$136	$87	$88	$87	$88	$88	$88	$88

- It is very important to note that as of yet there are no listed species of fish in the Chehalis basin although stocks are in decline. However, the current status of fisheries

228 Cantry. 2011. Funding for salmon recovery in Washington state. for the Governor's Salmon Recovery Office and the Council of Regional Salmon Recovery Organizations.

229 Habitat Work Schedule. Washington State Recreation and Conservation Office and Washington State Governor's Salmon Recovery Office. http://hws.ekosystem.us/home.

is not as bad as the other basins where species have already been listed as threatened or endangered and this is therefore a ecosystem asset of value.

- Flooding is increasing and is expected to continue in the future with changing climate and continued development

6.7 Puget Sound Basin

The Puget Sound Basin (PSB) is the most populous basin in Washington, containing the capital of Olympia, and the major cities of Seattle, Tacoma, Renton, Bellingham, and Anacortes, among many others. Mount Rainier, Mount Baker, and the North Cascades arise in the eastern part of the basin. Multiple major rivers, including the Nooksack, Skagit, Stillaguamish, Snohomish, Cedar, Samish, Duwamish, Green, Puyallup, White, Nisqually, Deschutes, Dosewallips, Quilcene, Elwha, and Dungeness Rivers, drain to Puget Sound and the Strait of Juan de Fuca. Predominant highways include Interstates 5 and 90. A map of the PSB is provided below in Figure 6-6.

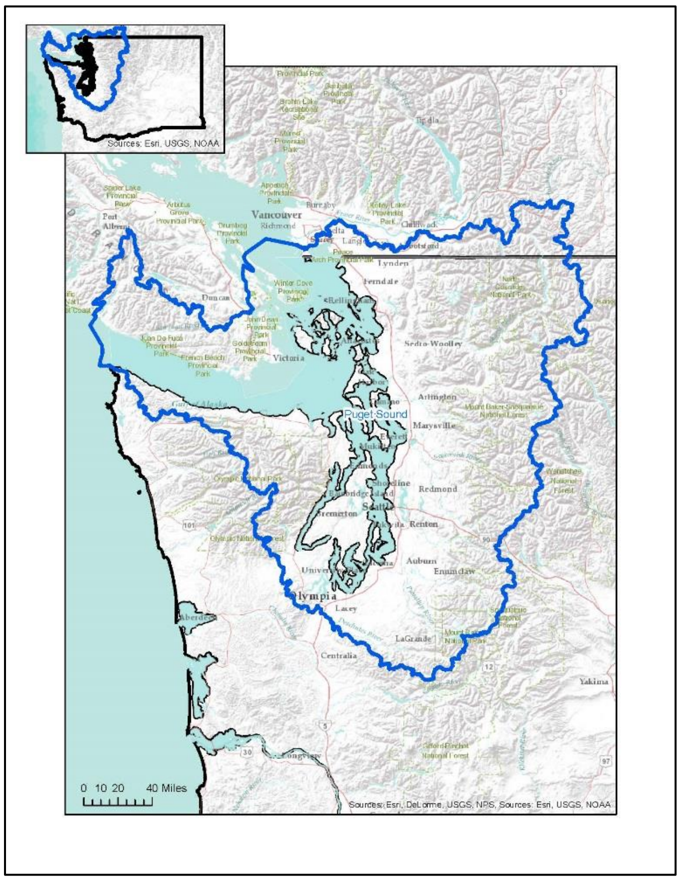

Figure 6-6: Map of Puget Sound Basin

6.7.2 Hydrology

This basin includes rivers and streams draining to Puget Sound. The Puget Sound Basin is the most urbanized basin in the state, and as such, response of this basin to flooding is more severe than in other less-urbanized or undeveloped basins. Higher level of urbanization is associated with more impervious surfaces that in turn yield higher flood peaks and flood volumes. The basin elevations range from over 14,000 feet (Mount Rainier) in the Cascade Mountains to the lowlands at the sea level. The basin's climate, typical for the Pacific Northwest, is characterized by warm and dry summers and wet and mild winters. Ninety (90) percent of precipitation falls between October and May as rain in the lowlands and snow in the mountains with frequent rain-on-snow events throughout the rainy season. Flooding events are typically associated either with prolonged and extensive rainfall or late winter/early spring rains (i.e. pineapple express) coinciding with warm days of snowmelt.

Existing water infrastructure

This basin has wide established water infrastructure including major water supply (storage) and hydroelectric reservoirs such as Ross, Diablo, and Gorge dams, and Baker reservoirs on Skagit River, and Mud Mountain Dam (on the White River) and Howard Hansen Reservoir (on the Green River) in King County. The US ACOE operates navigation locks (Hiram C. Chittenden Locks) on the ship canal constructed in 1931 between Puget Sound and Lake Washington. The Locks is recognized as a Civil Engineering landmark by the American Society of Civil Engineers and is also listed on the National Register of Historic Places[230]. Other water infrastructure in the basin includes storm-drain and sewer distribution systems, wastewater treatment plants, water supply distribution systems, river and port infrastructure supporting river and ship traffic, and infrastructure supporting different flood mitigation measures.

Flood history

The PSB has been subjected to numerous flooding events. Historic floods and snow events in the PCB (according to the NOAA Western Regional Climate Center[231]) are summarized:

- **November 1990 Flood**, causing widespread flooding in northwest Washington. Many rivers (including the Cedar, Snoqualmie, Skykomish, Snohomish, and Stillaguamish Rivers) reached record flood stage.
- **January/February 1916**, when the greatest recorded snowfall (21 inches in 24 hours) fell in Seattle, causing snow drifts of over 5 feet.
- **February 1996**, with widespread regional flooding in Washington, Oregon, and Idaho.

Drought history

The PSB did not experience many droughts in the recorded history. The following droughts have occurred:

- The worst recorded drought in Puget Sound history was in 1976-1977 (NOAA Western Regional Climate Center[232]), when precipitation was significantly below normal levels. This drought caused regional water rationing and power consumption restrictions; the area's ski resorts were closed for most of the season. This drought caused significant economic impacts.
- Statewide 2014-2015 drought, which led to a shortened ski season, extremely low instream flows, and the lowest recorded snowpack in the Cascade Mountains.

[230] https://en.wikipedia.org/wiki/National_Register_of_Historic_Places

[231] http://www.wrcc.dri.edu/extreme-events/washington/

[232] http://www.wrcc.dri.edu/extreme-events/washington/

Washington's governor declared a statewide drought emergency in spring of 2015; however, economic impacts from this drought were not significant, as rains returned in the late summer of 2015 and replenished water supply and minimum instream flows in many rivers.

Climate Change

The Basin is not only subject to direct impacts from climate change, but also to the growing impact from ocean acidification associated with climate change.[233] The 2015 Puget Sound report recognizes the following impacts from climate change (which coincides with projected impacts in other basins):

- Warmer temperatures, more weather extremes, and more droughts;
- Small changes in precipitation, with heavy rainfall becoming more extreme;
- Declining spring snowpack;
- Streamflow flood stages occurring earlier in the year, with an increase in winter flows, decline of summer flows, and increased frequency of floods;
- Sea level rise in coastal areas, with the possible exception of areas such as the northwest Olympic Peninsula (where the land is uplifting); and
- Ocean temperatures are projected to increase by 2 degrees F by the 2040s (in a medium greenhouse scenario alternative).

6.7.3 Economy

The counties that are included in the economic analysis for the PSB are Clallam County, Island County, Jefferson County, King County, Kitsap County, Mason County, Pierce County, San Juan County, Skagit County, Snohomish County, Thurston County, and Whatcom County. Within these counties, the largest notable cities are Seattle, Tacoma, Everett, Bellingham, Olympia, Bremerton, Mount Vernon, and Port Angeles. The primary industries, based on employment, of the counties within the basin include local government, retail trade, health care and social assistance, manufacturing, construction, professional & technical services, and accommodation and food services.

The current (2015) population from census estimates and the most recent county population forecast from OFM is presented in 0 by county and for the overall basin. By far the largest populated basin in Washington state, the total basin population is expected to grow from 4,850,596 (67.6 percent of Washington's population) in 2015 to 5,736,395 (67.1 percent of the state population) in 2036. Currently, nearly half of that population is in King County alone (2,105,100). That share is expected to decrease slightly to just over 41 percent (2,364,682) over the projection period.

[233] Puget Sound Partnership "2015 State of the Sound – Report on the Vital Puget Sound Vital Signs", PSEMP and Puget Sound Partnership report to Washington State legislature.

Table 6-32: OFM Population Projections for PSB

	2015	2017	2018	2019	2020	2025	2030	2035	2036
Washington	7,170,351	7,178,675	7,256,835	7,334,646	7,411,977	7,793,173	8,154,193	8,483,628	8,546,278
Clallam	73,486	72,617	72,956	73,290	73,616	75,022	76,112	76,786	76,893
Island	82,910	81,307	81,796	82,273	82,735	85,073	87,621	90,239	90,848
Jefferson	30,466	31,108	31,405	31,709	32,017	33,678	35,657	37,914	38,349
King	2,105,100	2,051,383	2,070,888	2,090,044	2,108,814	2,196,202	2,277,160	2,350,576	2,364,682
Kitsap	260,131	267,433	270,161	272,865	275,546	289,265	301,642	311,737	313,547
Mason	61,023	64,968	65,816	66,675	67,545	71,929	76,401	80,784	81,616
Pierce	843,954	849,678	858,691	867,659	876,565	923,912	967,601	1,006,614	1,013,921
San Juan	16,320	16,052	16,122	16,189	16,256	16,606	16,939	17,216	17,264
Skagit	122,270	124,246	125,567	126,902	128,249	136,410	144,953	153,632	155,451
Snohomish	772,860	772,428	783,224	794,090	805,015	857,939	908,807	955,281	963,854
Thurston	269,536	275,194	279,516	283,875	288,265	307,930	326,426	343,019	346,059
Whatcom	212,540	216,228	219,209	222,235	225,307	241,138	256,643	271,142	273,911
Total Basin	4,850,596	4,822,642	4,875,351	4,927,806	4,979,930	5,235,104	5,475,962	5,694,940	5,736,395

The economic sector breakdown by employment for the largest industrial sectors in the basin's counties is provided in Table 6-33. Health care and social assistance is the largest employment sector throughout the basin (264,621 in total). Retail trade is also a strong employment sector in all of the counties, providing over 250,000 jobs throughout the basin. The next two largest sectors are accommodation and food services and manufacturing, each providing about 187,500 jobs throughout the PSB.

Table 6-33: 2015 County Employment by Largest Economic Sectors

County	Number of Jobs
Clallam County	
1. Local government	5,783
2. Retail trade	3,308
3. Healthcare and social assistance	2,639
4. Accommodation and food services	2,462
5. Manufacturing	1,159
Island County	
1. Local government	2,877
2. Retail trade	2,121
3. Accommodation and food services	1,882
4. Healthcare and social assistance	1,748
5. Construction	770
Jefferson County	
1. Local government	1,871
2. Accommodation and food services	1,036
3. Retail trade	1,011
4. Healthcare and social assistance	833
5. Manufacturing	544
King County	
1. Healthcare and social assistance	139,850
2. Retail trade	131,946
3. Professional & Technical Services	113,015
4. Manufacturing	106,258
5. Accommodation and food services	103,913
Kitsap County	
1. Healthcare and social assistance	12,512
2. Local government	10,747
3. Retail trade	10,343
4. Accommodation and food services	7,515

County	Number of Jobs
5. Construction	3,798
Mason County	
1. Local government	4,360
2. Retail trade	1,765
3. Manufacturing	1,158
4. Healthcare and social assistance	1,141
5. Accommodation and food services	1,107
Pierce County	
1. Healthcare and social assistance	44,745
2. Retail trade	35,622
3. Local government	33,696
4. Accommodation and food services	26,214
5. Construction	18,743
San Juan County	
1. Accommodation and food services	1,279
2. Retail trade	655
3. Local government	635
4. Construction	596
5. Healthcare and social assistance	395
Skagit County	
1. Local government	9,189
2. Retail trade	6,844
3. Manufacturing	5,740
4. Healthcare and social assistance	5,149
5. Accommodation and food services	4,123
Snohomish County	
1. Manufacturing	63,579
2. Retail trade	34,828
3. Healthcare and social assistance	31,059
4. Local government	30,270
5. Accommodation and food services	21,344

County	Number of Jobs
Thurston County	
1. State government	23,509
2. Healthcare and social assistance	13,338
3. Retail trade	12,138
4. Local government	11,730
5. Accommodation and food services	8,312
Whatcom County	
1. Healthcare and social assistance	11,212
2. Retail trade	10,914
3. Local government	9,706
4. Manufacturing	9,070
5. Accommodation and food services	8,365

Total employment, wage, and number of firms for the basin in 2015 are displayed in Table 6-34, in total and by county. The PSB had an average of over 150,000 firms, providing over $138 billion in wages, for over 2.2 million jobs. Average annual wages by county range between $32,000 in San Juan County and $72,000 in King County.

Table 6-34: 2015 Basin Industry Employment, Wages, and Firms by County

Area	Avg. Firms	Total 2015 wages paid	Average annual employment	Average annual wage
Clallam County	2,329	$813,162,248	22,198	$36,632
Island County	1,904	$553,995,321	15,294	$36,223
Jefferson County	1,092	$296,127,299	8,124	$36,451
King County	79,008	$92,329,315,854	1,274,371	$72,451
Kitsap County	6,282	$3,993,618,130	84,692	$47,155
Mason County	1,275	$519,211,774	13,746	$37,772
Pierce County	20,113	$13,365,313,397	285,425	$46,826
San Juan County	973	$181,443,685	5,551	$32,687
Skagit County	3,840	$2,097,128,328	48,586	$43,163
Snohomish County	18,837	$15,466,202,440	275,524	$56,134
Thurston County	7,601	$4,961,725,373	106,143	$46,746
Whatcom County	6,824	$3,639,737,795	85,726	$42,458
Total	150,078	$138,216,981,644	2,225,380	

6.7.4 Fisheries and Habitat

The WRIAs included in the PSB include the Nooksack, San Juan, Lower Skagit-Samish, Upper Skagit, Stillaguamish, Island, Snohomish, Cedar/Samish, Duwamish/Green, Puyallup/White, Nisqually, Chambers-Clover, Deschutes, Kennedy-Goldsborough, Kitsap, Snohomish-Dosewallips, Quilcene-Snow, Elwha-Dungeness, and Lyre-Hoko. The lowlands of the east side of Puget Sound are highly developed, although the headwaters of the eastern streams largely run through national parks, national forests, and commercial timberland. The western side of Puget Sound is less developed. Smaller communities are present in the lowlands. Most of the area of the basins on the west side of Puget Sound lies within the Olympic National Park and the Olympic National Forest where there is little to no development.

The fish species listed under the ESA include Puget Sound Chinook salmon, Puget Sound steelhead, Hood Canal (only) chum salmon, and bulltrout. At least one of these species is found in all of the WRIAs in Puget Sound except Island and San Juan WRIAs (Table 6-35). Other salmonids common in Puget Sound include chum, coho, pink, and sockeye salmon and cutthroat trout.

Table 6-35: Bull trout, salmon, and steelhead presence in the basins within the PSB[234].

Basin	Chinook (threatened)	Steelhead (threatened)	Chum (not listed except in Hood Canal)	Coho (not listed)	Pink (not listed)	Sockeye (not listed)	Cutthroat (not listed)	Bulltrout (threatened)
Nooksack	X	X	X	X	X		X	
San Juan				X				
Lower Skagit-Samish	X	X	X	X	X		X	X
Upper Skagit	X	X	X		X	X		
Stillaguamish	X	X	X	X	X		X	
Island				X				
Snohomish	X	X	X	X	X		X	X
Cedar/Samish	X	X		X		X		
Duwamish/Green	X	X	X	X				
Puyallup/White	X	X	X	X	X		X	X
Nisqually	X	X	X	X	X		X	
Chambers-Clover		X	X	X			X	
Deschutes		X	X	X			X	
Kennedy-Goldsborough		X	X	X			X	
Kitsap		X	X	X			X	
Snohomish-Dosewallips	X	X	X	X	X			X
Quilcene-Snow		X	X	X			X	
Elwha-Dungeness	X	X	X	X	X		X	X
Lyre-Hoko	X	X	X	X			X	

234 Washington Department of Fish and Wildlife fish inventory maps. https://fortress.wa.gov/dfw/score/score/maps/map_wria.jsp.

Condition of habitat

Habitat conditions vary across the PSB. The greatest impacts to habitat are generally in the vicinity of urban areas (with exceptions). Most of the headwater areas are located in national parks, national forests, and/or commercial timberland. The primary factors impacting habitat varies from basin to basin[235]. Recommendations for future actions listed in NMFS' five year review included the following[236:]

1. Implement Research Monitoring and Evaluation actions to address critical uncertainties.
   - Quantitative analysis of net habitat loss and restoration
   - Assessment of the effectiveness of salmon habitat protection efforts
   - Plan implementation effectiveness
   - Steelhead stock status monitoring; improve lack of data
   - Secure funding for status monitoring for other species
   - Audit effectiveness of regulatory mechanisms and enforcement reporting
   - Need for relative reproductive success, relative fitness, and gene flow studies directed at sub-yearling hatchery program-origin Chinook salmon
   - Identify important gaps in specific watershed chapters of the Puget Sound Chinook salmon recovery plan, e.g., stormwater, floodplain restoration, instream flows, etc.
2. Encourage participation of Federal, state, local and tribal partners in Recovery Plan implementation.
3. Finalize, fund, and implement adaptive management components of recovery plans.
4. Ensure Mid-Hood Canal and Sammamish Chinook salmon population delineations are reviewed in light of new information.
5. Work with FEMA on their implementation of the Puget Sound National Flood Insurance Program Biological Opinion and compliance monitoring of FEMA's program.
6. Develop and implement management solutions to address conflicts between Marine Mammal Protection Act and ESA species (e.g. predation, pile driving).
7. Provide technical support to local entities responsible for development, implementation and enforcement of stormwater management standards consistent with the recovery needs of Puget Sound salmon and steelhead.
8. Complete National Environmental Policy Act (NEPA) and ESA review and determination processes for Puget Sound hatchery salmon and steelhead programs

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[235] NMFS. 2007. Puget Sound salmon recovery plan. NMFS. Seattle, WA. http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/puget_sound/chinook/pugetsoundchinookrecoveryplan.pdf.

[236] NMFS. Undated (thought to be 2016). 5-year review: Summary and evaluation of Puget Sound Chinook, Hood Canal summer chum, Puget Sound steelhead. NMFS. Portland, OR. http://www.nmfs.noaa.gov/pr/pdfs/species/pugetsound_salmonids_5yearreview.pdf.

affecting populations of Puget Sound Chinook salmon, Hood Canal summer-run chum salmon, and Puget Sound steelhead.

Many of these action items address critical uncertainties related to habitat condition and stock abundance and productivity.

Trends

NMFS' five year review summarized the following trends in the listed Puget Sound populations[237:]

Puget Sound Chinook: The escapement abundance of all Puget Sound Chinook salmon populations is well below targeted levels required to meet the criteria for low extinction[238]. In addition, most populations are consistently below the productivity goals identified in the recovery plan[239.] Most populations have declined in total natural origin recruit abundance since the last status review (2005). Several of the risk factors identified in the previous status review are still present, including high fractions of hatchery fish in many populations and widespread loss and degradation of habitat. Over the last five years, the Puget Sound Chinook salmon have made little progress toward meeting the recovery criteria and current trends in abundance are negative. However, available information does not indicate that extinction risk has increased significantly. Puget Sound Chinook remain at moderate risk of extinction.

Hood Canal Summer Chum: The spawning abundance of Hood Canal summer chum has increased since the time of listing, although the recent abundance is down from the previous 5 years. Spawning abundances have remained relatively high compared to the low levels in the early 1990s. The spawning distribution within most streams has been extended further upstream as abundance has increased; however, the Hood Canal summer chum population has not consistently reached the recovery criteria required for delisting. The Hood Canal chum populations remain at moderate risk of extinction.

Puget Sound steelhead: For all but a few populations of steelhead in Puget Sound, estimates of mean population growth rates are declining 3 to 10 percent annually. Steelhead in Puget Sound remain at moderate risk of extinction.

Harvest rates on Puget Sound Chinook salmon are variable across the populations and in recent years have ranged from 20 percent to over 60 percent annually[240]. The recent increases are largely due to higher harvest levels in offshore fisheries. The 2008 Pacific Salmon Treaty includes provisions to reduce the allowable annual catch in the Southeast

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[237] N MFS. Undated (thought to be 2016). 5-year review: Summary and evaluation of Puget Sound Chinook, Hood Canal summer chum, Puget Sound steelhead. NMFS. Portland, OR. http://www.nmfs.noaa.gov/pr/pdfs/species/pugetsound_salmonids_5yearreview.pdf.

[238] NMFS. Undated (thought to be 2016). 5-year review: Summary and evaluation of Puget Sound Chinook, Hood Canal summer chum, Puget Sound steelhead. NMFS. Portland, OR. http://www.nmfs.noaa.gov/pr/pdfs/species/pugetsound_salmonids_5yearreview.pdf.

[239] NMFS. 2007. Puget Sound salmon recovery plan. NMFS. Seattle, WA. http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/puget_sound/chinook/pugetsoundchinookrecoveryplan.pdf.

[240] Northwest Fisheries Science Center. 2015. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest. Northwest Fisheries Sci. Center. Seattle, WA.

Alaskan and West Coast Vancouver Island fisheries by 15 percent and 30 percent, respectively[241]. These provisions are expected to benefit PSB Chinook salmon

There are no directed fisheries for Hood Canal summer chum salmon, although they are taken indirectly in other fisheries. Harvest rates on natural steelhead in recent years have been generally less than 5 percent.

Climate Change

Trends in warming and ocean acidification are highly likely to continue during the next century. Both freshwater and marine productivity tend to be lower in warmer years for most salmonid populations. These trends suggest that the population might decline as mean temperature rises. However, populations residing in rivers and streams that currently are cool and have ample summer flow may have some resilience to climate change provided that water temperatures remain within a range that is suitable for rearing of young salmonids. Where water temperatures are higher under current conditions, warming temperatures are likely to result in decreased availability of habitat over time.

6.7.5 Projects and Needs

A list of infrastructure investment projects and needs are grouped into the different investment categories and summarized below. Other projects are likely to exist within each the basin, but the list included in this report is intended to be representative of basin projects.

Water Supply

The PSB contains some of the largest population centers in the state. Most of these cities experienced significant population growth throughout the 2000s, particularly in Seattle and surrounding areas. Although the recession slowed growth in 2008-2009, the population continues to expand and put stress on the water resources. Given this, most of the ongoing water supply projects, as well as project needs identified for this basin relate to municipal and industrial supplies.

Over $2.3 billion worth of ongoing, future, and proposed projects are identified in the PSB through research and interviews with stakeholders. About $2.2 billion of these investments are related to projects under the various utilities' CIP over the next six to 20 years. At nearly $1 billion (spread out over the next 20 years), the largest investment among the utilities is for the Seattle Public Utilities CIP.

Another major individual project proposed in the PSB is the $80 million Recycled Water Distribution System in East King County. This project proposal would fund a recycled water distribution infrastructure on King County's east side to ensure water resource resiliency for the region. King County has been working with cities, local parks, athletic field managers, and farmers to evaluate the potential of using recycled water for irrigation.

[241] N MFS. Undated (thought to be 2016). 5-year review: Summary and evaluation of Puget Sound Chinook, Hood Canal summer chum, Puget Sound steelhead. NMFS. Portland, OR. http://www.nmfs.noaa.gov/pr/pdfs/species/pugetsound_salmonids_5yearreview.pdf..

Several projects have proven to be technically feasible and have customer and community support, but have been stalled because of limited financing options.[242]

Flood Protection

Within the PSB, the focus of current and future flood reduction projects in the data base is in Snohomish County. According to Will Hall, the Director of Snohomish County Surface Water Management, over $22 million is needed over the next decade for Snohomish County flood reduction, drainage, and failing infrastructure projects. This is roughly $2 million annually to reduce the economic impact of floods within the basin. Other areas have been identified as vulnerable to flooding within this basin, and many stormwater projects will also serve to mitigate the impacts of flooding. Consequently, projects identified have been classified as 'multiple benefit' types of projects. Also, the PSB, and Puyallup in particular has been identified as vulnerable to mudslides (lahars) from Mt. Rainier,[243] but no investment projects were identified for this report.

Stormwater Management

Since the PSB is the most populous basin in Washington, stormwater management is of considerable concern. Over $3.5 billion will be spent in the next three years to maintain and improve stormwater management systems in the PSB. This includes $7.7 million for capital improvements in the City of Fife, $16.4 million for stormwater projects in King County, $6.4 million for stormwater projects in Pierce County, $1.9 million for stormwater projects in Snohomish County, $1.1 million for stormwater projects in Thurston County, and $0.6 million for stormwater projects in Kitsap and Skagit Counties. The City of Oak Harbor will install a $45 million wastewater treatment plant, $22 million will be spent on toxic cleanup in the Puget Sound, $25 million will be spent on roadway realignment along SR-530 and SR-542, $20 million will be spent on a Rainier Valley "wet weather storage" project, and over $35 million is needed annually for storm and wastewater upkeep in the City of Tacoma.

Needs are similarly costly over the next years; reaching close to $1 billion dollars annually for stormwater and wastewater replacement, retrofits, and source control efforts. This is independent of new needs or construction projects that may arise. $860 million of the annual cost is for retrofitting stormwater facilities and conveyance systems for improved treatment in the Green and Duwamish Watershed. Due to the large population of the basin, these costs are not large or surprising.

Fisheries and Restoration

As of 2011, the estimated cost for recovery of listed species was estimated at $1,960 million for the PSB[244]. The majority of the projects funded since 2011 are listed on the Habitat Work Schedule website (http://hws.ekosystem.us/home). Since 2011, $781 million has

[242] Personal communication with Sharman Herrin, Government Relations, King County Wastewater Treatment Division. Email dated October 10, 2016.

[243] See Cakir, Recip, and Timothy Walsh, 2012. Loss Estimation Pilot Project for Lahar Hazards from Mt. Rainier, Washington, Information Circular 113, Washington Division of Geology and Earth Resources, Washington Department of Natural Resources. Available on line at: http://file.dnr.wa.gov/publications/ger_ic113_mt_rainier_lahar_hazards.pdf

[244] Cantry. 2011. Funding for salmon recovery in Washington state. for the Governor's Salmon Recovery Office and the Council of Regional Salmon Recovery Organizations.

been expended on projects in the Subbasin, leaving an estimated cost for recovery of $1,179 million over the next 20 years (Table 6-36). Projects are likely to be implemented as funding becomes available.

Generally, the estimated costs of implementing projects summarized in recovery plans did not include an accurate estimate of the costs of replacing culverts to meet current passage standards. Therefore, the costs listed below likely do not include Washington state Department of Transportation's costs of replacing culverts and upgrading passage at stream crossings. The estimated costs below include only those projects listed at the Habitat Work Schedule. Other projects likely have been implemented through funding sources that are not tracked by those sites, including projects implemented by the U.S. Forest Service, BLM, and private individuals. Additionally, the recovery plan listed numerous projects for which cost estimates were not available. Therefore, the total estimated cost listed below is likely an underestimate. We also note that estimates of project costs developed during the recovery planning process were frequently "ball park" estimates and are subject to change once projects go into detailed planning.

Table 6-36: Estimated costs in $millions for recovery as of 2011, funds allocated since 2011, and estimated remaining cost for recovery of the Puget Sound ESA listed species.

Project type	Estimated Remaining Costs in 2011[245]	Funds Allocated between 2011 and Present[246]	Estimated Remaining Costs as of the end of 2016
Habitat Restoration	1315	563	752
Land and Easement Acquisition	218	111	107
Passage Barrier Retrofits	161	0	161
Total Capital Projects	1694	673	1021
Non-Capital Projects (Operations, RM&E, Outreach)	266	107	159
Total	1960	781	1179

In addition to this, several hatchery renovations are planned totaling $36 million and a little over $51 million in the basin are allocated over the next ten years for the Snohomish County Fish Passage culvert replacement and other projects.[247]

6.7.6 Summary of Basin Water Infrastructure and Fisheries and Habitat Needs

PSB water infrastructure investment needs by type in total and projected through time is presented in Table 6-37. The PSB has the highest dollar value for water infrastructure

245 Cantry. 2011. Funding for salmon recovery in Washington state. for the Governor's Salmon Recovery Office and the Council of Regional Salmon Recovery Organizations.

246 Habitat Work Schedule. Washington State Recreation and Conservation Office and Washington State Governor's Salmon Recovery Office. http://hws.ekosystem.us/home.

247 Personal communication with Will Hall, Director, Snohomish County Surface Water Management. Email dated October 7, 2016.

investment needs of all the Washington state water basins. Total estimated costs in current (2016) dollars is $23.8 billion, with the largest shares for stormwater and water supply projects, with $18.3 billion and $2.3 billion respectively. The largest of the stormwater projects include two projects for the City of Tacoma for annual stormwater and wastewater replacement, totaling $702 million.

Table 6-37: Puget Sound Basin Water Infrastructure Investment Needs Projection by Type

	Millions of Dollars								
Investment Type	**Total**	**2017**	**2018**	**2019**	**2020**	**2025**	**2030**	**2035**	**2036**
Water supply	$2,315	$229	$207	$189	$168	$132	$97	$56	$56
Stormwater	$18,266	$1,081	$906	$909	$906	$904	$904	$904	$904
Flooding	$22	$2	$2	$2	$2	$2	-	-	-
Fish & habitat	$1,278	$111	$64	$64	$64	$64	$59	$59	$59
Multiple	$1,873	$768	$78	$83	$82	$65	$44	$44	$44
Total	$23,754	$2,192	$1,257	$1,247	$1,221	$1,167	$1,103	$1,062	$1,062

- The PSB represents a great diversity of watersheds, with some very rural, some highly urbanized, and some that represent the critical headwaters of the hydrologic system.
- The high degree of urbanized and developed area represents some of the greatest need for infrastructure investment because the development aggravates flooding and stormwater runoff.
- The high degree of urbanized and developed area represents some of the greatest need for infrastructure investment because there is greater demand for water supply, and greater vulnerability to hazards due to the concentration of population and built assets.
- As commented in other basins, the projects identified to improve fish habitat were not based on a true limiting factors analysis, but rather an evaluation of all the potential pathways through which anthropogenic activities could be affecting fish habitat.
- If the limiting factor is related to freshwater habitat, the priority projects would include those that address the limiting factor. In the absence of a true limiting factors analysis, it is impossible to estimate the reduction in fish habitat costs that are possible, but the costs of addressing only the limiting factors is likely to range between zero (0) to fifty (50) percent of the current total estimated costs for fish habitat projects.

6.8 Lower Snake River Basin

The Lower Snake River Basin (LSRB) intersects Idaho, Oregon, and the southeast corner of Washington. The only major city in the region is Pullman, and rivers include the Grande Ronde and the Palouse. Major highways include Highways 12, 95, and 195. A map of the LSRB is provided below in Figure 6-7.

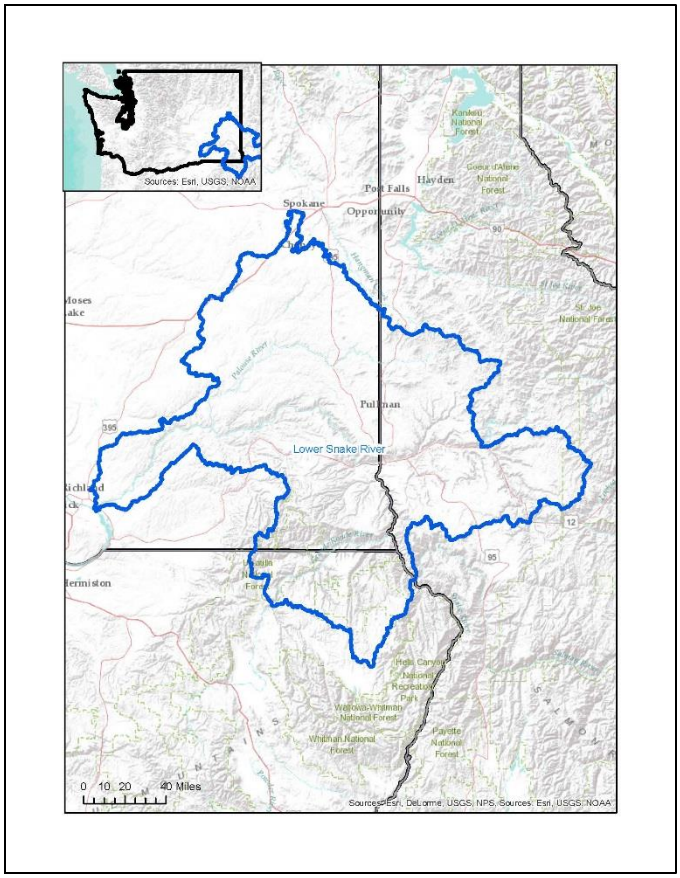

Figure 6-7: Map of Lower Snake River Basin

6.8.2 Hydrology

The LSRB is part of the Columbia River watershed and the Snake River is the largest tributary of Columbia River. Its average discharge at the mouth with the Columbia River constitutes 31 percent of the Columbia's flow at that point. The Snake River originates in Western Wyoming and flows through southern Idaho and Eastern Oregon before entering Washington state. The LSRB includes southeastern Washington and parts of southwest Idaho and northern Oregon. The LSRB watershed elevations vary from over 5,000 feet in the mountains to 350 feet at McNary Dam (at the confluence with Columbia River). Average annual precipitation in this watershed is 20 inches with more rainfall/snow occurring in the mountains. The LSRB experiences long dry summers and relatively dry winters. Air temperature in the basin ranges from 20s degrees F in the winter to over 100 degrees F in the summer. Most of the LSRB consists of wide, arid plains and rolling hills, bordered by high mountains. In the upper parts of the watershed (Blue Mountains), however, the river flows through an area with a distinct alpine climate. There are also stretches where the river and its tributaries have incised themselves into tight gorges.

Existing water infrastructure

The major water infrastructure in the LSRB include the ACOE run-of-the-river dams and locks on the Snake River (at Lower Granite, Little Goose, Lower Monument, and Ice Harbor). Other water infrastructure in the basin include water supply wells and water supply and irrigation distribution systems, and infrastructure supporting Snake River dam operations and river navigation. There are total of fifteen dams along the full length of Snake River.

Flood history

This area experienced numerous more recent flood events:

> The flood stages on Snake River were recorded at the USGS gage at Anatone[248] Washington on June 18, 1974 (4 feet above the flood stage), May 31, 1984 (3.4 feet above the flood stage), June 1, 1986, May 27, 1998, and June 5, 2010. All of the floods are caused and/or directly coincide with the peak of the snowmelt originating from the meltdown and runoff from the Rocky Mountains and other mountains on the Snake River upstream watersheds.

Drought history

This basin is part of the Columbia River Basin, and has been subjected to numerous historic droughts. The following historic droughts were identified (using tree-ring methodology[249]):

- Multi-year drought: 1840 – 1855 – most severe and persistent drought on the record,
- Multi-year droughts 1790-1800, 1840s, 1870s,
- 1-year droughts in 1775, 1805, and 1925,
- 1890s and 1930s – periods of extremely low flows in the river.

The most recent droughts in the LSRB (and throughout Eastern Washington) occurred in 1995 and then in 2014-15. The Snake River water and adjacent groundwater has been extensively used for water supply and irrigation so any potential drought could have an immediate economic impact.

248 USGS gage 13334300 Snake River near Anatone, Washington, http://nwis.waterdata.usgs.gov/wa/nwis/peak?site_no=13334300&agency_cd=USGS&format=html

249 Gedalof, Peterson, and Mantua, Columbia River Flow and Drought since 1750, in Journal of the American Water Resources Association, December 2004, Paper No. 03073, pp. 1- 14.

Climate Change

Climate impact assessments for the LSRB were recently conducted by the UW Climate Impact Group[250], and the US Bureau of Reclamation in 2016[251]. In general, climate impacts coincide with the Columbia River basin climate impacts; however predicted temperature extremes are even higher in the LSRB, and, specifically, the "Snake River Basin would exhibit largest increases in temperature…and these largest increases would occur during summer months." (US Bureau of Reclamation, 2016[252], page ES-5). The US Bureau of Reclamation hydrologic study estimated gradual increases in the Snake River mean annual runoff (4 to 18 percent by 2080). The majority of the annual runoff would increase during the winter (December through March). The spring/early summer runoff (April through July) could either decrease by 4 percent or increase up to 21 percent, due to an estimated decrease in the mean April 1st snow water equivalent by 43 to 80 percent by 2080 (US Bureau of Reclamation, 2016[253], page ES-7).

6.8.3 Economy

The counties that are included in the economic analysis for the LSRB are Asotin, Garfield, and Whitman counties. Within these counties, the largest notable cities are Pullman and Pomeroy. The primary industries, based on employment, of the counties within the basin include healthcare and social assistance, retail trade, state and local government, accommodation and food services, manufacturing, federal government, wholesale trade, agriculture, forestry, fishing, and hunting.

The current (2015) population from census estimates and the most recent county population forecast from OFM are presented in Table 6-38 by county and for the total basin. The total basin population is expected to grow from 72,501 (1.0 percent of Washington's population) in 2015 to 76,297 (0.9 percent of the state population) in 2036. Currently, over 65 percent of that population is in Whitman County (48,177). That share is expected to increase slightly to 68 percent (51,763) over the projection period.

Table 6-38: OFM Population Projections for LSRB

	2015	2017	2018	2019	2020	2025	2030	2035	2036
Washington	7,170,351	7,178,675	7,256,835	7,334,646	7,411,977	7,793,173	8,154,193	8,483,628	8,546,278
Asotin	22,105	21,905	21,954	21,996	22,033	22,196	22,313	22,358	22,364
Garfield	2,219	2,231	2,228	2,225	2,220	2,210	2,202	2,175	2,170
Whitman	48,177	46,822	47,165	47,501	47,826	49,346	50,577	51,563	51,763
Total Basin	72,501	70,958	71,347	71,722	72,079	73,752	75,092	76,096	76,297

250 Van Rheenen, N.T., Palmer,, R.N., Hamlet, A.F., and Lettenmaier, D.P. "Climate Change, fish, agriculture, and power: Impacts and Implications for Future Snake River water resources management", in *Agriculture, Climate, PNW Climate: Hydrology and Water Resources* 2003.

251 US Dept. of Interior, Bureau of Reclamation, Pacific Northwest Office – Managing Water in the West – West-wide Climate Risk Assessment: Columbia River Basin Climate Impact Assessment, Final Report, March 2016.

252 US Dept. of Interior, Bureau of Reclamation, Pacific Northwest Office – Managing Water in the West – West-wide Climate Risk Assessment: Columbia River Basin Climate Impact Assessment, Final Report, March 2016.

253 US Dept. of Interior, Bureau of Reclamation, Pacific Northwest Office – Managing Water in the West – West-wide Climate Risk Assessment: Columbia River Basin Climate Impact Assessment, Final Report, March 2016.

The economic sector breakdown by employment for the largest industry sectors in the basin's counties is provided in Table 6-39. State and local government are the largest employment sectors, providing 5,576 and 3,436 jobs throughout the LSRB. The majority of those jobs are in Whitman County (5,576 state and 2,131 local government jobs). A large share of the state government employment is likely due to Washington State University in Pullman. Health care and social assistance and retail trade are also strong employment sectors, each providing over 2,500 jobs throughout the basin.

Table 6-39: 2015 County Employment by Largest Economic Sectors

County	Number of Jobs
Asotin County	
1. Healthcare and social assistance	1,120
2. Retail trade	1,050
3. Local government	975
4. Accommodation and food services	640
5. Manufacturing	433
Garfield County	
1. Local government	330
2. Federal Government	127
3. Wholesale Trade	91
4. Ag., forestry, fishing, and hunting	55
5. Retail trade	49
Whitman County	
1. State government	5,576
2. Local government	2,131
3. Accommodation and food services	1,643
4. Healthcare and social assistance	1,478
5. Retail trade	1,443

Total employment, wage, and number of firms for the basin in 2015 are displayed in Table 6-40, in total and by county. The LSRB had an average of over 2,000 firms, providing over $1.0 billion in wages, for over 24,600 jobs. Average annual wages by county range between $34,000 in Asotin County and $43,000 in Whitman County.

Table 6-40: 2015 Basin Industry Employment, Wages, and Firms by County

Area	Avg. Firms	Total 2015 wages paid	Average annual employment	Average annual wage
Asotin County	619	$201,371,913	5,836	$34,505
Garfield County	115	$29,748,171	728	$40,863
Whitman County	1,272	$785,114,494	18,076	$43,434
Total Basin	2,006	$ 1,016,234,578	24,640	

6.8.4 Fisheries and Habitat

The LSRB includes the Lower Snake, Upper Snake, and Palouse WRIA. The upper Snake WRIA includes the Tucannon, Asotin, and a portion of the Grand Ronde Rivers. No listed species are known to be present in the lower Snake or Palouse WRIAs[254] with the exception of species present in the mainstem Snake River migrating to upstream watersheds or outmigrating to the ocean. The upper Snake River basin supports populations of bull trout, spring and fall Chinook salmon, and Snake River steelhead, all of which are listed as threatened under the ESA. All the basins also support an assortment of smaller resident fish species.

Condition of habitat

Recommendations for future actions listed in NMFS' five year review included the following:[255]

- Completion, adoption and implementation of a Snake River Recovery Plan for the four ESA-listed Snake River salmon and steelhead species
- Implementation of the 2008 Harvest Biological Opinion,
- Implementation of the new U.S. v. OR Agreement,
- Implementation the 2010 FCRPS Biological Opinion, and the completion of the ESA consultations on the hatchery programs in the Snake River ESUs
- Implement Research Monitoring and Evaluation (RM&E) actions to address critical uncertainties regarding smolt migration timing and mortality, mortality of fish passing through the hydro system, impacts of handling of fish during fish studies, effects of hatchery fish on natural populations, effects of climate change, and effects of adoption of alternative life history patterns in populations.
- Habitat actions recommended to be implemented include continue to focus and prioritize recovery actions on limiting factors, and implement the TMDLs and the Snake River basin adjudication,
- Hatchery actions recommended include evaluate the impacts of other hatchery species releases (both anadromous and resident) on listed populations, and evaluate relative reproductive success and spawner effectiveness of hatchery fish.
- Improve estimates of harvest catch and release impacts.

Many of these recommended actions involve research, monitoring and evaluation to help close critical data gaps.

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[254] Washington Department of Fish and Wildlife fish distribution webpage. https://fortress.wa.gov/dfw/score/score/maps/map_wria.jsp.

[255] NMFS. 2016. 5-year review: summary and evaluation of Snake River sockeye, Snake River spring-summer Chinook,, Snake River fall-run Chinook, Snake River basin steelhead. NMFS. Portland Oregon. http://www.nmfs.noaa.gov/pr/pdfs/species/snakeriver_salmonids_5yearreview.pdf.

Trends

The Asotin population of spring Chinook is considered extirpated (extinct)[256]. The spring-summer Chinook populations in the Tucannon and Grand Ronde Rivers has generally increased over the past several years, although the populations are still small and do not meet targets for population viability defined by NMFS[257].

The abundance of naturally spawning Snake River fall-run Chinook has been gradually, but steadily increasing of the past 15 years. The population currently is considered viable but must meet a standard of highly viable to be eligible for delisting[258]. Delisting would also require that threats have been addressed.

The population of Snake River steelhead in the Grande Ronde has been relatively steady in recent years[259]. No population estimates are available for the other rivers in the Upper Snake WRIA. No trend data were identified for bull trout.

Harvest rates of Snake River spring-summer Chinook are generally less than 14 percent[260]. Harvest rates of the Snake River Fall-run Chinook tend to be between 40 and 50 percent annually, most of which occurs in ocean fisheries. Harvest rates on Snake River steelhead range from 5 to 20 percent.

Climate Change

Trends in warming and ocean acidification are highly likely to continue during the next century. In winter across the west, the highest elevations will shift from consistent longer (>5 months) snow-dominated winters to a shorter period (3-4 months) of reliable snowfall[261.] Watersheds will experience more intense precipitation events with possible shifts in the timing of the most intense rainfall. Warmer summer air temperatures will increase both evaporation and direct heading. When combined with reduced winter water storage, warmer summer air temperatures will lead to lower minimum flows in many basins.

Studies examining the effects of long term climate change to salmon populations have identified a number of ways that climate change is likely to influence salmon sustainability. These include direct effects of temperature such as mortality from heat stress, changes in

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256 NMFS. 2016. 2016 5-year review: Snake River sockeye, Snake River spring-summer Chinook, Snake River fall-run Chinook, Snake River basin steelhead. NMFS. Portland, OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/multiple_species/final_2016_5-yr_review_snake_river_species.pdf.

257 Northwest Fisheries Science Center. 2015. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest. Northwest Science Center. Seattle, WA.

258 Northwest Fisheries Science Center. 2015. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest. Northwest Science Center. Seattle, WA.

259 Northwest Fisheries Science Center. 2015. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest. Northwest Science Center. Seattle, WA.

260 Northwest Fisheries Science Center. 2015. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest. Northwest Science Center. Seattle, WA.

261 NMFS. 2016. 2016 5-year review: summary and evaluation of middle Columbia River steelhead. NMFS. Portland, OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_middle-columbia.pdf. NMFS. 2016. 5-year review: lower Columbia River Chinook salmon, Columbia River chum salmon, lower Columbia River coho salmon, lower Columbia River steelhead. NMFS. Portland OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_lower-columbia.pdf.

growth and development rates, reduced habitat availability due to lower flows and higher water temperatures, reduced disease resistance, and shifts in seasonal timing of important life history events, such as the adult migration, spawn timing, fry emergence timing, and the juvenile migration. The Snake River populations occupy habitat that currently tends to be warmer than desired. Further increases in water temperature are likely to reduce the area of habitat suitable to support salmonid species.

6.8.5 Projects and Needs

A list of infrastructure investment projects and needs are grouped into the different investment categories and summarized below. Other projects are likely to exist within each the basin, but the list included in this report is intended to be representative of basin projects.

Water Supply

There is evidence of some recent water supply concerns in the LSRB, although no infrastructure investment projects have been identified. The primary water supply sources for Pullman and Washington State University (WSU) are the Grand Ronde aquifers. With development in and around Pullman, increasing amounts of water are being extracted from the Grande Ronde aquifers. If surface water was available to recharge these aquifers at a rate equal to extraction, this would not cause concern. However it is not, and water levels in the deep wells providing water for WSU and Pullman have been dropping approximately 1-3 feet annually for decades. Current the recharge rate is very small, and pumping greatly exceeds recharge. This pattern is not sustainable and future efforts to address water supply will be required.

Flood Protection

No projects or needs were identified. There is evidence of some recent flooding in the LSRB, although no infrastructure investment projects have been identified. Asotin County experienced some of its worst flooding ever in 1996, when Asotin Creed and Grande Ronde River overflowed. The Grande Ronde River flooded the Snake River Road up to three feet, and Asotin Creek, a Snake River tributary, topped its levee near the western end of the town of Asotin.

Stormwater Management

Within the LSRB, $13 million will be spent in 2017 for improved stormwater management. $11.7 million of this is for adding a passing lane to US-195, which will alter stormwater flow. The remaining costs are for temperature control in the Palouse River basin, developing wastewater facility plans for Palouse and Odessa, improvements to the stormwater system in Clarkston, and water quality projects in Asotin County.

Fisheries and Restoration

As of 2011, the estimated cost for recovery of listed species was estimated at $248 million for the LSRB[262]. The majority of the projects funded since 2011 are listed on the Habitat Work Schedule website (http://hws.ekosystem.us/home) and the Columbia fish and

[262] Cantry. 2011. Funding for salmon recovery in Washington state. for the Governor's Salmon Recovery Office and the Council of Regional Salmon Recovery Organizations.

Wildlife website (https://www.cbfish.org/). Since 2011, $49 million has been expended on projects in the Lower Snake River Subbasin, leaving an estimated cost for recovery of $199 million over the next 20 years. Projects are likely to be implemented as funding becomes available.

Generally, the estimated costs of implementing projects summarized in recovery plans did not include an accurate estimate of the costs of replacing culverts to meet current passage standards. Therefore, the costs listed below likely do not include Washington State Department of Transportation's costs of replacing culverts and upgrading passage at stream crossings. The estimated costs below include only those projects listed at the Habitat Work Schedule and the Columbia Fish and Wildlife websites. Other projects likely have been implemented through funding sources that are not tracked by those sites, including projects implemented by the U.S. Forest Service, BLM, and private individuals. Additionally, the recovery plan listed numerous projects for which cost estimates were not available. Therefore, the total estimated cost listed below is likely an underestimate. We also note that estimates of project costs developed during the recovery planning process were frequently "ball park" estimates and are subject to change once projects go into detailed planning.

Table 6-41: Estimated costs in $millions for recovery as of 2011, funds allocated since 2011, and estimated remaining cost for recovery of LSRB listed species.

Project type	Estimated Remaining Costs in 2011[263]	Funds Allocated between 2011 and Present[264]	Estimated Remaining Costs as of the end of 2016
Habitat Restoration	143	23	120
Land and Easement Acquisition	25	4	21
Passage Barrier Retrofits	39	20	19
Total Capital Projects	207	47	160
Non-Capital Projects (Operations, RM&E, Outreach)	41	0	41
Total	248	49	201

6.8.6 Summary of Basin Water Infrastructure and Fisheries and Habitat Needs

LSRB water infrastructure investment needs by type in total and projected through time is presented in Table 6-42. Total estimated costs in current (2016) dollars is $214 million, with the largest share for fish and habitat projects, with $201 million. More than one-half of the fish and habitat costs are associated with habitat restoration projects ($120 million).

263 Cantry. 2011. Funding for salmon recovery in Washington state. for the Governor's Salmon Recovery Office and the Council of Regional Salmon Recovery Organizations.

264 Habitat Work Schedule. Washington State Recreation and Conservation Office and Washington State Governor's Salmon Recovery Office. http://hws.ekosystem.us/home. Columbia Basin Fish and Wildlife Program. https://www.cbfish.org/.

Table 6-42: LSRB Water Infrastructure Investment Needs Projection by Type

	Millions of Dollars								
Investment Type	**Total**	**2017**	**2018**	**2019**	**2020**	**2025**	**2030**	**2035**	**2036**
Water supply	-	-	-	-	-	-	-	-	-
Stormwater	$13	$13	-	-	-	-	-	-	-
Flooding	-	-	-	-	-	-	-	-	-
Fish & habitat	$201	$10	$10	$10	$10	$10	$10	$10	$10
Multiple	-	-	-	-	-	-	-	-	-
Total	$214	$23	$10	$10	$10	$10	$10	$10	$10

- Generally, the projects identified to improve fish habitat were not based on a true limiting factors analysis, but rather an evaluation of all the potential pathways through which anthropogenic activities could be affecting fish habitat.
- An analysis of the true limiting factor(s) for this basin and identification of the subset of projects that address the true limiting factors will likely result in a significant reduction in overall expected costs for fish habitat projects.
- Water supply is expected to increase in priority in the future as groundwater supplies are decreasing. As a result, the impact of future drought may be expected to be more severe than in other basins.
- Warm water associated with low flows is expected to increase with a changing climate.

6.9 Yakima River Basin

The Yakima River Basin (YRB) is centrally located within Washington, containing the Kittitas and Yakima Valleys. The basin overlaps Yakima, Benton, and Kittitas counties, and includes the cities of Yakima, Sunnyside, and Richland. The only major river is the Yakima River. Two interstates intersect the region, 182 and 90, with Highway 97 intersecting the basin from north to south. The basin is shown in Figure 6-8.

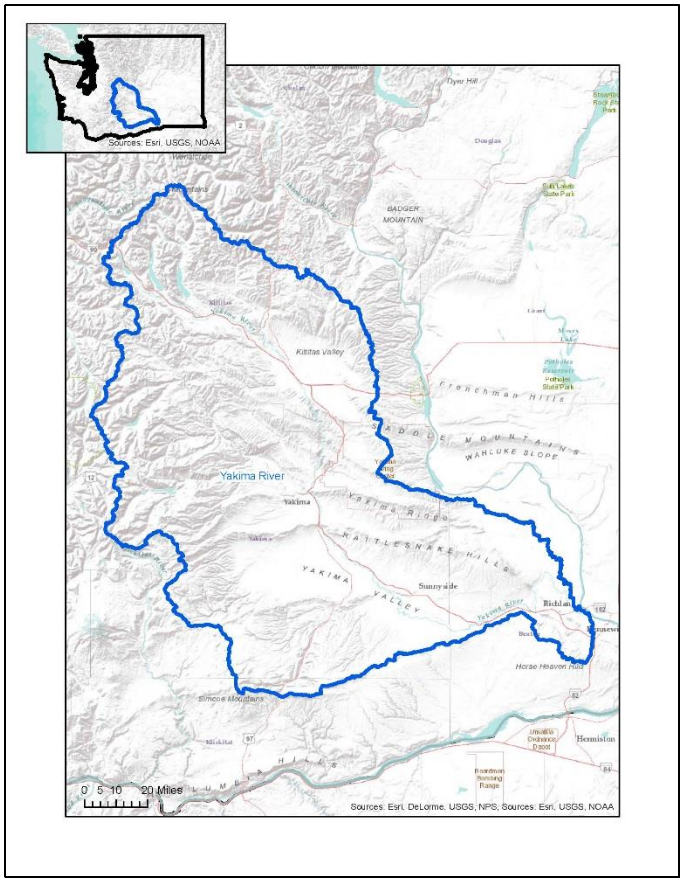

Figure 6-8: Map of Yakima River Basin

6.9.2 Hydrology

The YRB is part of the Columbia River watershed and the Yakima River is one of the major tributaries of the Columbia River. The Yakima River originates in the Cascade Mountains at an elevation of about 3,280 feet near Snoqualmie Pass. The river flows south-southeast through Ellensburg and Yakima, and enters the Columbia River near Richland at an elevation of 340 feet. The YRB encompasses areas designated by Ecology as the Upper Yakima WRIAs 38 and 39 and the Lower Yakima WRIA 37. The dividing line between these northern and southern sections is the confluence of the Naches and Yakima rivers.

Average annual precipitation in this watershed ranges from over 100 inches in the mountains to less than 10 inches in the Yakima Valley. The YRB experiences long dry summers and relatively dry winters with mountain snow (usually above 2,000 feet). The average monthly temperature in the watershed ranges from 20s degrees F in the winter to over 85 degrees F in the summer. The YRB lowlands have a semi-arid climate with vegetation oasis around the rivers and desert-like landscape elsewhere. The upper basin is heavily forested, transitioning from a Douglas fir/alpine forest to ponderosa forests from west to east.

The middle and lower YRB supports extensive irrigation and agriculture.

Existing water infrastructure

The majority of the infrastructure projects in the basin consists of numerous dams and irrigation canals. The major water storage reservoirs are Keechelus dam, Easton diversion dam, Roza diversion dam, Wapato Dam, Sunnyside Dam, Prosser Dam, Wannavish Dam (all on Yakima River), Cle Elum reservoir (on Cle Elum River), Kachess Dam, Bumping Lake Dam (on Bumping River), and Tieton River Dam. Other water infrastructure (such as levees, diversion structures, pipeline, fish passage, groundwater storage reservoirs) supports flood protection and mitigation, irrigation, and water supply. The most comprehensive list of the existing and planned water infrastructure is provided in the YRB Integrated Water Resources Management Plan[265].

The irrigation runoff is in places returned to the river through canal drains. The irrigation system in the YRB causes periods of both severe river dewatering and elevated flows, relative to the historic streamflow regime. As a result, the Yakima River flows are heavily affected by the irrigation system.

Flood history

Flooding events in this basin occur very often. Since available flow records began in 1894, the river exceeded flood stage 47 times (on average once every 3 years) (Yakima County, 2016)[266]. The largest flood on record occurred in 1933 despite completion of the Yakima River reservoir system by the US Bureau of Reclamation. In 1938, designs for a federal levee system on the Yakima River were completed, but this project was not constructed until after World War II, completed in 1948, and repaired and extended the next year after the 1948 flood. These works were constructed to protect the urban areas of Yakima and Terrace Heights. A series of large floods during the 1970s prompted further studies by the ACOE, and the levees earlier constructed under ACOE authority were raised twice in the 1970s and the 1990s. There were three major flood events in the 1990s culminating in the 1996 flood. During this flood, several areas along the ACOE levees protecting the urban area were successfully reinforced in emergency actions.

Drought history

The YRB-IWRM[267] recognizes drought conditions on the watershed when water supply in the basin fall below 70 percent of the normal.[268] The USGS gage recorded the lowest flows in the Yakima River in 1941, resulting in the lowest average annual flow on record (874 cfs at the USGS gage 12479500 - Yakima River at Cle Elum, and 1,335 cfs at the USGS gage 12484500 –Yakima River at Umtanum, Washington). Thus, 1941-42 is considered the driest year on the record in the YRB. Significant drought also occurred in 2001 resulting in the

[265] Bureau of Reclamation (Pacific Northwest Region), and Washington State Department of Ecology, Yakima River Basin Integrated Water Resources Management Plan, Final Programmatic EIS, Benton, Kittitas, Klickitat, and Yakima counties, Yakima, Washington, , Ecology Publication No. 12-12-002, March 2012.

[266] http://www.yakimacounty.us/415/Yakima-River-Basin-Flood-History

[267] Bureau of Reclamation (Pacific Northwest Region), and Washington State Department of Ecology, Yakima River Basin Integrated Water Resources Management Plan, Final Programmatic EIS, Benton, Kittitas, Klickitat, and Yakima counties, Yakima, Washington, , Ecology Publication No. 12-12-002, March 2012

[268] This is slightly different than the State of Washington RCW 43.83B.400, which recognizes a "drought" when water supply for significant portion of geographic area fall below 75 percent of the normal.

second lowest average annual flows. The latest drought in the YRB occurred in 2015. The moderate and significant droughts are summarized below:

- Significant drought 1941-42;
- Moderate droughts in 1977, 1979, and 1987;
- Multi-year moderate to significant drought 1992-1994;
- Severe droughts in 2001 and 2005.

Any drought condition (even minor) has a severe impact on water users in the basin, as the restriction of water use goes into effect when allocated water supply for irrigators are reduced under the drought conditions. Under the 1945 Consent Decree agreement, all entities with grandfathered water rights (non-pro-ratable users) still receive 100 percent of water allocation[269], but new water right users (pro-ratable users) have their water supply reduced (down to 30 percent during severe drought conditions).

Hydrologic Trends

The YRB is in the Columbia River Basin, so it is subject to the same trends in hydrology as discussed for the Columbia Basin, specifically: (a) steady increase in the basin-wide mean annual temperature from the 1890s to 1930s, and then again from the 1980s through 2000s; (b) no significant change in the mean annual precipitation in the basin; (c) a regional trend of increasing precipitation during the wet season and an increase in extreme precipitation events; (d) a decline in spring snowmelt (mostly as a result of increase in temperature, and more precipitation falling as rain than snow in winter), and (e) reduction of annual streamflow during dry years. However, the effects of (d) and (e) resulted only recently in a more localized "drought effect" in the basin, as recognized in the YRB IWRM. Generally one single year drought occurs every 5 years and one multi-year (3-year) drought occurs every 20 years.

Climate Change

Similar to the patterns exhibited in the other parts of the Columbia River Basin, all climate impact scenarios (more warming/dry, more warming/wet, median, less warming/dry, and less warming/wet) suggest increasing temperatures in the YRB over the next century, with the largest increases in temperature occurring in the summer months. Precipitation projections are more varied between the scenarios, but generally suggest wetter conditions in the spring, winter and fall, and drier conditions in the summer (US Bureau of Reclamation, 2016[270], pp. 33).

Drier conditions in the summer could potentially increase frequency of droughts. The YRB-IWRM[271] recognizes that, on average, seven droughts are expected to occur every twenty years (including one single year drought every 5 years, and one multi-year (3-year) drought)

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[269] However, at extreme drought conditions, non-pro-ratable users will also have their water supply reduced, when all non-proratable users have all of their water supply taken

[270] US Dept. of Interior, Bureau of Reclamation, Pacific Northwest Office – Managing Water in the West – West-wide Climate Risk Assessment: Columbia River Basin Climate Impact Assessment, Final Report, March 2016.

[271] Bureau of Reclamation (Pacific Northwest Region), and Washington State Department of Ecology, Yakima River Basin Integrated Water Resources Management Plan, Framework for Implementation Report, prepared by HDR et al., October 2012.

for an average climate change scenario. Periodically wetter conditions in winter could result in more severe storms and larger localized floods.

6.9.3 Economy

The counties that are included in the economic analysis for the YRB are Benton, Kittitas, and Yakima counties. Within these counties, the largest notable cities are Yakima and Ellensburg. The primary industries, based on employment, of the counties within the basin include agriculture, forestry, fishing, and hunting,

The current (2015) population from census estimates and the most recent county population forecast from OFM are presented in Table 6-43 by county and for the total basin. The total basin population is expected to grow from 72,501 (1.0 percent of Washington's population) in 2015 to 76,297 (0.9 percent of the state population) in 2036. Currently, over 65 percent of that population is in Whitman County (48,177). That share is expected to increase slightly to 68 percent (51,763) over the projection period.

Table 6-43: OFM Population Projections for YRB

	2015	2017	2018	2019	2020	2025	2030	2035	2036
Washington	7,170,351	7,178,675	7,256,835	7,334,646	7,411,977	7,793,173	8,154,193	8,483,628	8,546,278
Benton	190,309	190,054	192,631	195,217	197,806	210,803	223,689	236,007	238,393
Kittitas	43,269	43,671	44,195	44,723	45,255	47,949	50,567	53,032	53,518
Yakima	248,830	261,462	264,150	266,780	269,347	282,057	294,445	306,636	309,052
Total Basin	482,408	495,187	500,976	506,720	512,408	540,809	568,701	595,675	600,963

The economic sector breakdown by employment for the largest industry sectors in the basin's counties is provided in Table 6-44. Healthcare and social assistance and local government are the largest employment sectors, each providing over 25,000 jobs throughout the Yakima basin. The majority of those jobs are in Yakima and Benton counties (14,930 and 10,482 respectively for healthcare and social assistance, and 13,147 and 10,466 respectively for local government). Retail trade is also a strong employment sectors, included in the top five industries for all three counties (third in Kittitas and Yakima counties, and fifth in Benton County).

Table 6-44: 2015 County Employment by Largest Economic Sectors

County	Number of Jobs
Benton	
1. Healthcare and social assistance	10,482
2. Local government	10,466
3. Professional & technical services	9,578
4. Administrative and waste services	9,355
5. Retail trade	9,340
Kittitas	
1. Accommodation and food services	2,548
2. Local government	2,156
3. Retail trade	1,664
4. State government	1,481
5. Healthcare and social assistance	1,217
Yakima	
1. Healthcare and social assistance	14,930
2. Local government	13,147
3. Retail trade	10,384
4. Manufacturing	8,279
5. Accommodation and food services	6,054

Total employment, wage, and number of firms for the basin in 2015 are summarized in Table 6-45, in total and by county. The YRB had an average of over 14,000 firms, providing over $8.6 billion in wages, for over 205,000 jobs. Average annual wages by county range between $35,000 in Yakima County and $51,000 in Benton County.

Table 6-45: 2015 Basin Industry Employment, Wages, and Firms by County

Area	Avg. Firms	Total 2015 wages paid	Average annual employment	Average annual wage
Benton County	5,322	$4,252,444,325	82,290	$51,676
Kittitas County	1,400	$524,478,732	14,001	$37,460
Yakima County	7,492	$3,874,499,540	108,833	$35,600
Total Basin	14,214	$8,651,422,597	205,124	

6.9.4 Fisheries and Habitat

The YRB includes the Lower and Upper Yakima WRIAs, and the Naches WRIA. Species listed under the Endangered Species Act include bull trout (threatened) and steelhead (threatened) (Table 6-46). Spring and fall Chinook and coho are also found in the subbasin.

Table 6-46: Bull trout, salmon, and steelhead presence in the basins within the UCRB[272].

	Bull Trout (threatened)	Steelhead (threatened)	Spring Chinook (not listed)	Fall Chinook (not listed)	Coho (not listed)
Lower Yakima	X	X		X	X
Upper Yakima	X	X	X		
Naches	X	X	X		

Condition of habitat

Human activities acting in concert with natural occurrences (e.g., floods, drought, fires, wind, etc.) within the YRB have impacted habitat conditions. Several water storage (irrigation) dams owned by the BLM are located within the YRB. Four of the reservoirs were originally natural lakes and historically supported sockeye salmon and other anadromous and resident fish[273]. The provision of fish passage at five dams has recently been considered[274] (see Table 4-43), feasibility evaluations have focused on Bumping Lake and Cle Elum Dams. The dams in the YRB have changed the hydrograph in the river; winter flows are captured in the reservoirs and captured waters are released in summer to provide flows for irrigation[275].

Water quality and quantity have also been affected by land-use and management activities. Loss of large woody debris and floodplain connectivity may have reduced overwinter habitat for salmon, steelhead, and bull trout in the larger rivers. The EDT model[276] developed for the YRB indicated that habitat under current conditions has the potential to support more than 3 times the current steelhead population, suggesting that freshwater habitat is not limiting in this basin. EDT model estimates can contain significant error since most of the parameters input into the model are based on best professional estimates and not data measured in the field. Therefore, there is uncertainty regarding the current carrying capacity in the basin as predicted by the EDT model.

272 Washington Department of Fish and Wildlife fish inventory maps. https://fortress.wa.gov/dfw/score/score/maps/map_wria.jsp.

273 Bureau of reclamation webpage; https://www.usbr.gov/pn/about/washington.html.

274 Bureau of Reclamation. 2008. Cle Elum and Bumping Lake Dams fish passage facilities planning report – draft. Bur. Reclamation.. Yakima WA. https://www.usbr.gov/pn/studies/fishpassage/planningreports/draftplanningreport.pdf.

275 NMFS. 2016. 2016 5-year review: summary and evaluation of middle Columbia River steelhead. NMFS. Portland, OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_middle-columbia.pdf.

276 Yakima Basin Fish & wildlife Recovery Board. 2009. 2009 Yakima steelhead recovery plan. Extracted from the 2005 Yakima subbasin salmon recovery plan with updates. http://www.ybfwrb.org/.

Table 6-47: U.S. Bureau of Reclamation dams in the YRB. (source: Bureau of reclamation webpage; https://www.usbr.gov/pn/about/washington.html).

Dam	Tributary Location	Passage Provided	Notes
Bumping Lake	Naches	Under consideration	Natural Lake originally Enlargement of the reservoir in planning phases
Kacheelus	Yakima	Under consideration	Natural Lake originally
Kachess	Kachess	Under consideration	Natural Lake originally
Cle Elum	Cle Elum	Under consideration	Natural Lake originally
Tieton	Tieton	Under consideration	
Clear Creek	North Fork Tieton	Yes[277]	
Easton Diversion	Yakima, near Easton	Yes	
French Canyon	Cowiche	No	
Roza Diversion	Diverts from Yakima	Yes	

Source: Bureau of reclamation webpage; https://www.usbr.gov/pn/about/washington.html

Habitat restoration and protection actions have been implemented to improve degraded habitat conditions and restore fish passage. These efforts expected to benefit the survival and productivity of the targeted populations, however, evidence demonstrating that improvements in habitat conditions have led to improvements in population abundance and/or productivity is lacking.

NMFS' most recent 5-year review[278] identified the following as specific areas of concern:

- Increase summer flows through modification of dam operations and irrigation efficiencies;
- NMFS and the Bureau of Reclamation complete the consultation on Bureau of Reclamation operations in the YRB;
- Hatchery managers reduce the extent of spawning by hatchery fish, especially out-of-DPS hatchery fish, in natural spawning areas within the DPS;
- Continue to implement actions that restore historical passage over dams;

[277] Thomas, J.A., P. Monk, and A. Thomas. 2013. Clear Creek Dam fish passage assessment. First annual progress report. USFWS and USBR. Yakima WA. https://www.usbr.gov/pn/programs/yrbwep/phase2/clearcreek/ccfinalrpt.pdf.

[278] NMFS. 2016. 2016 5-year review: Summary & evaluation of upper Columbia River steelhead upper Columbia River spring-run Chinook salmon. NMFS. Portland, OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_upper-columbia.pdf.

- State and tribal fisheries co-managers continue to develop annual estimates of wild steelhead escapement, and evaluate the effects of hatchery releases on the production of wild steelhead in the Yakima River.
- Continue to implement actions to reduce stream temperature in the Yakama River.

Trends

In their latest 5-year review, NMFS found that natural origin steelhead abundance has increased since the previous 5-year review was completed. However abundance continues to be very low relative to the total amount of habitat available. NMFS' overall viability ratings improved from maintained status to viable for the Satus Creek and Toppenish Creek populations (located in the Lower Yakima WRIA), but remained at maintained status for the Naches River and at high risk for the Upper Yakima River population. Harvest rates are less than 10 percent annually.

Climate Change

Trends in warming and ocean acidification are highly likely to continue during the next century. In winter across the west, the highest elevations will shift from consistent longer (>5 months) snow-dominated winters to a shorter period (3-4 months) of reliable snowfall.[279] Watersheds will experience more intense precipitation events with possible shifts in the timing of the most intense rainfall. Warmer summer air temperatures will increase both evaporation and direct heading. When combined with reduced winter water storage, warmer summer air temperatures will lead to lower minimum flows in many basins.

Studies examining the effects of long term climate change to salmon populations have identified a number of ways that climate change is likely to influence salmon sustainability. These include direct effects of temperature such as mortality from heat stress, changes in growth and development rates, reduced habitat availability due to lower flows and higher water temperatures, reduced disease resistance, and shifts in seasonal timing of important life history events, such as the adult migration, spawn timing, fry emergence timing, and the juvenile migration. Populations occupying habitats with cool water and plenty of flow may be somewhat resilient to changes in climate; however, populations occupying habitats that are currently warm and/or that have low flow will likely have less habitat available as the climate warms.

6.9.5 Projects and Needs

A list of infrastructure investment projects and needs are grouped into the different investment categories and summarized below. Other projects are likely to exist within each the basin, but the list included in this report is intended to be representative of basin projects.

[279] NMFS. 2016. 2016 5-year review: summary and evaluation of middle Columbia River steelhead. NMFS. Portland, OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_middle-columbia.pdf. NMFS. 2016. 5-year review: lower Columbia River Chinook salmon, Columbia River chum salmon, lower Columbia River coho salmon, lower Columbia River steelhead. NMFS. Portland OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_lower-columbia.pdf.

Water Supply

The YRB is an agriculture-rich region in central Washington state that contains the largest agricultural economy in the state. Most crops in the basin are irrigated with the Yakima River Reservoir system, which supplies irrigation water to over 180,000 irrigated hectares (450,000 acres). Thirty-four percent of the irrigated land in the three counties included within the basin is planted in tree crops and vineyards. The remainder is mostly planted in forage, pasture, and annual vegetable and field crops, but also includes specialty crops such as mint and hops.[280] The U.S. Bureau of Reclamation operates a system of five reservoirs that supply water to the basin. Much of the basin's runoff is derived from mountain snowpack and the reservoirs are small enough that they generally fill in the springtime of most years. Climate change is expected to cause continued decline in snowpack and earlier snowmelt resulting in reduced water supplies, a process that is already underway. The 2015 drought is one example, in which reduced spring snowmelt resulted in curtailment of water deliveries in the basin, especially to junior water rights holders.

The two main sources of project needs identified in this basin are the 2011 Yakima River Basin Integrated Water resource Management Plan and the City of Yakima.

Yakima River Basin Integrated Water Resource Management Plan

The Yakima River Basin Integrated Water Resource Management Plan (Integrated Plan or YBIP)[281] is the result of many years of effort by a number of concerned entities to address current water supply problems and anticipated future climate change-related impacts. The development of this Integrated Plan was initiated in 2009, when Washington state Department of Ecology (Ecology) and U.S. Bureau of Reclamation brought representatives from the Yakama Nation, irrigation districts, environmental organizations, and federal, state, county, and city governments together to form the Yakima River Basin Water Enhancement Project (YRBWEP) Working Group. The goal of this was to help develop a consensus-based solution to the basin's water problems. This group worked over the next 18 months to develop the Integrated Plan.

The proposed Integrated Plan represents a comprehensive approach to water management and habitat enhancement in the YRB. It is intended to restore ecological functions in the Yakima River system and to provide more reliable and sustainable water resources for the health of the riverine environment, as well as agriculture, municipal and domestic water users. The Integrated Plan offers a package of projects to meet these needs while anticipating changing water uses and effects of predicted climate change on water resources in the basin.

The Integrated Plan includes the following seven elements:

- Fish Passage
- Fish Habitat Enhancement

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280 U.S. Department of Agriculture (2004) 2002 Census of Agriculture. Washington State and County Data, Volume 1, Geographic Area Series, Part 47. AC-02-A-47. U.S. Department of Agriculture, Washington, D.C., pp 483

281 U.S. Bureau of Reclamation and Washington State Department of Ecology. 2011. *Yakima River Basin Study - Volume 1 - Proposed Integrated* Water Resource Management Plan. April. Available at http://www.ecy.wa.gov/programs/wr/cwp/ybip.html OR http://www.usbr.gov/pn/programs/yrbwep/2011integratedplan/plan/integratedplan.pdf

- Modifying Existing Structures and Operations
- Surface Storage
- Market-Based Reallocation
- Groundwater Storage
- Enhanced Water Conservation

Table 6-48 presents the actions/projects proposed in the Integrated Plan, along with the estimated costs associated with these. The total base cost of implementing the YBIP was estimate at approximately $4 Billion. A large portion of these costs are associated with the dams and storage projects, with the most expansive project, Wymer Dam, estimated to cost over $1.6 billion. This is followed by the enlargement of Bumping Lake Reservoir, with an estimated cost of about $403 million.

Other Projects Identified in the Yakima Basin

In addition to projects in the YBIP, the City of Yakima has identified the following water supply projects as its current needs. These amount to a total of $40 Million in 2016 dollars:[282]

Ageing Infrastructure Replacement (Water Supply and Management): Replace about 200,000 feet of water distribution main lines that are either reaching the 100 year make or are already past 100 years. The normal life of these is 50 years. This will cost about $20 Million in 2016 dollars. Such projects are typically financed through a low interest Public Works Trust Fund Loan, but the legislature took the loan funds out of this source. If these are not replaced, there will be damage to property when any main line has a failure and breaks, as that water will damage the street, sidewalks, curb and gutter, over task the stormwater system, flush mud into stormwater, and cause damage to private property. It will also cause disruption in water service, including firefighting water.

Nelson Dam Refurbishment (both a Water Supply and Management and a Flood Management project): Replace a concrete ogee dam with a roughened channel type structure. This will cost about $12 Million in 2016 dollars, and the city is looking for a combination of self-fund and grants from any source to insure delivery of irrigation water to citizens of Yakima. It will also provide vastly improved flood conveyance.

Aquifer Storage and Recovery for Yakima (Water Supply and Management): Add two wells for recharge and recovery of drinking water. This will cost about $8 Million in 2016 dollars. These will provide water to meet the drinking and firefighting needs of Yakima during droughts and other water supply challenges due to climate change.

282 Personal communication with David Brown, Water/Irrigation Manager, City of Yakima. Email dated September 23, 2016.

Table 6-48: Elements and Associated Actions included in the Integrated Plan and Cost Estimates

Elements and Associated Actions included in the YBIP (Table 1-1 of YBIP)		Cost Estimates (Table 3-1 of YBIP)			
Action	Description	Construction Plus Non Contract Costs (in Millions of 2011 Dollars)			Annual O & M (in Millions of 2011 Dollars)[1]
		Base Cost	Range		
			Lower	Upper	
Fish Passage					
Clear Creek Dam	Improve upstream and downstream fish passage at Clear Lake	$3.0	$2.4	$4.2	$0.07
Cle Elum Dam	Add upstream and downstream fish passage facilities at other dam sites	$87.6	$70.0	$122.6	$0.30
Bumping Dam		$26.6	$21.3	$37.3	$0.30
Tieton Dam Keechelus Dam Kachess Dam		$292.5	$234.0	$409.5	$0.90
Structural and Operational Changes					
Raise Pool at Cle Elum Dam	Three-foot increase in storage pool elevation	$16.8	$13.5	$23.6	$0.00
KRD (Kittitas Reclamation District) Canal Changes	Reduce seepage and enhance tributary flows	$35.9	$28.7	$50.3	$0.15
Keechelus to Kachess Pipeline	Optimize storage between two reservoirs	$190.7	$152.5	$266.9	$0.09
Subordinate Power at Roza Dam and Chandler Power Plants	Reduce water diversions to support fish migration				
Wapatox Canal Improvements	Improve efficiency and consolidate diversions	$82.1	$65.7	$115.0	$0.21
Surface Water Storage					
Wymer Dam	New off-channel reservoir (162,500 acre-feet). Also investigate removal of Roza Dam	$1,638.8	$1,311.1	$2,294.4	$4.05
Lake Kachess Inactive Storage	Tap inactive storage volume (up to 200,000 acre-feet)	$253.8	$203.1	$355.3	$0.28
Enlarged Bumping Lake Reservoir	Enlarge reservoir to 190,000 acre-feet	$402.5	$322.0	$563.5	$0.21
Columbia River Pump Exchange with Yakima Basin Storage	Conduct feasibility study; and periodically evaluate need for additional supplies	$4.1	$3.3	$5.7	$0.00

Elements and Associated Actions included in the YBIP (Table 1-1 of YBIP)		Cost Estimates (Table 3-1 of YBIP)			
Action	Description	Construction Plus Non Contract Costs (in Millions of 2011 Dollars)			Annual O & M (in Millions of 2011 Dollars)[1]
		Base Cost	Range		
			Lower	Upper	
Groundwater Storage					
Shallow Aquifer Recharge	Late winter/early spring infiltration prior to storage control				
Aquifer Storage and Recovery	Off-season recharge of municipal supplies				
Habitat Protection and Enhancement					
Mainstem Floodplain Restoration	Program to fund a range of fish habitat projects	$270.0	$216.0	$378.0	$0.50
Tributaries Habitat Enhancement	Program to fund a range of fish habitat projects	$180.0	$144.0	$252.0	$0.00
Targeted Watershed Protection and Enhancements	Program to acquire and protect sensitive lands, including aquatic and terrestrial habitats				
Enhanced Water Conservation					
Agricultural Water Conservation	Program to fund a range of projects	$400.0	$320.0	$560.0	$0.00
Municipal Water Conservation	Program to fund a range of projects and encourage conservation by residents	N/A	N/A	N/A	$1.00
Market Reallocation					
Near-term Effort Long-term Effort	Reduce barriers to trading Additional steps to reduce barriers	$2.0	$1.6	$2.8	$0.20
ADDITIONAL FROM TABLE 3-1 THAT WERE NOT IN TABLE 1-1					
Fish Passage at Box Canyon Creek		$1.2	$0.9	$1.6	$0.03
Groundwater Infiltration (Pilot study)		$4.7	$3.7	$6.5	$0.00
Groundwater Infiltration (Full Scale)		$98.2	$54.3	$163.6	$2.15
OTHERS NOT IN IP TABLE 1-1 BUT IN WSU BCA					
Kachess Drought Relief Pumping Plant					
TOTAL		***$3,990***	***$3,168***	***$5,613***	***$10***

Source: U.S. Bureau of Reclamation and Washington state Department of Ecology. 2011. *Yakima River Basin Study - Volume 1 - Proposed Integrated Water Resource Management Plan*. April. Available at http://www.ecy.wa.gov/programs/wr/cwp/ybip.html OR http://www.usbr.gov/pn/programs/yrbwep/2011integratedplan/plan/integratedplan.pdf

Flood Protection

Within the YRB, there is considerable need for investment in flood protection projects, particularly around Naches. In 2016, a $1.5 million levee for floods, fish, and outfall optimization was constructed in Naches, according to Darcy Batura, the Lead Entity Coordinator for Salmon Recovery at the Yakima Basin Fish and Wildlife Recovery Board.

Within the next twenty years, multiple projects totaling $155 million have been identified in the Yakima County 2016 Flood Risk 20-year CIP. These projects included improved water management projects in Naches ($21 million), a dam project in Gleed ($23 million), and the replacement of infrastructure and levees in gap crossings ($62 million) and the Lower Yakima ($36 million). These projects result in a roughly $8 million cost annually for flood hazard mitigation projects in the YRB.

Stormwater Management

Close to $8.1 million will be spent in 2017 on stormwater improvement projects in the YRB. The majority of this cost is $6.2 million for wastewater sustainability improvements in Kennewick. $1.2 million is for sewer improvement, $0.5 million is for creek relocation and restoration, and the rest is for developing sewer plans and water consolidation.

Fisheries and Restoration

As of 2011, the estimated cost for recovery of listed species was estimated at $524 million for the MCRB[283]. This estimate included the YRB and the MCRB as delineated in this report. We were not able to separate the 2011 estimates into the two Subbasins. Based on a review of the Middle Columbia Steelhead Recovery Plan action items, the majority of the 2011 costs are likely associated with actions to be completed in the YRB. The majority of the projects funded since 2011 are listed on the Habitat Work Schedule website (http://hws.ekosystem.us/home) and the Columbia fish and Wildlife website (https://www.cbfish.org/). Since 2011, $17.9 million has been expended on projects in the MCRB and YRB, combined. Funds expended solely in the YRB totaled $9.5 million. Subtracting the funds expended in the MCRB and YRB from the 2011 estimate of cost for recovery, the estimated costs to complete projects in the MCRB and YRB, combined, is $501 over the next 20 years (Table 6-49). Projects are likely to be implemented as funding becomes available.

Generally, the estimated costs of implementing projects summarized in recovery plans did not include an accurate estimate of the costs of replacing culverts to meet current passage standards. Therefore, the costs listed below likely do not include Washington state Department of Transportation's costs of replacing culverts and upgrading passage at stream crossings. The estimated costs below include only those projects listed at the Habitat Work Schedule and the Columbia Fish and Wildlife websites. Other projects likely have been implemented through funding sources that are not tracked by those sites, including projects implemented by the U.S. Forest Service, BLM, and private individuals. Additionally, the recovery plan listed numerous projects for which cost estimates were not available. Therefore, the total estimated cost listed below is likely an underestimate. We also note that

[283] Cantry. 2011. Funding for salmon recovery in Washington state for the Governor's Salmon Recovery Office and the Council of Regional Salmon Recovery Organizations.

estimates of project costs developed during the recovery planning process were frequently "ball park" estimates and are subject to change once projects go into detailed planning.

Table 6-49: Estimated costs in $millions for recovery as of 2011, funds allocated since 2011, and estimated remaining cost for recovery of Middle Columbia and Yakima (combined) steelhead.

Project type	Estimated Remaining Costs in 2011[284]	Funds Allocated between 2011 and Present[285]	Estimated Remaining Costs as of the end of 2016
Habitat Restoration	232	18	214
Land and Easement Acquisition	93	2	91
Passage Barrier Retrofits	86	0	86
Total Capital Projects	411	21	390
Non-Capital Projects (Operations, RM&E, Outreach)	113	2	111
Total	524	23	501

6.9.6 Summary of Basin Water Infrastructure and Fisheries and Habitat Needs

YRB water infrastructure investment needs by type in total and projected through time is presented in Table 6-50. Total estimated costs in current (2016) dollars is $2.4 billion, with the largest shares for Water Supply and Fisheries projects, with $1.7 billion and $0.5 billion respectively. $1.4 billion of the $1.8 billion water supply needs is for surface water storage.

Table 6-50: YRB Water Infrastructure Investment Needs Projection by Type

	Millions of Dollars								
Investment Type	**Total**	**2017**	**2018**	**2019**	**2020**	**2025**	**2030**	**2035**	**2036**
Water supply	$1,733	$80	$48	$48	$48	$48	$116	$116	$116
Stormwater	$8	$8	-	-	-	-	-	-	-
Flooding	$156	$9	$8	$8	$8	$8	$8	$8	$8
Fish & habitat	$502	$25	$25	$25	$25	$25	$25	$25	$25
Multiple	-	-	-	-	-	-	-	-	-
Total	$2,399	$123	$80	$80	$80	$80	$148	$148	$148

284 Cantry. 2011. Funding for salmon recovery in Washington state. for the Governor's Salmon Recovery Office and the Council of Regional Salmon Recovery Organizations.

285 Habitat Work Schedule. Washington State Recreation and Conservation Office and Washington State Governor's Salmon Recovery Office. http://hws.ekosystem.us/home. Columbia Basin Fish and Wildlife Program. https://www.cbfish.org/.

- The YBIP represents a coordinated effort to address all water infrastructure needs in the basin. It is unique in this and shows a promising strategy for other basins in terms of developing support for water infrastructure investment.
- The YRB is near to completion of a basin-wide water rights adjudication process that may be a precursor to coordinated planning at that scale. The adjudication process not only resolves questions of water rights, but also demands that research and documentation of water use be developed and verified.
- The EDT model completed for the YRB suggests that there is suitable habitat to support more than three times the current population of steelhead; suggesting that freshwater habitat is not limiting. Given the uncertainty inherent in the EDT modeling process, the accuracy of the EDT estimates is uncertain. The data from the Fish Passage Center (www.fpc.org) indicates that tens of thousands of steelhead disappear between Bonneville and McNary dams. The fate of these fish is unknown.
- This situation was addressed in NMFS' Middle Columbia River 5-year review and was identified as an area in need of further evaluation. It is possible that salmon production in the YRB is not limited by freshwater habitat but by other out-of-basin influences. Further analysis of limiting factors would provide greater clarity regarding the contribution of habitat degradation to the current population size. If the factor limiting the population is determined to be some factor other than freshwater habitat, the estimated costs for habitat restoration discussed above may be unnecessary.
- Changing climatic conditions in this basin suggest longer and drier summers paired with more intensive rains in winter and therefore more flooding.
- Although going forward with planned infrastructure investment has been questioned by many stakeholders based on the idea that investment will further harm fish populations, the many permitting processes (such as hydraulic project approval through WDFW and the ACOE) will ensure no harm is done to listed species.

7. STATEWIDE RESULTS AND DISCUSSION OF BENEFITS

The results of the basin by basin analysis to the state as a whole are presented in this chapter. The significant cost of these water infrastructure investments and habitat restoration needs also should be understood in terms of the economic benefits or gains to the state. Where analyses have been completed, the economic benefits are reviewed or evaluated. Otherwise a general discussion of benefits is provided at the basin level.

Table 7-1 shows the number of infrastructure projects by basin and by investment type. The basins with the greatest water supply needs include Puget Sound and Upper Columbia (21 and 11 respectively), with Puget Sound requiring the largest number of stormwater project investments by far at 139. Flooding project needs are greatest in the Washington Coastal basin (which includes the Chehalis basin), with 36 projects. Fishery and habitat projects have all been primarily summed into four categories for each basin, with no fisheries projects in the Kootenai-Pend Oreille-Spokane basin. Some basins include additional hatchery projects not included in the four general categories. The costs of the various types of projects are commensurate with the number of projects by basin, are shown in Table 7-2. The total cost is $32.7 billion over the 20 year forecast between 2017 and 2036. Puget Sound basin has the highest share of the cost at $23.8 billion, the majority of which is for stormwater projects ($18.2 billion). The Yakima basin has the second highest cost at $2.4 billion, with nearly $2 billion of that for water supply projects.

Table 7-1: Number of Washington State Water Infrastructure Investment Projects Analyzed by Type and Basin

Investment Type	Yakima	Washington Coastal	Upper Columbia	Puget Sound	Middle Columbia	Lower Columbia	Lower Snake	Kootenai-Pend Oreille-Spokane	Multi-Basin	Total State
Water supply	8	1	11	21	8	2			38	119
Stormwater	14	23	27	139	7	15	11	20	25	281
Flooding	10	36	0	1	0	0	0		1	48
Fish & habitat	4	5	4	16	4	5	4		0	42
Multiple				47					17	64
Total	38	65	42	224	19	22	15	20	81	524

Table 7-2: Total Washington State Water Infrastructure Investment Needs Identified by Type and Basin ($ in millions)

Investment Type	Yakima	Washington Coastal	Upper Columbia	Puget Sound	Middle Columbia	Lower Columbia	Lower Snake	Kootenai - Pend Oreille-Spokane	Multi-Basin	Total State
Water supply	$1,733	$3	$35	$2,315	$766	$179	-	-	$299	$5,330
Stormwater	$8	$19	$8	$18,266	-	$7	$13	$11	$361	$18,694
Flooding	$156	$1,181	-	$22	-	-	-	-	$35	$1,395
Fish & habitat	$502	$598	$844	$1,278	-	$1,252	$201	-	-	$4,675
Multiple	-	-	-	$1,873	$5	-	-	-	$754	$2,632
Total	**$2,399**	**$1,802**	**$886**	**$23,754**	**$771**	**$1,439**	**$214**	**$11**	**$1,449**	**$32,765**

Washington state water infrastructure investment needs by type in total and projected through time for all basins is presented in Table 7-3. Total estimated costs in current (2016) dollars is $32.7 billion, with the largest shares for stormwater and water supply projects, with $18.7 billion and $5.3 billion respectively.

Table 7-3: Total Washington State Water Infrastructure Investment Identified Needs Projected by Type

	Millions of Dollars								
Investment Type	**Total**	**2017**	**2018**	**2019**	**2020**	**2025**	**2030**	**2035**	**2036**
Water supply	$5,370	$1,381	$276	$257	$236	$191	$221	$174	$174
Stormwater	$18,694	$1,502	$906	$910	$906	$904	$904	$904	$904
Flooding	$1,395	$138	$67	$67	$67	$67	$65	$65	$65
Fish & habitat	$4,675	$284	$234	$234	$234	$234	$229	$229	$229
Multiple	$2,632	$1,527	$78	$83	$82	$65	$44	$44	$44
Total	$32,765	$4,832	$1,560	$1,551	$1,524	$1,462	$1,462	$1,416	$1,416

A wide variety of economic benefits are associated with the collection of water infrastructure projects that needed within Washington state. As discussed in Chapters 2 and 3 of this report, some of these are difficult to measure especially as they relate to the value of ecosystem services and environmental and habitat preservation. Some of the reasons are that environmental quality doesn't often have a convenient price associated with it and so economists often measure the marginal 'willingness to pay' by communities to estimate the equivalent monetary values for ecological services. The other difficulty is that when ecological services are lost or become scarce, their marginal value increases and so there could be a perverse economic result that economic value increases as, for example, as fishery stocks become more scarce. Floodplains are another ecological commodity for which there are no good economic estimates of the value in terms of ecosystem services that are provided by the floodplain. Still we do know that floodplains improve water quality, reduce flooding, and support aquifer recharge and these functions are lost when the floodplain are lost. So wherever possible, measuring these losses and gains is key to understanding the economics of water infrastructure – even when monetary estimates of value are uncertain.

The infrastructure projects described in Chapter 6 are at best a representative collection of water resource investment projects. Following the general guidance provided by the PR&Gs, prior economic analyses, and the most widely accepted approaches to measuring benefits of water infrastructure investment, this chapter provides an assessment of the economic consequences (both negative and positive) of the representative infrastructure projects in the database. Consistent with appropriate measurement, it is first key to understand what would happen in the absence of investment.

7.1 Without Project Conditions

The categories included in this study (water supply, flood protection, stormwater, and fish) are interrelated and it is important that decision-makers consider the positive externalities associated with their investment. For example, by investing in improved stormwater management, one is also investing in improving water quality, which is beneficial to fish, and is also investing in improved flood protection management. These multiple benefits are further realized when investing in green infrastructure versus traditional grey infrastructure. A failure to invest in infrastructure that supports one of these categories (water supply, flood protection, stormwater, or fish), is also a failure to invest in support for the other categories.

The 2013 Report Card for Washington's infrastructure gives the state of Washington a grade of "C". The report concludes that while Washington has diversity of infrastructure and high quality facilities located across the state, a lack of planned and guaranteed funding and inadequate maintenance are reported across all nine infrastructure categories: aviation, bridges, dams, drinking water, rail, roads, schools, solid and hazardous waste, and transit. By investing in preserving and improving these systems, Washington can avoid larger costs in the future. It is less expensive to invest in maintenance and improvement, than in the construction of new capital systems. It is also less expensive to prepare for and mitigate the impacts of climate change, than to rebuild after catastrophic impacts.

Investing in water supply, flood protection, stormwater, and fish habitat infrastructure have further regional economic benefits, by decreasing water and weather dependency, protecting the supply chain from vulnerability to water extremes, and improving the economic resilience of the region.

7.1.1 Water Supply

Uncertainty in water supply creates uncertainty in business operations, creating risk for water-dependent industries that operate in Washington, including manufacturing, technology, and agriculture. A 2011 report from EIRIS Ltd found that the majority of companies surveyed by EIRIS face water risks, but fewer than one percent were able to demonstrate adequate management of the risks posed by water scarcity. The World Wildlife Fund found that the government faces risk from water scarcity, including slowed economic growth, decreased food security, increased poverty and inequality, increased reliance on trade, and negative health impacts. This is exacerbated by the risks assumed by businesses operating in a state suffering from water scarcity, including physical risk, financial risk, regulatory risk, and reputational risk. The risks suffered between government and business in regards to water supply are synergistic, thus further exacerbating the negative risks caused by water scarcity. The state of Washington can attract and retain water dependent industries by managing and investing in water supply infrastructure. Failing to do so risks negative economic impacts and reduces the economic resiliency of the region.

The Climate Impacts Group (CIG) at the University of Washington cautions that in addition to managing current conditions, the impacts of climate change must also be considered in planning for water supply infrastructure. Expected impacts of climate change include drier summers (an average of 22 percent reduction in summer rainfall). Changes in precipitation patterns will be one of the largest impacts of climate change in the Puget Sound, altering river flows, affecting dams, reservoirs, power generation, and water supply, while intensifying droughts and flooding. Climate change is expected to cause a 3 to 10 percent increase in rainfall during extreme events, exacerbating flooding, a 5 to 10 percent decrease in stream flow, and a 5 to 15 percent reduction in crop yield. April 1 snowpack is expected to decrease by 59 percent by the 2080s. Some entities are anticipating the impacts of climate change on water supply; King County, seeking to mitigate risk from increased drought severity and frequency, built a new 8-mile water pipeline to supply water to agriculture and industry in the Sammamish River Valley. But a failure by other jurisdictions to make similar investments in their water supply will lead to economic declines in the agriculture sector, food insecurity, loss of ecosystems that depend on abundant water supply, an inability to attract population or business, and ultimately negatively impact the economic resilience of Washington.

While there are numerous studies that demonstrate the positive correlation between infrastructure investment and GDP output, job creation, etc. in developed countries, few have analyzed connections with water infrastructure specifically. Studies on general infrastructure investments include a study by Groote et all (1999) focused on equipment, machinery, and transportation investment in The Netherlands, Herranz-Locan (2007) on similar investments in Spain, Pereira and Andraz (2005) on railway, airport, ports, highways, municipal roads, national roads, and transportation investment in Portugal, and a Fedderke, Perkins, and Luis (2005) study on transportation, telecommunication, and electricity investment in South Africa. A study in the US and Canada (Voss 2002) found no correlation between public investment and private investment output. Yet, improvements in water management improvement resiliency to rainfall variability, which is tied to economic resiliency, especially in regions reliant on water for manufacturing or agriculture. Specific to water infrastructure investments, Grey and Sadoff (2007) found positive relationships between investment in the water sector and economic development, though this is more important for developing countries. They argue that developed countries should make "management investments" (support institutions and water management), as opposed to infrastructure investments.

7.1.2 Flood Protection

Washington state has recently witnessed flood events damaging to the economy; floods in December 2007 and January 2009 in the Washington Coastal Basin closed Interstate-5 and interrupted train service for several days. These events disrupted the flow of goods in

Washington and created a need for infrastructure investments to repair the damaged roads, businesses, and homes.

Climate change will aggravate these impacts. It is expected that climate change could cause a sea level rise of 4 to 56 inches, depending on the scenario, exacerbating coastal flooding and harming coastal infrastructure. Changes in streamflow patterns due to changed precipitation patterns and earlier snowmelt will also cause increased flooding risk. A fivefold increase in the heaviest rain events is expected by the 2080s, further exacerbating flood risk. Changes in precipitation patterns will be one of the largest impacts of climate change in the Puget Sound, altering river flows, affecting dams, reservoirs, power generation, and water supply, while intensifying droughts and flooding. Increased sedimentation due to decreasing snow and ice will further increase flooding. Many residential communities are built on flood plains and will be forced to reconsider flood management. By the 2040s, models predict that the Skagit River's 100-year floods will become 22 year-floods, and 30-year floods will be seven-year floods. The Snohomish River will see 100-year floods turn into 30-year floods. By 2080, a once in a century flooding event is expected to occur as frequently as once per decade. The King County Hazard Mitigation Plan concludes that, "The changing hydrograph caused by climate change could have a significant impact on the intensity, duration, and frequency of storm events. […] The risk associated with the flood hazard overlaps the risk associated with other hazards, such as earthquake and landslide. This provides an opportunity to seek mitigation alternatives that can reduce risk for multiple hazards".

Failing to invest in flood protection infrastructure to manage and mitigate these hazardous impacts, poses risk to human health and safety, capital investments, public and private buildings, agriculture, power generation, and ultimately, the economy of Washington state.

7.1.3 Stormwater Management

In areas where human impacts are limited, rain and snowmelt events are beneficial components of the natural cycle of water use and recharge. Water from these events makes its way slowly through a watershed. It is taken up by plants, it infiltrates into the groundwater or is taken back into the atmosphere. According the Washington Department of Ecology, in an unaltered ecosystem, less than 1 percent of the water from a rainfall event finds its way into streams, rivers or other water ways as "runoff". [286] However, in areas where there are impervious surfaces such as roadways, parking lots, and roofs that percentage can jump to as high as 30 percent[287].

The presence of impervious surfaces causes harm in two ways. Firstly, as water moves across these surfaces it moves at a far faster rate than it would otherwise. When rapidly moving water enters another water body it can cause erosion and scour. Erosion and scour can destroy habitat and stir up particles that are damaging to small fish. Higher volumes of water, moving faster can also create flooding events. We have all seen video footage of trucks and cars being suddenly swept away by floodwaters during heavy rain events.

286 Protecting Washington's Waters From Stormwater Pollution. Ecology publication #07-10-058 http://www.ecy.wa.gov/biblio/0710058.html. Pg. 3

287 ibid

Historically, the response to increasing flood pressures from stormwater runoff has been focused on storage and conveyance during peak events attempting to concentrate the water and to move it away from population centers and property as fast as possible.

As a result, in most of our major urban areas we have constructed a whole infrastructure of pipes, drains and ditches that are designed to move water quickly away from what are perceived to be vulnerable areas towards receiving bodies of water where immediate harm to humans is less obvious.

These same conveyance systems that are designed to protect human interests in the short term, in fact are responsible for concentrating and exacerbating the damage from stormwater runoff. As stormwater moves across impervious surfaces it picks up contaminants: toxic chemicals (including copper), oil and grease, pesticides and herbicides and bacteria from livestock and pet waste. These contaminates are concentrated as water flows are concentrated in the system of conveyances and are dumped, untreated into receiving water bodies.

Pollution from stormwater runoff has been identified by the Puget Sound Partnership as one of the primary sources of pollution in Puget Sound and one of the biggest threats to Salmon and Orca's. It is estimated that nearly 13 billion gallons of untreated stormwater enter waterways that feed Puget Sound annually. In 2014 some 115.5 million gallons of combined sewage and stormwater flowed into waterbodies that feed the Sound in 406 different overflow events[288].

But Seattle is not the only urban area in Washington with stormwater runoff issues. Stormwater runoff is managed under the Clean Water Act through the issuance of NPDES permits. Permits issued under this system govern activities associated with municipal storm sewer systems; construction, transportation and industrial activities as well as some mining and oil and gas exploration and development[289]. The Washington Department of Transportation had identified a number of cities across the state as either a Phase 1 or Phase 2 area for stormwater permits. In addition to the entire area surrounding the Puget Sound these areas include: Spokane, Ellensburg, Vancouver, Pasco, Moses Lake, Pullman, Walla Walla, Sunnyside, Bellingham, Port Angeles, Aberdeen and Centralia. [290]

Calculations performed by the Washington Department of Ecology suggest that for every acre of pavement or every 1200 square foot roof, an inch of rain or snowmelt generates between 748 and 27,150 gallons of runoff[291] (see Table 7-4).

[288] Green Stormwater Infrastructure in Seattle Implementation Strategy 2015-2020. City of Seattle., pg. 4

[289] EPA https://www.epa.gov/npdes/oil-and-gas-stormwater-permitting#undefined

[290] WSDOT 2016 Stormwater Report WSDOT Facilities Within Phase I and II Municipal Stormwater Permit Areas., pg. 3

291 Protecting Washington's Waters From Stormwater Pollution. Ecology publication #07-10-058 http://www.ecy.wa.gov/biblio/0710058.html. Pg. 3

Table 7-4: How much stormwater

Potential Runoff	1,200 square foot roof	1 acre of pavement
1 inch of rain or snow melt	748 gallons	27,150 gallons
Average annual precipitation		
Seattle (37 in./yr)	27,700 gallons	1 million gallons
Spokane (17 in./yr)	12,700 gallons	0.5 million gallons
Olympia (51 in./yr)	38,100 gallons	1.4 million gallons

The Washington Department of Ecology has predicted that untreated stormwater and the pollution it creates has the potential to cost the Puget Sound region over $1 billion dollars in the next decade (when costs to tourism, fishing and human health are calculated).[292]

7.1.4 Fisheries and Restoration

A failure to invest in protecting fish habitat is detrimental to the health and economy of Washington state. Water in the state of Washington is over-allocated; rights have been granted to take more water from rivers, streams, and aquifers, than can be sustainably provided. By one measure in 2002, fully one quarter of the state's 62 WRIAs did not have sufficient water to meet the needs of both people and fish.[293] This is damaging since fishing is of particular importance to regional economies within Washington state, particularly along the Coast, the Strait of Juan de Fuca, and the Puget Sound. King County alone provides 21 percent of total annual wages for commercial fishing in the United states as a whole, and all of Washington's commercial fishing operations comprise more than a quarter of total annual wages for commercial fishing in the United states.

It is important to stress that fish have value beyond commercial fishing operations; recreational fishing in Washington is of particular importance, and fish are a vital part of ecosystem and river health. A 2008 economic analysis of non-treaty commercial and recreational fisheries found that recreational fisheries, including both resident and non-resident anglers, contribute $376 million to statewide income, roughly $230 million more than commercial fishing.

Human activities (land-use, land management, climate change, etc.), in combination with natural occurrences (floods, drought, fires, wind, etc.) have impacted fish habitat across Washington, damaging water quality (temperature, sedimentation, contamination) and water quantity. Fish management, including introductions and persistence of non-native species continues to affect habitat in some locations (e.g., presence of brook trout in bull trout habitat). Significant habitat restoration and protection actions have been implemented to improve degraded habitat conditions and restore fish passage. These efforts expected to benefit the survival and productivity of the targeted populations, however, evidence demonstrating that improvements in habitat conditions have led to improvements in

[292] Damages and Costs of Stormwater Runoff in the Puget Sound Region, 2006; Derek B. Booth, Bernadette Visitacion and Anne C. Steinemann

[293] Center for Environmental Law & Policy and the Washington Environmental Council. March 2002. Dereliction of Duty: Washington's Failure to Protect our Shared Waters. Available at http://wecprotects.org/issues-campaigns/water-for-washington/dereliction.pdf

population abundance and/or productivity is lacking. While trends show increasing abundance relative to prior review for most fish populations, the natural origin abundance and productivity of most fish populations remain well below viability thresholds for most populations. Several fish species are threatened with extinction; it will be impossible to revive these populations, once extinct. Protecting fish populations and fish habitat is vital to the economic resilience of Washington and vital to protecting water resources within the state.

7.1.5 Summary

Appropriate economic analysis must define a 'without project' condition so that conditions with a proposed project have a baseline from which to measure essential gains (and losses). As described above these measurements can be very difficult to define, but must be done with care because all results are based on the assumptions about what would happen in the absence of the project. The key factors that complicate measurement of environmental baselines is that results are often based on models which are never certain, and also that environmental outcomes often are very complex and interdependent, so not as easily understood. In hydrologic baseline definitions, the changing outcomes due to climate change and changing land uses similarly makes the baseline forecasting challenging. Finally, the economic 'without project' conditions are similarly uncertain but are perhaps historically more stable than the hydrologic and environmental baseline forecasts. Where possible it is always prudent to explore how results change given alternative baseline scenario definitions. On the other hand, even an imperfect baseline definition can also provide a benchmark against which to compare alternative solutions to provision of clean and plentiful water, economic growth and output, maintenance of ecosystem services, and expected damages from natural hazards.

7.2 Columbia River Basin

The analysis of benefits for the three sub-basins of the Columbia River Basin (CRB) (Upper, Middle, and Lower) are aggregated below.

7.2.1 Water Supply

The Office of Columbia River of the Department of Ecology recently released a draft of the 2016 Columbia River Basin Long-Term Water Supply and Demand Forecast (2016 Forecast).[294] This study provides the most updated assessment of water supply in the basin and the demand for water over the next 20 years (until 2035). The previous forecast was developed in 2011.

The 2016 Forecast explores three broad types of changes that are expected to occur during the study period – climatic, economic, and water management. In terms of the geography of analysis, results are presented at three levels:

[294] Office of Columbia River, Washington State Department of Ecology (in collaboration with Washington State University, Washington Department of Fish and Wildlife, and State of Washington Water Research Center). November 2016. 2016 Washington State Legislative Report - Columbia River Basin Long-Term Water Supply and Demand Forecast (DRAFT). Publication No. 16-12-001. Available at (http://www.ecy.wa.gov/programs/wr/cwp/2016Forecast.html), accessed November, 2016.

- The entire Columbia River Basin upstream of Bonneville Dam, across seven U.S. States and one Canadian Province.
- Each watershed in eastern Washington, as delineated by eastern Washington's 34 WRIAs.
- Washington's Columbia River Mainstem, from the Canadian border to Bonneville Dam.

The discussion and insights provided in this section relate to the second and third geographic levels – the 34 WRIAs in Eastern Washington and Washington's Columbia River Mainstem. According to the forecast, seasonal shifts in timing of water supply and demand will be a dominant issue overall. However, irrigation demand was forecast to decrease on average, due to wetter springs and a shifting of the growing season into the spring, when rain is projected to be more plentiful. Under warming temperatures, some crops will also reach maturity faster, thus decreasing irrigation demand later during the irrigation season. This decrease in demand will help to alleviate a reduction in summer water supply, at least in non-drought years.

Forecasts for 2035 suggest that there will be an overall increase in annual water supplies across the Washington's Columbia River Mainstem, and a shift in supply timing away from times when demands are the highest. Annual surface water supplies generated within the Washington portion of the Columbia River Basin are expected to increase approximately 4.0 percent (±1.7 percent) by 2035, on average.[295] The changes in supply for the Washington portion of the major rivers ranged from 7.1 percent (±2.7 percent) for the Spokane watershed to 50.7 percent (±2.7 percent) for the Methow watershed. These rivers will experience shifts in timing of stream flow. The rivers experiencing the greatest shift in supply timing are those for which streamflow was predominantly derived from snowmelt during the historical period, such as the Methow River.

Within the Washington state portion of the Columbia River, out-of-stream water demands across eastern Washington are forecast to decrease by 22,900 (±24,200) ac-ft per year by 2035. The Forecast anticipates 272,100 (±29,200) ac-ft decrease in total (ground and surface) agricultural irrigation water demand annually assuming no change in irrigated acreage, and no additional water supply development.[296] In terms of municipal and domestic demand, it anticipates 80,000 ac-ft in additional total diversion annually, which represents an 18 percent increase over 2015. This increase in municipal and domestic demand is due to a 17 percent increase in population expected between 2015 and 2035. The greatest concentrations of current and future agricultural irrigation and municipal water demand are in the Rock Glade (WRIA 31), Walla Walla (32), Lower Snake (33), Yakima (37, 38, 39), Lower Crab (41), Esquatzel Coulee (36), and the Okanogan (49) watersheds.

At the individual basins level, per the 2016 Forecast, 20 of the 34 WRIAs in Eastern Washington will have surface water supplies in excess of the demand for surface water for

[295] This calculation includes the major watersheds of the Walla Walla, Palouse, Colville, Yakima, Wenatchee, Chelan, Methow, Spokane, and Okanogan Rivers. While most rivers show increases in supply regardless of the climate scenario used, three watersheds—Colville, Chelan, and Okanogan—showed mixed results, ranging from increasing to decreasing supplies, depending on the climate scenario used.

[296] It is important to highlight that, though there is a decrease in overall agricultural demand, additional surface water will be needed annually in the future, to replace demand currently being met by groundwater in the Odessa Subarea.

agricultural and municipal purposes by 2035. Table 7-5 presents the comparison between surface water supplies and surface water agricultural and municipal demand by each individual WRIA within the five basins in that geography. The analysis in Table 7-5 is based on middle value of the range of climate change scenarios considered, and uses the median supply and demand conditions. It is also important to note that the data used to develop the analysis in Table 7-5 do not consider water curtailment. In the remaining 14 WRIAs, the periods when supplies are not anticipated to meet demands are typically the peak growing seasons. For example, in the three WRIAs within the Yakima River Basin, supplies are forecast to be less than demand during the months of June and July. The longest periods of water shortages are projected to be in Little Spokane (WRIA 55), within Kootenai-Pend Oreille-Spokane Basin, and in Okanogan (WRIA 49) within the UCRB.

Table 7-5: Comparison of Forecast (2035) Surface Water Supply and Surface Water Agricultural and Municipal Demand for Water Basins in Eastern Washington

Basin/HUC4	WRIA No.	WRIA Name	Months (cells with "X" indicate supply exceeding demand in that WRIA during a specific month)											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Middle Columbia	29	Wind-White Salmon	X	X	X	X	X	X	X	X	X	X	X	X
	30	Klickitat	X	X	X	X	X	X	X	X	X	X	X	X
	31	Rock-Glade	X	X	X	X	X				X	X	X	X
	32	Walla Walla	X	X	X	X	X	X					X	X
Lower Snake River	33	Lower Snake	X	X	X	X	X				X	X	X	X
	34	Palouse	X	X	X	X	X	X	X	X	X	X	X	X
	35	Middle Snake	X	X	X	X	X	X	X	X	X	X	X	X
Yakima River	37	Lower Yakima	X	X	X	X	X			X	X	X	X	X
	38	Naches	X	X	X	X	X			X	X	X	X	X
	39	Upper Yakima	X	X	X	X	X			X	X	X	X	X
Upper Columbia	36	Esquatzel Coulee	X	X	X	X						X	X	X
	40	Alkali-Squilchuck	X	X	X	X	X	X	X	X	X	X	X	X
	41	Lower Crab	X	X	X	X							X	X
	42	Grand Coulee	X	X	X	X	X	X			X	X	X	X
	43	Upper Crab-Wilson	X	X	X	X	X	X	X	X	X	X	X	X
	44	Moses Coulee	X	X	X	X	X	X	X	X	X	X	X	X
	45	Wenatchee	X	X	X	X	X	X						X
	46	Entiat	X	X	X	X	X					X	X	X
	47	Chelan	X	X	X	X	X	X	X	X	X	X	X	X
	48	Methow	X	X	X	X	X	X		X	X	X	X	X

Basin/HUC4	WRIA No.	WRIA Name	Months (cells with "X" indicate supply exceeding demand in that WRIA during a specific month)											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	49	Okanogan	X	X	X	X								
	50	Foster	X	X	X	X	X	X	X	X	X	X	X	X
	51	Nespelem	X	X	X	X	X	X	X	X	X	X	X	X
	52	Sanpoil	X	X	X	X	X	X	X	X	X	X	X	X
	53	Lower Lake Roosevelt	X	X	X	X	X	X	X	X	X	X	X	X
	58	Middle Lake Roosevelt	X	X	X	X	X	X	X	X	X	X	X	X
	59	Colville	X	X	X	X	X	X	X	X	X	X	X	X
	60	Kettle	X	X	X	X	X	X	X	X	X	X	X	X
	61	Upper Lake Roosevelt	X	X	X	X	X	X	X	X	X	X	X	X
Kootenai-Pend Oreille-Spokane	54	Lower Spokane	X	X	X	X	X	X	X	X	X	X	X	X
	55	Little Spokane		X	X	X								
	56	Hangman	X	X	X	X	X	X	X	X	X	X	X	X
	57	Middle Spokane	X	X	X	X	X	X	X	X	X	X	X	X
	62	Pend Oreille	X	X	X	X	X	X	X	X	X	X	X	X

Notes:
1) Based on middle value of the range of climate change scenarios considered.
2) Based on median supply and demand conditions.
3) These results do not consider water curtailment.
Source: Data based on Office of Columbia River, Washington state Department of Ecology (in collaboration with Washington State University, Washington Department of Fish and Wildlife, and state of Washington Water Research Center). November 2016. 2016 Washington state Legislative Report - Columbia River Basin Long-Term Water Supply and Demand Forecast (DRAFT). Publication No. 16-12-001. Available at (http://www.ecy.wa.gov/programs/wr/cwp/2016Forecast.html), accessed November, 2016.

This analysis raises the question of whether or not there are significant water supply needs within the UCR under the baseline, or without project conditions. In doing so this raises questions about the measurement of benefit from investment. Still, just because water is available in theory, does not mean that there will be water available in fact. Some sharing of water, or buying and selling might need to occur for any additional crops to be grown or for the economy to continue to grow to accommodate new populations. Hence there is continued potential for investment in water infrastructure if needed to foster growth and to expand the agriculture and other water users in the basin.

7.2.2 Flood Protection

No flood protection investment projects were reviewed for this report.

7.2.3 Stormwater Management

According to the Bureau of Reclamation, the UCRB will see an average annual precipitation increase of roughly 7 percent by 2050. According to the OFM, the population of the Basin is expected to grow 33 percent in the next twenty years. These issues in combination imply that the UCRB will need to invest in improved stormwater management. Currently, $8 million is planned to be spent in the Basin in 2017 on improving stormwater infrastructure, which will help improve water quality, reduce urban flooding, protect salmonid habitat, and reduce exceedances of TMDLs. This has benefits to ecosystems, human health, and the built environment.

Similarly to the UCRB, the MCRB will see an average annual precipitation increase of roughly 7 percent by 2050.[297] According to the OFM, the population of the Basin is expected to grow by only 11 percent in the next twenty years. The needs of improved stormwater management are lesser in this Basin than in others across Washington, due to the smaller population and low level of urbanization, though still beneficial. Investing in improved stormwater management will improve water quality, reduce urban flooding, protect salmonid habitat, and reduce exceedances of TMDLs, which will benefit the rich ecosystem of the Columbia River, local human health, and the built environment.

Major interstates and highways cross the Lower Columbia River Basin, and it includes the cities of Vancouver and Longview. Similarly to the Upper and MCRBs, the Lower Columbia River Basin will see an average annual precipitation increase of roughly 7 percent by 2050.[298] According to the OFM, the population of the Basin is expected to grow by 25 percent in the next twenty years. These issues in combination imply that the Lower Columbia River Basin will need to invest in improved stormwater management. Currently, $6 million is planned for 2017 for improved stormwater management at the Port of Vancouver. Other projects within the Basin include channel restoration and concrete retrofits for stormwater improvement. These projects have benefits across multiple sectors, by improving water quality, reducing urban flooding, protecting fish habitat, and reducing exceedances of TMDLS, benefitting ecosystems, human health, and the built environment.

7.2.4 Fisheries and Restoration

In the LCRB, significant habitat and restoration actions are underway, and are expected to bring about benefits in terms of population abundance and growth. In turn, the growth in fish populations will have commercial, recreational, and cultural benefits for years to come. However, evidence to support the relationship between additional habitat improvement and additional population growth is lacking. NMFS noted in their latest 5-year review that extensive habitat is available for Chinook salmon, suggesting that freshwater habitat is not limiting the growth of Lower Columbia River Chinook Salmon. This suggests that habitat enhancement projects are not likely to result in increased populations in the near term, although they will benefit populations once those populations have recovered to the extent that they have utilized the existing habitat. The same is likely true for Columbia River chum;

[297] US Dept. of Interior, Bureau of Reclamation, Pacific Northwest Office – Managing Water in the West – West-wide Climate Risk Assessment: Columbia River Basin Climate Impact Assessment, Final Report, March 2016.

[298] US Dept. of Interior, Bureau of Reclamation, Pacific Northwest Office – Managing Water in the West – West-wide Climate Risk Assessment: Columbia River Basin Climate Impact Assessment, Final Report, March 2016.

chum salmon abundance is extremely low and the populations are not likely utilizing the existing habitat. The limiting factors for Lower Columbia River coho salmon are not known and abundance and productivity estimates are poorly documented for the species. Therefore, the benefit of habitat restoration projects for Lower Columbia coho salmon cannot be estimated. For additional projects to be justified in terms of economic value, more research on the limiting factors for different populations should be conducted so that additional investment may be targeted at effective strategies to address restoration.

In the MCRB, freshwater habitat does not appear to be fully seeded. The removal of Condit dam in the White Salmon basin opened up extensive habitat which is not currently utilized. The Klickitat basin has met or nearly met recovery goals for the past 7 years and has abundant habitat which does not appear to be fully utilize. Limiting factors in the Rock Creek basin have been evaluated and have been determined to be the natural condition. Further investment in freshwater habitat restoration in this subbasin may not yield the desired returns. An assessment of the factors limiting these populations (expected to be out of basin factors) should be evaluated. Those factors may include harvest, pinniped predation, and/or ocean conditions.

In the UCRB, some of the basins (especially the Okanogan) tend to have excessively warm water and a paucity of side channel habitat. It is likely that continued habitat improvement including additional flows to reduce temperatures and provision of additional side channels, could yield improved populations and fishery production. Therefore, additional investments in habitat enhancement, focused on reducing stream temperature and providing mainstem side channel habitat, may result in higher returns of fish.

7.3 Kootenai-Pend Oreille – Spokane Basin

No projects were analyzed in this basin for water supply investment or for flood protection.

7.3.1 Stormwater Management

Climate change is expected to cause precipitation changes of anywhere between a decrease of 7 percent to an increase of 18 percent by 2050. This uncertainty means stormwater systems should be able to manage a variety of scenarios within that range. Interstate 90 crosses this Basin, which contains the major city of Spokane. Within the next twenty years, population is expected to grow by 18 percent within the region. The combination of climate change and population growth implies that investments will need to be made in stormwater infrastructure in the Kootenai-Pend Oreille-Spokane Basin. Currently, $11 million is planned for stormwater infrastructure improvements in the Basin in 2017. These projects include a riverside interceptor for protecting water quality, improvements to CSOs, and stormwater retrofits on major roads. These projects will improve the stormwater system's ability to manage uneven flow, which will become a more persistent problem with climate change, and also reduce water pollution. This has benefits to ecosystems, water storage, the built environment, fish habitat, and human health.

7.4 Washington Coastal Basin

The current Chehalis Basin Strategy is a broad strategy aimed at providing flood protection while preserving and restoring fishery habitat. No water supply projects were identified in this basin.

7.4.1 Water Supply

There is not sufficient information to analyze the water supply projects identified in this basin.

7.4.2 Flood Protection

Investment in flood damage reduction in the WCB is focused on the Chehalis basin where a draft Environmental Impact Study (DEIS) is currently under review. In the DEIS, a range of alternative projects are evaluated in terms of flood damage reduction benefits and show that between $72 million and $1.4 billion in flood damages may be brought about by the alternative strategies which will cost between $600 million and $1.7 billion. In the economic appendix to this effort, the results show that a favorable benefit/cost ratio (showing greater benefits than costs) is seen in but two of the 14 alternatives proposed with another four showing that benefits and costs of the alternative are about equal. The analysis also conducted a sensitivity analysis to address the uncertainty surrounding the estimates and the results of that analysis show that when ranges including a minimum, maximum, and middle value are developed only one of the 14 alternatives has a benefit to cost ratio for the minimum value that is greater than one (or in other words feasible). Still, this analysis does not include any ecosystem service values for the services provided by the floodplains. If this analysis is completed, then the numbers of alternatives that are feasible may change, and the favorability of one alternative over another may be changed.

7.4.3 Stormwater Management

This basin includes the Chehalis Basin, Interstate-5, and the cities of Centralia and Aberdeen. Climate change is expected to cause sea level rise along the coast, causing potential damage to coastal infrastructure by 2050. Population growth is expected to be moderate over the next twenty years, at only 11 percent. Investments in improved stormwater management are essential in this basin, as flooding is a persistent problem, and improved stormwater infrastructure helps prevent sedimentation, flow issues, and severe flooding. By investing the $15 million in projects identified in this report for improved stormwater management within the Basin, benefits will be realized through reduced flood damages, improved ecosystem services, preserved or improved fish habitat, protected built environment, and protected human health.

7.4.4 Fisheries and Restoration

Unlike the other basins in Washington, the WCB does not have any species of salmon that are currently listed as threatened or endangered with the exception of the Ozette Lake sockeye salmon. This is a fundamental asset for the basin that needs to be considered as a starting point. It is much easier to measure environmental losses once they have occurred, or even gains from restoration, than it is to make an accurate estimate of the economics of a functioning stock as an environmental asset. Considering the large investment needed to restore habitat and fisheries in basins with ESA listed species, those sums provide an idea of the costs of restoration that may be avoided in a basin that as yet does not support ESA listed species. It is important to note that projects that restore floodplains to reduce flood damage will also tend to restore or enhance fish habitat, providing additional protections to the species and reducing the likelihood that those species will be listed in the future.

The DEIS prepared for the Chehalis Basin Strategy identifies two levels of restoration for aquatic species habitat: high and low.[299] The importance of restoring aquatic species habitat is paramount, since over 87 percent of aquatic species habitat has been lost, harming fish and reducing the biodiversity of the region. For fish, 54 percent of habitat is impaired for fall-run Chinook, 56 percent of habitat is impaired for winter-run steelhead, 72 percent of habitat is impaired for Coho, and 87 percent of habitat is impaired for spring-run Chinook. The potential restorations measures are developed by the Washington Department of Fish and Wildlife in their Aquatic Species Restoration Plan. The "Low" restoration alternative considered in the Chehalis Basin Strategy DEIS restores fewer river miles (21 – 63 river miles, total) and fewer acres of reaches (1,150 – 2,900 acres). The focus of "Low" restoration is on spring-run Chinook spawning reaches and most of the habitat that is restored is primarily in managed forestland. Alternatively, the "High" restoration alternative restores 71 – 214 river miles and 3,900 – 9,750 acres of reaches. Habitat protected includes spawning habitat for spring and fall-run Chinook, Coho, chum, and steelhead. The "High" restoration alternative provide a significant increase in the abundance levels estimated at 53 percent; while the Low restoration alternatives are expected to increase abundance by 2 percent. A cost-benefit analysis finds that the High restoration alternatives are more expensive and do not pass a cost-benefit analysis, whereas the Low restoration alternatives achieve positive net benefits. More information on benefits measured to fisheries was provided in an earlier analysis of the Chehalis Basin. This is briefly reviewed below.

The 2014 Analysis of Alternatives for the Chehalis Basin Strategy[300] calculated the benefits of restoring habitat for fish. These benefits were estimated based on projected population changes under different proposed actions and on derived valuations of fish. The commercial value of fish was estimated from profits of fish harvests. The sport fishery value was estimated based on the travel-cost method (how much recreational fishers will pay to travel to fish) and from a contingent valuation that used a questionnaire to derive the willingness to pay for fishing. The passive-use value, or existence valuation was derived from studies estimating the willingness for households in Washington to pay for preservation of fish habitat. The cultural values that fish provide to Quinault and Chehalis tribes were not included in the passive-use valuation, and it is thus is not a full representation of the value of fish. High, medium, and low estimates were used for all valuations in order to account for uncertainty. Using the projected fish populations under alternative actions, the value of each action to preserve fish habitat was calculated by multiplying the derived value of fish by the projected increase in population under the action.

The results were presented from the Basin (Lewis, Thurston, and Grays Harbor counties), State, and Federal (National Economic Development account) perspectives since the costs impacts vary by perspective.

299 Washington State Department of Ecology. Chehalis Basin Strategy EIS Executive Summary: Reducing Flood Damages and Restoring Aquatic Species Habitat. September 29, 2016.

300 EES Consulting and HDR. Chehalis Basin Strategy: Reducing Flood Damage and Enhancing Aquatic Species: Comparison of Alternatives Analysis. Prepared for the State of Washington. September 16, 2014. Accessible at http://chehalisbasinstrategy.com/wp-content/uploads/2015/09/Comparison-of-Alternatives-Report_Final.pdf

Appendix K of the 2014 Analysis[301] provides details on the baseline fish population forecasts (Tables K-2 through K-3), the population estimates for different actions and the resulting changes in population relative to the baseline (Tables K-8 through K-15), and the derived fish values (Tables K-16 through K-20), which in concert are used to calculate the value provided by each of the actions (number of fish saved multiplied by the value of the fish, dependent on fish species, fishing type (commercial or sport) and region of Washington). In the 2014 study, the derived commercial fish values are $9.91 for a Coho salmon and $46.61 for a Chinook salmon. The derived sport fish values are much larger, since they are calculated from a travel-cost method or a willingness to pay survey, which traditionally inflate values. The ocean-caught sports valuations range from $35 to $71 for a Coho and $55 to $127 for a Chinook, depending on the size of the fish and the region of the fishing. For river sports fishing, the value of a fish ranges from $60 to $761 depending on the study, with the Yakima River Basin Study reporting extraordinarily large values, due to different baseline estimates. The passive use valuation was derived from the Layton, Brown, and Plummer (1999) study that is used by the Department of Ecology and other agencies to estimate this use. Results of this study are highly sensitive to initial assumptions about fish population status.

The current DEIS for the Chehalis Basin Strategy finds that all of the flood retention facilities proposed would reduce fish populations compared to the No-Action Alternative (NAA), except if paired with Aquatic Species Habitat Actions, which would increase fish populations as compared to the NAA.[302] This shows the importance of investing in green infrastructure in addition to protect the values offered by ecosystem services within project areas.

7.4.5 Basin Summary

Because of the problems with flooding and fish restoration in the Chehalis basin, the net benefits of investing in flood damage reduction and fisheries and habitat preservation and restoration have been studied extensively. The economic gains and losses and decision making analyses have been, and continue to be conducted in a manner that is consistent with infrastructure investment guidance. However, at present an ecosystem services analysis for the project has not been completed although it is reportedly underway. There is the potential for such an ecosystem service analysis to change the economic feasibility of the alternatives, though since the fisheries have been studied at length the fishery results may have adequately covered the relative impacts to other ecosystem services.

7.5 Puget Sound Basin

Puget Sound is the largest of the HUC basins in terms of population, economic development and identified investment needs. The majority of investment dollars are in multiple benefit projects that will serve flood prevention, stormwater management, and

[301] EES Consulting and HDR. Chehalis Basin Strategy: Reducing Flood Damage and Enhancing Aquatic Species: Comparison of Alternatives Analysis. Prepared for the State of Washington. September 16, 2014. Accessible at http://chehalisbasinstrategy.com/wp-content/uploads/2015/09/Comparison-of-Alternatives-Report_Final.pdf

[302] Washington State Department of Ecology. Chehalis Basin Strategy: EIS Executive Summary: Reducing Flood Damage and Restoring Aquatic Species Habitat. September 19, 2016.

fishery enhancement benefits. No analysis was conducted for any specific flood prevention projects.

7.5.1 Water Supply

The vast majority of water supply projects slated for development in the Puget Sound Basin are to be developed by the water utilities and have been included in this analysis even though the funding for these projects is often through local bonds and by customers paying for the capital improvement. In these cases (local funding) such projects can be considered economically feasible because they are bought and sold in a market. However, many water utilities are not for-profit entities and so the usual metrics of willingness to pay may not be appropriate. For one thing, utilities are often quasi-monopolistic in that there may be no alternative to using the public utility for homeowners in a given neighborhood. Further, funding for capital investment projects has historically come at least in part from the state and other sources, so changing the availability of public funding may be expected to result in fewer water supply needs being met. This is a concern for utility managers because even maintaining and repairing existing systems can be costly. In addition, utilities and local governments are under increasing pressure to conduct more research on water quality parameters.

7.5.2 Flood Protection

No flood protection projects were analyzed for this report.

7.5.3 Stormwater Management

The Puget Sound Basin is the most populous Basin in Washington, containing two-thirds of the state's population, with nearly half of the Basin population residing within King County. Within the next two decades, population is expected to increase by 18 percent. More extreme rainfall events are expected, and more extreme weather, in general, is expected due to the effects of climate change by 2050. Improving stormwater management in the region will help keep water temperatures low, which is beneficial to fish habitat, and of particular concern as stream and river temperatures rise with climate change. All of these factors in combination explain why improved stormwater management offers critical benefits to the Puget Sound Basin. Currently, over $3.5 billion in stormwater investments are planned for the next three years, and close to $1 billion is planned annually for the next two decades. Most of this cost is for maintenance and retrofits to existing systems. The benefits of pursuing these investments are large, considering the size of the population and economy affected, by reducing flood damages, improving ecosystem services, improving water quality, protecting fish habitat, maintaining the built environment, and supporting infrastructure that benefits human health.

7.5.4 Fisheries and Restoration

Because Puget Sound has four listed species (Hood Canal chum, Puget Sound coho, steelhead, and Chinook). The benefits of investing in habitat restoration for one species often benefits other species as well; in this way the investment in habitat enhancement projects can be highly cost-effective, provided that freshwater habitat is limiting one or more populations within the basin. EDT model results for the two basins that have published carrying capacity under existing conditions suggest that those two basins are currently capable of supporting much larger populations than are present at this time. This suggests that the limiting factor for fish production may not be freshwater habitat in those basins. It is likely that the same conclusion could be drawn for other basins. Where freshwater habitat is not limiting, other factors such as ocean habitat, pinniped predation, or harvest may be limiting the populations. Even in subbasins where freshwater habitat may be the limiting factor, it may not be clear which component of the freshwater habitat is lacking and so investment funds will be most beneficial when the component of limiting factor is known (e.g. spawning vs. rearing habitat).

7.6 Lower Snake River Basin

No projects were analyzed in this basin for water supply investment or for flood protection Water Supply

7.6.1 Stormwater Management

Population growth over the next two decades is minimal; only five percent, and the population is already quite small (fewer than 75,000). The needs of improved stormwater management are lesser in this Basin than in others across Washington, due to the smaller population and low level of urbanization, though still beneficial. Investing in improved stormwater management will improve water quality, reduce urban flooding, protect fish habitat by reducing water temperatures, and reduce exceedances of TMDLs, which will benefit the rich ecosystem of the Snake River, local human health, and the built environment.

7.6.2 Fisheries and Restoration

Fish populations in the LSRB are generally improving and additional restoration efforts are likely to bring additional benefits. However, the limiting factors have not clearly been identified in the basin; further exploration of limiting factors for fish production, such as pinniped predation, harvest, and ocean conditions, is encouraged. Better definition of the actual limiting factors for production of salmonids in the Subbasin would help to focus future funding on the conditions that are most likely to benefit the population. Current population size, productivity, and harvest rates are also poorly documented in the Subbasin.

7.7 Yakima River Basin

Since its approval, a number of analyses of the Yakima Integrated Plan and its components have been conducted and published. Because it is an integrated plan, the review of these analyses is handled as an integrated review. Notable among the analyses are the "Four Accounts Analysis" of the benefits and costs of the Integrated Plan completed by Reclamation in 2012,[303] and a "disaggregated" benefit-cost analysis of the Integrated Plan

[303] U.S. Bureau of Reclamation. 2012. Yakima River Basin Integrated Water Resource Management Plan - Four Accounts Analysis of the Integrated Plan. October. Available at http://www.ecy.wa.gov/programs/wr/cwp/ybip.html OR http://www.usbr.gov/pn/programs/yrbwep/reports/fouraccounts.pdf

conducted by WSU in 2014.[304] This section provides more information regarding these analyses, along with a comparison of the two studies.

The "Four Accounts Analysis" by the Bureau of Reclamation compares the net benefits of the Integrated Plan as a whole against a no-Integrated Plan alternative. This analysis estimates agricultural benefits of 0.8 billion, municipal benefits of 0.4 billion, fish benefits ranging from $5 to $7.4 billion, with overall benefits ranging from $6.2 billion to $8.6 billion. It reports costs ranging from $2.7 billion to $4.4 billion. Using the high-end value of benefits and the low-end value of costs, the Reclamation analysis estimates the largest benefit-cost ratio of 3.2. Using the low-end value of benefits and the high-end value of costs, the analysis results in the smallest benefit-cost ratio of 1.4. In all cases, however, the benefit-cost ratio is greater than one, which means that the value of the benefits associated with the Integrated Plan outweighs the value of its costs in aggregate net present value. Therefore, Four Accounts Analysis recognized the synergistic effects of the interconnected projects and activities and resulted in highly favorable composite benefit-cost ratios.

In 2014, under a legislative provision (Section 5057 of the state of Washington Capital Budget for 2013), the state of Washington Water Research Center at Washington state University (SWWRC-WSU) was directed to prepare a separate benefit-cost analyses for each of the projects proposed in the Integrated Plan, or a "disaggregated" benefit-cost analysis. The analysis divided the Integrated Plan into individual components and evaluated the efficacy of those components in isolation. Existing hydrologic and water management models of the Yakima River basin were used to examine the impact of proposed water storage projects, conservation, and proposed instream flows on drought impacts under a limited set of climate scenarios. Overall, the study suggested that if the full Integrated Plan were implemented (assuming the moderate climate change and market scenario), the estimated net present value of fish benefits would be $1 to $2 billion, while agriculture and municipal benefits were estimated at approximately $117 million and $32 million, respectively (Table 7-6).

304 Yoder, Jonathan, Jennifer Adam, Michael Brady, Joseph Cook, Stephen Katz, Daniel Brent, Shane Johnson, Keyvan Malek, John McMillan, and Qingqing Yang. 2014. Benefit-Cost Analysis of the Yakima Basin Integrated Plan Projects. State of Washington Water Research Center – Washington State University. December. Available at https://swwrc.wsu.edu/2014ybip. 196.pp.

Table 7-6: Costs and Benefits Associated with the Integrated Plan - Overall

Benefit/Cost Category	Reclamation/ Ecology BCA - $Million	SWWRC-WSU BCA - $Million
Fish	$5,000 - $7,400	$1,000 - $2,000
Irrigation/Agriculture	$800	$117
Municipal and Domestic Water Supply	$400	$32
Costs	$2,700 - $4,400	

Sources: U.S. Bureau of Reclamation. 2012. *Yakima River Basin Integrated Water Resource Management Plan - Four Accounts Analysis of the Integrated Plan*. October. Available at http://www.ecy.wa.gov/programs/wr/cwp/ybip.html OR http://www.usbr.gov/pn/programs/yrbwep/reports/fouraccounts.pdf,
Yoder, Jonathan, Jennifer Adam, Michael Brady, Joseph Cook, Stephen Katz, Daniel Brent, Shane Johnson, Keyvan Malek, John McMillan, and Qingqing Yang. 2014. *Benefit-Cost Analysis of the Yakima Basin Integrated Plan Projects.* State of Washington Water Research Center – Washington State University. December. Available at https://swwrc.wsu.edu/2014ybip.

As evident in Table 7-6, the SWWRC-WSU study estimated benefits to be lower for each category compared to the 2012 Reclamation/Ecology analysis. This is due to a host of reasons. Notably, the assumed climate regime has substantial consequences for agricultural benefits, and the baseline salmonid abundance in the Columbia River Basin has important consequences for fish benefits. Following are the key sources of difference between the two analyses:

- The treatment of fish population baseline abundance and growth rates over time is different between the two analyses. First, the Four Accounts Analysis used a study done by Ecology in the late 1990's as the basis of their fish abundance estimates. The SWWRC-WSU team found that fish are now more numerous than they were in the late 1990's, when the fish valuation study used in the Four Accounts Analysis was performed, so the value that the public places on adding more fish should now be lower. Second, the two studies differ in the population growth rates assigned to fish in the Yakima River Basin. The SWWRC-WSU study team believed that the population growth rates assigned to fish in the Yakima River Basin in the Four Accounts Analysis do not conform to observations of habitat restoration programs in other locations (40 percent per year growth rate in the fish population implied by the Four Accounts Analysis, vs. only 5 percent per year growth rate observed in other locations). In terms of non-market valuation of fisheries value, both the analyses used the best valuation information available.

- While both the studies looked at the opportunities for water market development, the SWWRC-WSU study also evaluated a range of water market scenarios from no trade to full trade. The study found gains from trade to be potentially substantial, but recognized that the actual market for water rights in the Yakima Basin may not function consistently with an economic model. The market analysis conducted by the SWWRC-WSU study team included senior water rights in the Kittitas Valley, which were not included in the Four Accounts Analysis.

- There is also differences in valuation of water for municipal uses, especially in terms of how values were calculated
- The two studies differed in their results of the crop valuation model, though their "proportional fallowing" run came close to each other
- The two studies used different approaches to modeling the frequency and severity of drought conditions

The disaggregated analysis conducted by SWWRC-WSU concluded that when viewed in isolation, the larger water storage components of the Integrated Plan do not yield positive cost-benefit ratios. The 2012 Reclamation/Ecology analysis drew the same conclusion, but recognized that operation of water storage facilities in the context of other projects and activities will yield different conclusions regarding the value of such storage facilities. Similarly, the disaggregated analysis concluded that the largest share of Integrated Plan benefits come from resident and anadromous fish recovery. The same conclusion was documented in 2012 Four Accounts Analysis.

With any infrastructure development, there exists the potential for damage to social and environmental resources. A review of the Yakima River Basin Integrated Water Resource Management Plan finds that a "loss of ecosystem services that would result from construction activities and the inundation of lands and habitat. […] These lands have resources with high scarcity value, including some habitat for threatened or endangered species".

But, the analysis found that all environmental quality scores (including subcategories within water resources, fish, threatened and endangered species, land use, vegetation and wildlife, and recreation) would improve under the Integrated Plan, as opposed to the NAA. While this may be true, it is worth evaluating the baseline and considering the limiting factor concepts for fish production. Steelhead populations for example have been improving in the most recent decade, but populations are still far below the assessed capacity of the watershed. EDT model results indicated that the current carrying capacity is much larger than the current population size. Consequently improving freshwater habitat may not be the best way to enhance fish production. Other potential limiting facts could include harvest, pinniped predation, or ocean conditions. Investment in developing a better understanding of the factors limiting salmon populations would likely help to focus future capital investments on actions that will have the greatest benefit to fish production.

Cultural resources (historic structures, cultural and archaeological resources, and subsistence resources) and sustainability benefits (improving water resource reliability and overall system resilience to climate change) were considered in the Other Social Effects evaluation. The analysis determined that under the Integrated Plan, losses would occur to historic properties and cultural and archaeological resources, as compared to the NAA, but the benefits to subsistence resources would outweigh the costs and, overall, cultural benefits in the Yakima River Basin would be higher under the Integrated Plan.

7.7.2 Stormwater Management

The Yakima River Basin contains the cities of Yakima and Richland, and the population is expected to grow by 25 percent within the next twenty years. The needs of stormwater management will only grow as population grows and urbanization increases. Close to $8 million is planned in 2017 for stormwater improvement projects within the Basin, but more investments will be necessary to protect water quality, water flows, water management, ecosystem services, fish habitat, and human health. Since water storage is of particular concern in this Basin, investing in improved stormwater management will also provide benefits within water storage, by better managing flows and water quality.

7.7.3 Summary

The economic benefits of water infrastructure are at once obvious and obscure. There are challenges associated with forecasting baselines, incorporating probabilistic weather events that have changing distributions, forecasting the impacts from projects, and understanding complex ecological interactions. Yet this is what is needed to make informed decisions about needed infrastructure and timing of the investment for optimal returns. Where possible to develop a formal benefit cost analysis that is ideal, though there may still remain differences in opinions about basic assumptions. Given the uncertainty in economics, pricing, ecology, climate, and catastrophic events, the importance of conducting lengthy sensitivity analyses cannot be understated. In fact it is prudent and relatively simple to develop user-friendly spreadsheet tools that allow decision makers to alter a wide variety of assumptions and explore the outcomes under a preponderance of scenarios believed to be reasonable by whomever is operating the tool. In particular these tools are helpful in exploring flood damage prevention since flood frequencies can be estimated based on historical information but also shift as basins like the Chehalis develop more and experience climatic shifts. So too does the value of agricultural benefits depend upon world markets, climatic events, and shifting land use patterns. In addition the inherent variability of water supplies means that infrastructure investment may have value even if water supplies are not improved but if water supply security is improved.

Upon review of the projects in Washington that have been analyzed for benefits and costs, the greatest omission is likely the failure to include thorough analyses of ecosystem services. The ecosystem service framework allows for the measurement of both ecological gains and losses through time in a formal process. The framework is similar to benefit cost analysis but it does not have to bring everything into monetary units (though it can). The approach improves decision making about infrastructure by including estimates of the value of the goods and services provided by the natural environment that are important to the community. Project based changes in these systems are not only of critical importance to the people of Washington state but help avoid accidental irreversible investments that can bring about unknown environmental hardship. Fishery restoration falls under ecosystem services, in that humans place values on fish for food, recreation and cultural uses.

Finally, benefit measurement can sometimes be used to compare across different kinds of investments so that limited funding can be leveraged to bring about the greatest returns on the investment. Keeping this in mind fishery and habitat restoration projects are a high priority in the state, it seems that consideration for additional research to better understand the limiting factors for fishery populations may in the long run bring greater benefits than less well informed but well-intended efforts aimed at improving habitat solely.

8. REGIONAL ECONOMIC IMPACTS

Changes in output and employment often occur locally as a result of business changes, and such changes have implications for other parts of the local economy. This study uses an input-output methodology to determine the economic and fiscal impacts of water infrastructure investment projects on the economy of the state, roughly within eight HUC water basins. Due to county boundaries not matching up perfectly with HUC boundaries, counties located within two or more HUC basins were assigned to a HUC basin based on the location of the primary economic and/or population area(s) within the county. The counties within each HUC basin are shown in Table 8-1. A regional input-output model traces the flow of interactions between local industries, with industries outside the region, and with final demand sectors in order to determine economic and fiscal impacts of the project. These models employ data on the intermediate and final goods produced. Information on the inputs for all industries is required in order to produce the dollar value of output for a specified industry.

Table 8-1: Counties included in each HUC Water Basin

Chehalis / Western Coast	Puget Sound	Yakima	Lower Columbia	Middle Columbia	Upper Columbia	Lower Snake	Kootenai-Pend Orielle-Spokane
Grays Harbor	Clallam	Benton	Clark	Columbia	Adams	Asotin	Pend Oreille
Lewis	Island	Kittitas	Cowlitz	Klickitat	Chelan	Garfield	Spokane
Pacific	Jefferson	Yakima	Wahkiakum	Skamania	Douglas	Whitman	
	King			Walla Walla	Ferry		
	Kitsap				Franklin		
	Mason				Grant		
	Pierce				Lincoln		
	San Juan				Okanogan		
	Skagit				Stevens		
	Snohomish						
	Thurston						
	Whatcom						

Total economic values were estimated through economic modeling with IMPLAN.

Ramboll Environ collected 2014 Washington county data from IMPLAN. IMPLAN measures economic impacts from data representing actual local economies. IMPLAN estimates regional contribution to jobs, income, revenue, GDP and taxes by following inter-industry spending from the original purchase through the full supply chain. IMPLAN reports economic contributions at three levels: (1) direct effects, (2) indirect effects, and (3) induced effects. The original purchase is known as the “direct” effect. “Indirect” effects are stimulated by the "direct" effect. Each supplier of an industry purchases inputs from other suppliers in order to create their own products. Increases in production not only require an increase in purchases of supplies, but typically also require an increase in total income paid to labor. The economic effects resulting from spending of labor income are known as "induced" effects. The sum total of direct, indirect, and induced effects is the total economic contribution of water infrastructure expenditures.

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Water dependent sectors have been identified in a previous study by TXP[305]. This study defined the following sectors as "water-dependent":

8.2 Water Dependent Sectors

Ramboll Environ staff reviewed several previous studies completed for similar purposes. RE staff assessed the adequacy and uses of each of the reviewed studies and determined that a study of water supply shortages for the City of San Antonio, Texas by TXP[306] was closely related to the analysis RE needed to perform. The methodology was sound and appropriate for the OFM study developed herein. The methodology developed in Chapter 3 of this study is based on the San Antonio study for determining baseline and specific sector analysis. TXP identified water dependent sectors for the San Antonio study, and Ramboll Environ staff determined that the same water dependent sectors would be applicable for this study. This study defines the following sectors as "water-dependent", with the IMPLAN sectors Ramboll Environ included in this analysis included in Table 8-2:

- Agriculture & Mining
- Manufacturing
  - Food/Kindred Products
  - Stone/Clay/Glass Products

[305] TXP, 2014. The Economic Impact of Potential Water Shortages on San Antonio's Economy, Prepared for an Antonio Chamber of Commerce, Winter.

[306] TXP, 2014. The Economic Impact of Potential Water Shortages on San Antonio's Economy, Prepared for an Antonio Chamber of Commerce, Winter

- Electronic Components Manufacturing
- Other Manufacturing

- Commercial
  - Hotels
  - Water Intensive Consumer
  - Other Commercial

Table 8-2: Water Dependent IMPLAN Sectors

Water Dependant Ag and Mining	Water Dependant Manufacturing	Water Dependant Commercial
111 Crop Farming	**Food and Kindred Products**	**Hotels**
112 Livestock	311 Food products	721 Accommodations
113 Forestry & Logging	312 Beverage & Tobacco	**Water Intensive Consumer**
114 Fishing- Hunting & Trapping	**Stone/Clay/Glass Products**	469 Landscape and horticultural services
115 Ag & Forestry Svcs	327 Nonmetal mineral prod	505 Car washes
212 Mining	Electronic Components Manufacturing	511 Dry-cleaning and laundry services
	334 Computer & oth electron	713 Amusement- gambling & recreation
	335 Electircal eqpt & appliances	**Other Commercial**
	Other Manufacturing	621 Ambulatory health care
	313 Textile Mills	622 Hospitals
	314 Textile Products	623 Nursing & residential care
	315 Apparel	711 Performing arts & spectator sports
	316 Leather & Allied	712 Museums & similar
	321 Wood Products	722 Food svcs & drinking places
	322 Paper Manufacturing	
	323 Printing & Related	
	324 Petroleum & coal prod	
	325 Chemical Manufacturing	
	326 Plastics & rubber prod	
	331 Primary metal mfg	
	332 Fabricated metal prod	
	333 Machinery Mfg	
	336 Transportation eqpmt	
	337 Furniture & related prod	
	339 Miscellaneous mfg	

Focusing on these sectors and then combining the rest of the sectors together for each of the basins allows us to make comparisons of impact to the full basin economy of dollar investment on output as well as employment impacts for each of the sectors for all of the basins. Table 8-3 through Table 8-10 present the strength of impact for each of the summary water-dependent sectors in terms of both weighted average multipliers and total employment and output. These tables also include a category that includes all of the remaining sectors not included in the water-dependent sectors (less water-intensive sectors) for each of these metrics. The multipliers indicate the impact on the full economy of the basin of 1 additional (or reduced) employee and $1 of output for the employment and output weighted multipliers respectively. For example, in the Washington Coastal Basin (Table 8-3), each additional employee added in a water dependent agriculture and mining sector creates an additional 0.342 Full Time Employee (FTE) throughout the rest of the basin economy (for a total of 1.342 employees throughout the basin economy), and for each dollar of water dependent agriculture and mining output, a full $1.36 of output is created throughout the full basin economy (or an *additional* $0.36).

Table 8-3: Washington Coastal Basin Water Dependent Sector Strength

	Employment		Output		Weighted Average Multipliers	
Description	**Total**	**Share of Total**	**Total ($ Million)**	**Share of Total**	**Employment**	**Output**
Water Dependent Ag and Mining	6,509	9.3%	$692	6.9%	1.34	1.36
Water Dependent Manufacturing	6,619	9.4%	$2,320	23.0%	2.05	1.40
Water Dependent Commercial	12,317	17.5%	$973	9.7%	1.29	1.45
All Other (Less Water Intensive) Industries	44,791	63.8%	$6,084	60.4%	1.43	1.42

For the Washington Coastal basin, water dependent manufacturing is a significant portion of the economy based on total output (23 percent). Water dependent commercial sectors are a significant portion of the economy when looking at employment (17.5 percent). However only water dependent manufacturing sectors produce a greater number of total employment (2.05) in the basin than the weighted average of all of the less water intensive industries (1.43). But when looking at the output multipliers, water dependent commercial sectors are more significant than less water intensive industries ($1 yielding $1.45 of output in the basin compared to $1.42), with agriculture and mining and manufacturing output multipliers slightly lower.

Table 8-4: Puget Sound Basin Water Dependent Sector Strength

	Employment		Output		Weighted Average Multipliers	
Description	**Total**	**Share of Total**	**Total**	**Share of Total**	**Employment**	**Output**
Water Dependent Ag and Mining	28,213	1.0%	$3,906	0.7%	1.54	1.63
Water Dependent Manufacturing	229,894	7.9%	$148,819	25.0%	2.75	1.53
Water Dependent Commercial	522,034	17.8%	$47,237	7.9%	1.47	1.85
All Other (Less Water Intensive) Industries	2,145,857	73.3%	$395,825	66.4%	1.61	1.76

For the Puget Sound basin, water dependent manufacturing is a notable portion of the economy based on total output (25 percent). Water dependent commercial sectors are also a main driver of the economy when looking at employment (17.8 percent). These are even more significant as the Puget Sound Basin is the largest economy in the state. However only water dependent manufacturing sectors produce a greater number of total employment (2.75) in the basin than the weighted average of all of the less water intensive industries (1.61). Similarly, when looking at the output multipliers, only the water dependent commercial sectors show higher impacts than the less water intensive industries ($1 yielding $1.85 of output in the basin compared to $1.76), with agriculture and mining and manufacturing output multipliers slightly lower.

Table 8-5: Yakima Basin Water Dependent Sector Strength

	Employment		Output		Weighted Average Multipliers	
Description	**Total**	**Share of Total**	**Total ($ Million)**	**Share of Total**	**Employment**	**Output**
Water Dependent Ag and Mining	39,066	16.0%	$3,442	9.8%	1.31	1.43
Water Dependent Manufacturing	13,547	5.5%	$5,866	16.8%	2.20	1.44
Water Dependent Commercial	44,032	18.0%	$3,791	10.8%	1.35	1.56
All Other (Less Water Intensive) Industries	148,146	60.5%	$21,888	62.6%	1.56	1.52

For the Yakima basin, water dependent agriculture and mining and commercial are large sectors of the economy based on total employment (16 percent and 18 percent respectively). Water dependent manufacturing sectors are also a main driver of the economy when looking at total output (16.8 percent). Only water dependent manufacturing sectors produce a greater number of total employment in the basin (2.2 total) than the weighted average of all of the less water intensive industries (1.56). However, when looking at the output multipliers, only water dependent commercial is slightly greater than less water intensive industries ($1 yielding $1.56 of total output in the basin compared to $1.52), with agriculture and mining and manufacturing output multipliers slightly lower.

Table 8-6: Upper Columbia Basin Water Dependent Sector Strength

	Employment		Output		Weighted Average Multipliers	
Description	Total	Share of Total	Total ($ Million)	Share of Total	Employment	Output
Water Dependent Ag and Mining	44,855	21.4%	$4,680	15.7%	1.41	1.42
Water Dependent Manufacturing	14,596	7.0%	$6,750	22.6%	2.33	1.43
Water Dependent Commercial	29,852	14.3%	$2,508	8.4%	1.31	1.46
All Other (Less Water Intensive) Industries	120,105	57.4%	$15,898	53.3%	1.46	1.45

For the Upper Columbia basin, water dependent agriculture and mining and commercial are large sectors of the economy based on total employment (21 percent and 14 percent respectively). Water dependent manufacturing sectors are also a main driver of the economy when looking at total output (23 percent). Only water dependent manufacturing sectors produce a greater number of total employment in the basin (2.33) than the weighted average of all of the less water intensive industries (1.46). However, when looking at the output multipliers, all are virtually the same, with water dependent commercial slightly greater than less water intensive industries ($1 yielding $1.46 of output in the basin compared to $1.45), and agriculture and mining and manufacturing output multipliers slightly lower.

Table 8-7: Middle Columbia Basin Water Dependent Sector Strength

	Employment		Output		Weighted Average Multipliers	
Description	Total	Share of Total	Total ($ Million)	Share of Total	Employment	Output
Water Dependent Ag and Mining	7,591	14.9%	$691	8.5%	1.29	1.36
Water Dependent Manufacturing	5,472	10.8%	$2,662	32.9%	2.01	1.31
Water Dependent Commercial	8,394	16.5%	$726	9.0%	1.30	1.45
All Other (Less Water Intensive) Industries	29,341	57.8%	$4,015	49.6%	1.42	1.43

For the Middle Columbia Basin, water dependent agriculture and mining and commercial are large sectors of the economy based on total employment (15 percent and 17 percent respectively). Water dependent manufacturing sectors are also a highly significant driver of the economy when looking at total output (33 percent). Water dependent manufacturing sectors produce a greater number of total employment in the basin (2.01) than the weighted average of all of the less water intensive industries (1.42). However, when looking at the output multipliers, only water dependent commercial sectors are slightly greater than less water intensive industries ($1 yielding $1.45 of output in the basin compared to $1.43), with agriculture and mining and manufacturing output multipliers lower.

Table 8-8: Lower Columbia Basin Water Dependent Sector Strength

	Employment		Output		Weighted Average Multipliers	
Description	Total	Share of Total	Total ($ Million)	Share of Total	Employment	Output
Water Dependent Ag and Mining	4,529	1.9%	$426	1.0%	1.31	1.39
Water Dependent Manufacturing	20,905	8.6%	$11,787	28.0%	2.03	1.26
Water Dependent Commercial	47,441	19.4%	$4,354	10.3%	1.34	1.47
All Other (Less Water Intensive) Industries	171,582	70.2%	$25,592	60.7%	1.51	1.41

For the Lower Columbia Basin, water dependent commercial sectors are key sectors of the economy based on total employment, with over 19 percent of all sectors. Water dependent manufacturing sectors are also a highly significant driver of the economy when looking at total output (28 percent). Only water dependent manufacturing sectors produce a greater number of total employment in the basin (2.03) than the weighted average of all of the less water intensive industries (1.51). However, when looking at the output multipliers, only water dependent commercial sectors are slightly greater than less water intensive industries ($1 yielding $1.47 of output in the basin compared to $1.41), with agriculture and mining and manufacturing output multipliers lower.

Table 8-9: Lower Snake Basin Water Dependent Sector Strength

	Employment		Output		Weighted Average Multipliers	
Description	Total	Share of Total	Total ($ Million)	Share of Total	Employment	Output
Water Dependent Ag and Mining	1,974	5.2%	$344	4.9%	1.32	1.27
Water Dependent Manufacturing	3,743	9.8%	$1,233	17.6%	1.49	1.23
Water Dependent Commercial	5,371	14.1%	$410	5.9%	1.16	1.29
All Other (Less Water Intensive) Industries	27,045	70.9%	$5,002	71.6%	1.36	1.27

For the Lower Snake Basin, water dependent commercial industries are large sectors of the economy based on total employment, with just over 14 percent of all employment. Water dependent manufacturing sectors are also a highly significant driver of the economy when looking at total output (nearly 18 percent). Water dependent manufacturing sectors produce a greater number of total employment in the basin (1.49) than the weighted average of all of the less water intensive industries (1.36). However, when looking at the output multipliers, all are virtually the same, with water dependent commercial slightly greater than less water intensive industries ($1 yielding $1.29 of output in the basin compared to $1.27), and agriculture and mining and manufacturing output multipliers slightly lower.

Table 8-10: Kootenai-Pend Oreille-Spokane Basin Water Dependent Sector Strength

	Employment		Output		Weighted Average Multipliers	
Description	Total	Share of Total	Total ($ Million)	Share of Total	Employment	Output
Water Dependent Ag and Mining	3,621	1.3%	$318	0.8%	1.33	1.47
Water Dependent Manufacturing	16,425	6.0%	$6,131	16.0%	2.37	1.53
Water Dependent Commercial	58,616	21.4%	$5,291	13.8%	1.56	1.82
All Other (Less Water Intensive) Industries	194,682	71.2%	$26,671	69.4%	1.74	1.74

For the Kootenai-Pend Oreille-Spokane basin, water dependent commercial sectors are key sectors of the economy based on total employment, with over 21 percent of all basin employment. Water dependent manufacturing and commercial sectors are also highly significant drivers of the economy when looking at total output (16 percent and 14 percent respectively). Only water dependent manufacturing sectors produce a greater number of total employment in the basin (2.37) than the weighted average of all of the less water intensive industries (1.74). However, when looking at the output multipliers, only water dependent commercial sectors are greater than less water intensive industries ($1 yielding $1.82 of output in the basin compared to $1.74), with agriculture and mining and manufacturing output multipliers lower.

Each of the basins have different economic compositions so the impact on water dependent sectors varies by basin. Table 8-11 presents the employment and output multipliers as well as total employment and output details for water dependent sectors.

Table 8-11: Basin Comparison of Water Dependent Multipliers and Industry Details

	Water Dependent Employment Multipliers			Water Dependent Output Multipliers			Water Dependent Industry Detail	
Basin	Ag and Mining	Manu-facturing	Commercial	Ag and Mining	Manu-facturing	Commercial	Employment (Share of total)	Output ($Million) (Share of total)
Washington Coastal	1.34	2.05	1.29	1.36	1.40	1.45	25,444 (36.2%)	$3,984 (39.6%)
Lower Columbia	1.31	2.03	1.34	1.39	1.26	1.47	72,876 (29.8%)	$16,566 (39.3%)
Middle Columbia	1.29	2.01	1.30	1.36	1.31	1.45	21,458 (42.2%)	$4,079 (50.4%)
Upper Columbia	1.41	2.33	1.31	1.42	1.43	1.46	89,303 (42.6%)	$ 13,938 (46.7%)
Puget Sound	1.54	2.75	1.47	1.63	1.53	1.85	780,141 (26.7%)	$199,962 (33.6%)
Lower Snake	1.32	1.49	1.16	1.27	1.23	1.29	11,088 (29.1%)	$1,987 (28.4%)
Kootenai-Pend Oreille-Spokane	1.33	2.37	1.56	1.47	1.53	1.82	78,662 (28.8%)	$11,740 (30.6%)
Yakima	1.41	2.33	1.31	1.43	1.44	1.56	96,645 (39.5%)	$13,099 (37.4%)
Total	N/A	N/A	N/A	N/A	N/A	N/A	1,175,617 (29.0%)	$ 265,355 (34.6%)

Middle Columbia and Upper Columbia Basins each have a large share of their industry in water dependent sectors (greater than 40 percent) using both employment and output metrics. Improving the water supply would strengthen water-dependent sectors, indicating that investment in water infrastructure in these basins would strengthen a larger portion of the economy than in other basins with a lower water-dependent share of the economy. The Kootenai-Pend Oreille-Spokane basin has the lowest share of water dependent industry employment and output (30 percent or lower for both metrics). This indicates that investment in water infrastructure in this basin would not yield as great a benefit as in each of the other basins in Washington. The other basins are all relatively strong in water dependent sectors, at between 30 and 40 percent using both metrics. When looking at multiplier impact, water dependent manufacturing is consistently stronger than the agriculture and mining and the commercial sectors, with all basins except Lower Snake achieving employment multipliers greater than 2.0, meaning each additional employee in these sectors will, on average, provide more than another additional employee elsewhere in the economy. Lower Snake only has a 1.49 multiplier. The Puget Sound basin consistently provides the largest impact when looking at water dependent output multipliers, with 1.63, 1.53, and 1.85 on average, respectively for agriculture and mining, manufacturing, and commercial sectors. This indicates a powerful impacts on employment throughout the basin economy when investing in water infrastructure in the Puget Sound Basin.

8.3 Fisheries

An Economic Analysis of the Non-Treaty Commercial and Recreational Fisheries, conducted in 2008 for the Washington Department of Fish and Wildlife[307] found that commercial and recreational fishing directly and indirectly contributed to 16,374 jobs and $540 million in income. This is equivalent to 0.4 percent of statewide employment. This study focused on data from 2006, when harvest value from Washington Fisheries totaled approximately 110 million pounds, or $65.1 million in ex-vessel value (the "price received by commercial fishers for fish landed at the dock"), excluding offshore fishing, aquaculture, and excluded catch area. Shellfish harvest value totaled $41.1 million, while groundfish ($9.6 million) and salmon ($9.5 million) contributed most of the remaining share. In total, including in-state-processing, the wholesale value of these products totaled $101 million in 2006. Of the $101 million in wholesale value, roughly 61 percent is from groundfish species, and 21 percent is from shellfish. The net economic value (NEV) for harvesters and processers is estimated to be $38 million, of which 46 percent is due to shellfish, and 32 percent to groundfish. The study notes that "While NEV is positive in the aggregate, it may mask what is happening at an individual fishery level or business level". In 2006, many of the losses for particular fisheries or harvesters were offset by the profits of others.

The number of full and part-time jobs, estimated using Bureau of Economic Analysis data, total 3,524, creating a total personal income of $148 million ($89 million from harvesting activities and $59 million from processing).

The study notes that "The economic effects generated by harvests from Washington waters represent a small part of Washington's economy, but are important at the community level along the Washington Coast, the Strait of Juan de Fuca, and the Puget Sound areas". At the County level, Gray's Harbor (including Aberdeen, Bay City, and Westport) contributes the most value from commercial fish landings (almost 30 percent of total), with Whatcom (Bellingham Bay, Blaine, and Point Roberts) producing 21 percent and King (Seattle) contributing 9 percent.

The study notes that recreational fisheries, including both resident and non-resident anglers, contribute $376 million to statewide income, roughly $230 million more than commercial fishing.

Data from the Bureau of Labor Statistics308 reinforces that although the commercial fishing industry is small in relation to Washington's economy, the fishing industry is vital to the

[307] TCW Economics. Economic Analysis of the Non-Treaty Commercial and Recreational Fisheries in Washington State. Prepared for the Washington Department of Fish and Wildlife. December 2008. Accessible at http://wdfw.wa.gov/publications/00464/wdfw00464.pdf

[308] Bureau of Labor Statistics. Quarterly Census of Employment and Wages. 2015 Annual Averages, Fishing, All Counties in Washington, All establishment sizes. Updated June 2016. Accessible at http://data.bls.gov/cew/apps/data_views/data_views.htm#tab=Tables

economy of particular counties. For example, in 2015, the annual average employment location quotient for commercial fishing is 77.74 in Grays Harbor County and 891.83 in Pacific County. Similarly, the total annual wages location quotient is 72.69 in Grays Harbor County and 726.2 in Pacific County. Further, the commercial fishing industry in Washington is a vital component of the commercial fishing industry in the United States. Total annual wages for commercial fishing in King County ($91 million) comprise 21 percent of total annual wages for commercial fishing in the United States as a whole. And all of Washington's commercial fishing operations comprise more than a quarter of total annual wages for commercial fishing in the United States.

A 2016 report by the National Oceanic and Atmospheric Administration (NOAA)[309] estimates that the seafood industry in Washington generated $7.3 billion in sales, $2 billion in income, $3 billion in value added impact, and 63,000 jobs. Note that this study incorporates commercial harvesting, seafood processing and dealing, seafood wholesale and distribution, importing, and seafood retail, which is a larger scale than the Washington Department of Fish and Wildlife (WDFW) study from 2008.

8.4 Infrastructure Construction Impacts

When infrastructure investment takes place in a basin, construction sectors are impacted. Table 8-12 shows the summary of the impact from applying IMPLAN multipliers for both employment and output for the consolidated construction sector to the total infrastructure needs by basin as identified in Chapter 6. These provide an idea of the full impact to the economy from the basin-specific construction investment for each basin on an average annual basis for employment. It is important to keep in mind not all projects are expected to occur equally over 20 years. This is a simplified way to assess the 20-year projection (2017-2036) by estimating an average for each year. Final demand or output is presented for both an annual average and a total 20-year study period. As expected, the greatest impact occurs within Puget Sound, where the infrastructure need is the highest at over $23 billion for the full projection period, or on average $1,188 million annually. That investment would add over 12,000 employees the first year and is expected to sustain that employment level with an annual infusion of over $2 billion into the basin-wide economy, with an expected 20-year total of over $42 billion. The Puget Sound basin, when compared to the other basins within the state, would receive the greatest economic impact. On the lowest end is the Kootenai-Pend Oreille-Spokane basin with total infrastructure needs identified of $11 million, or on average $0.6 million annually, leading to an additional 7 jobs and $1 million infused into the basin economy annually. Over the full 20-year projection period a total of $20 million injection into the economy would be expected. Therefore the Kootenai-Pend Oreille-Spokane basin would receive the smallest economic impact from the full infrastructure needs investment from construction of the projects, compared to all of the other basins. Each of the other basins would receive impacts between these two extremes from construction of the infrastructure projects indicated as needed for each basin.

[309] NOAA. NOAA Technical Memorandum NMFS-F/SPO-163. Fisheries Economics of the United States, 2014: Pacific Region. May 2016. Accessible at https://www.st.nmfs.noaa.gov/Assets/economics/publications/FEUS/FEUS-2014/Report-and-chapters/FEUS-2014-FINAL-04-Pac-V2.pdf

Table 8-12: Employment, and Output increases Associated with Identified Infrastructure Investment Projects

Basin	Total Infrastructure needs ($Million)	Average Annual Investment Needs ($Million)	Increased Average Annual Employment	Increased Annual Final Demand or Output ($Million)	Total 20-year Increased Final Demand or Output ($Million)
Washington Coastal	$1,802	$90	953	$132	$2,638
Lower Columbia	$1,439	$72	650	$101	$2,017
Middle Columbia	$771	$39	383	$54	$1,083
Upper Columbia	$886	$44	457	$66	$1,310
Puget Sound	$23,754	$1,188	12,293	$2,150	$42,995
Lower Snake	$214	$11	96	$14	$283
Kootenai-Pend Oreille-Spokane	$11	$0.6	7	$1	$20
Yakima	$2,439	$122	1,238	$187	$3,734
Total State	**$31,316**	**$1,566**	**$16,077**	**$2,704**	**$54,079**

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Chehalis River	Chehalis Basin Habitat Restoration and Flood Control, WDFW, 2015	http://wdfw.wa.gov/about/legislative/2015/chehalis_basin.pdf	January 2015
Chehalis River	Impact of Climate Variability and Climate Change on Transportation Systems and Infrastructure in Pacific Northwest, Alan Hamlet, 2012.	http://cses.washington.edu/db/pdf/hamlettransportation743.pdf	March 2012
Chehalis River	Shoreline Restoration Plan, Grays Harbor County, prepared by Watershed Company, 2015	http://ghcsmp.org/library/GHCo%20Restoration%20Plan%2006-30-15.pdf	June 2015
Puget Sound	2015 State of the Sound - Report on the Puget Sound Vital signs	https://pspwa.app.box.com/v/2015-sos-vitalsigns-report	May 2014
Puget Sound	2015 State of the Sound - Report to the Governor and Legislature	https://pspwa.app.box.com/v/2015-sos-governor-report	2015(no date)
Puget Sound	Puget Sound Acquisition and Restoration (PSAR) projects	https://app.box.com/s/5h7adnq2hd7u3srmiqqd	November 12, 2015
Puget Sound	2014/15 Action Agenda for Puget Sound	http://www.psp.wa.gov/downloads/2014_action_agenda/Final%202014%20action%20agenda%20update/2014-2015_Action_Agenda_for_Puget_Sound.pdf	May 1, 2014
Puget Sound	2016 Action Agenda Comprehensive Plan	http://psp.wa.gov/action-agenda-document.php	June 2016
Puget Sound	2016 Action Agenda Implementation Plan	http://psp.wa.gov/action-agenda-document.php	June 2016
Spokane-Pend Orielle-Kootenai	Watershed Management - Lower Spokane	http://www.ecy.wa.gov/programs/eap/wrias/Planning/54.html	updated
Spokane-Pend Orielle-Kootenai	Watershed Management Plan - WRIA 55 (Little Spokane River) and WRIA 57 (Middle Spokane River)		January 31, 2006
Spokane-Pend Orielle-Kootenai	Water Resources Watershed Plan Implementation and Flow Achievement Plan	http://www.ecy.wa.gov/programs/wr/funding/pdfs/WRPIFA-1517-SCUWRS-00039.pdf	July 1, 2015

APPENDIX B
WORKSHOP MATERIALS

a. Workshop Notification

b. Workshop Format/Program

c. Workshop Presentations

d. Workshop Participants

Washington State Senate

Dear Water Resource Stakeholders:

Washington State Senators Honeyford and Keiser invite you to attend one of two state-level public workshops to provide input on an economic analysis of proposed major water infrastructure and fisheries habitat restoration investments in Washington state. The workshop agenda is attached.

Thursday, September 22
3:30 – 7:00 pm
Southeast Community Center
1211 S 7th St,
Yakima, WA 98901

Thursday, September 29
3:30 – 7:00 pm
Edmonds Community College
20000 68th Ave. W
Lynnwood, WA 98036

This analysis was initiated as a result of bi-partisan legislation to inform policy decisions about the scale and timing of new investments in flood reduction, storm water/water quality, and water supply. Our goal is to understand the economic consequences of investing – and not investing - in water infrastructure and fisheries habitat across the state. The results of this study will be used to inform state budget decisions.

This is your opportunity to participate. We will be presenting preliminary results of a water investment needs assessment for the next 20 years and will be seeking your input on two fundamental topics:

1. Have we captured all the major water infrastructure and fisheries habitat restoration projects that are known to be proposed or likely to be proposed in the next 20 years? And,

2. How do you interpret the economic opportunities of these investments and the economic consequences of failing to invest in specific projects?

As water demands grow and change, it is important that we use state resources in a thoughtful and cost effective manner. The results of this project will play a major role in shaping water infrastructure investment and fisheries habitat decisions into the future.

If you are interested in the genesis of this effort, please see Engrossed Substitute House Bill 2380 (ESHB 2380)[1]

If you cannot attend but would like to provide input, please call the project consultant, Ramboll Environ before October 10th. Contact Rabia Ahmed at rahmed@ramboll.com., or Sam Leick at sleick@ramboll.com.

[1] http://lawfilesext.leg.wa.gov/biennium/2015-16/Pdf/Bills/Session%20Laws/House/2380-S.SL.pdf

Please feel free to share this opportunity with anyone you know of who might be interested.

Thank you in advance for your interest and participation,

Senator Jim Honeyford, 15th District

Senator Karen Keiser, 33rd District

Public Workshop and Open House

Economic Analysis of Water Infrastructure Investment in Washington State

3:30 – 7:00 pm
WORKSHOP AGENDA

The tentative format for the workshops will involve three stations where participants can view exhibits in each of the subject matter areas. Focus groups will be held for those who wish to participate. Two identical sessions are scheduled at each workshop to accommodate different stakeholder schedules.

SESSION I

3:30 Introductions and Project Overview

3:40 Q&A

3:50 Open House: View Exhibits, Project Lists

4:15 – 5:00 Focus Groups

- Flood and Habitat Restoration
- Storm water/Wastewater and Habitat Restoration
- Water Supply and Habitat Restoration

SESSION 2

5:30 Introductions and Project Overview

5:40 Q&A

5:50 Open House: View Exhibits, Project Lists

6:15 – 7:00 Focus Groups

- Flood and Habitat Restoration
- Storm water/Wastewater and Habitat Restoration
- Water Supply and Habitat Restoration

ECONOMIC ANALYSIS OF WATER INFRASTRUCTURE INVESTMENT

STATE OF WASHINGTON

RAMBOLL ENVIRON

OVERVIEW

- Welcome and Workshop Agenda
- Introduction
- Today's Event
- Project Schedule
- Analytic Framework
- What We Need from You
- Ways to Participate

WELCOME TO THE WORKSHOP!

We have a lot going on today.

We are part Open House and part Focus Group and Workshop

Please ask questions throughout the open house and workshop

Thank you and we look forward to your participation.

OPEN HOUSE AND WORKSHOP AGENDA

SESSION I	SESSION 2
3:30-3:45 Open House, View Exhibits, Project Lists (participants please sign in, pick up a welcome sheet and visit stations) 3:45-4:00 Introductions and Project Overview 4:00-4:10 Q&A 4:10-4:30 Open House: View Exhibits, Project Lists 4:30-5:15 Focus Groups • Flood Risk Reduction • Water Quality and Stormwater Runoff • Water Supply and Management 5:15-5:30 Open House, View Exhibits, Project Lists	5:30-5:40 Introductions and Project Overview 5:40-5:50 Q&A 5:50-6:10 Open House, View Exhibits, Project Lists (participants please sign in, pick up a welcome sheet and visit stations) 6:10-6:50 Focus Groups • Flood Risk Reduction • Water Quality and Stormwater Runoff • Water Supply and Management 6:50 -7:00 Summary and Wrap Up

INTRODUCTION

- Ramboll Environ - Retained by Washington State Legislature to Conduct an Independent Economic Analysis of Water Infrastructure Investment in the State
  - Seven Economists, Two Aquatic Ecologists, Two Water Resource Engineers (one a certified floodplain manager), a Hydrogeologist, and others working on the project
  - International Reputation for Ecosystem Services Analysis
  - Environmental Consulting Firm based in Denmark
  - 12,000+ Employees in 35 Countries
  - Expertise in Water Resources Management and Risk Assessment
  - Experience with Large and Small Infrastructure Planning

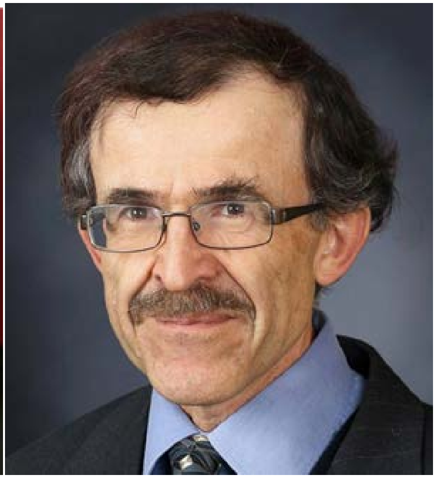
- Lisa Dally Wilson, Water Resource Engineer and Professional Facilitator

INTRODUCTIONS


Gretchen Greene


Bea Covington


Rabia Ahmed


Felix Kristanovich


Steve Roy


Jonathan Leonardsen


Lisa Dally Wilson

Regina Edwards

from Ramboll Environ

RAMBOLL ENVIRON

Dally Environmental

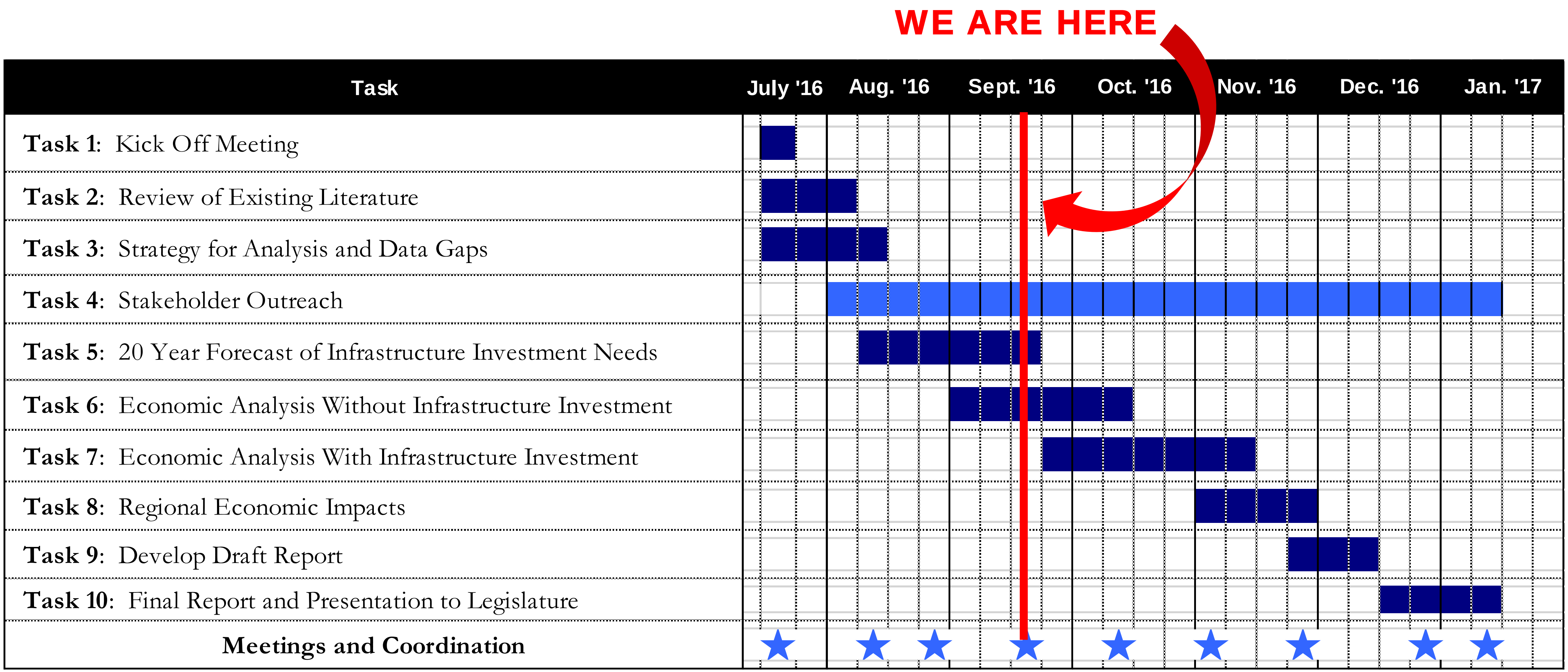
INTRODUCTION

- Economic Analysis of Water Infrastructure Investment
- State Legislature Wants to understand the Economic Consequences of Investing – and Not Investing - in Water Infrastructure
- Economic Analysis of Investments that:
  - Enhance Water Supplies
  - Mitigate the Impacts of Floods
  - Manage Storm Water
- Presently Gathering Data to Inform Our Work

OVERALL PURPOSE OF TODAY'S WORKSHOP

- Share Example Lists of Water Infrastructure Projects Already Identified
- Seek Input on Whether We Captured All the Major Water Infrastructure and Fisheries Habitat Restoration Projects:
  - Known to be Proposed over the Next 20 Years **AND**
  - ***Likely to be Needed in the Next 20 Years***
- Seek Input on How to Interpret:
  - Economic Opportunities of these Investments
  - Economic Consequences of Failing to Invest in Specific Projects

PROJECT SCHEDULE AND ACTIVITIES



ANALYSIS FRAMEWORK: TYPES OF WATER INFRASTRUCTURE INVESTMENT

- Based on the language contained in the enabling legislation, we have identified three overall categories, or “buckets” that we will use to organize the information we receive
- Within each ‘bucket,’ we have created sub-categories, or “cups” that we will use to further organize our information
- The next graphic presents the organization of buckets and cups
- Tonight's table presentations and focus groups are organized by buckets

FRAMEWORK : "BUCKETS AND CUPS" OF PROJECT TYPES

Water Supply and Management

- Agricultural and Municipal Water Storage
- Fisheries Habitat and Passage Improvements
- Instream or Out of Stream Needs
- Drought Mitigation

Flood Risk Reduction

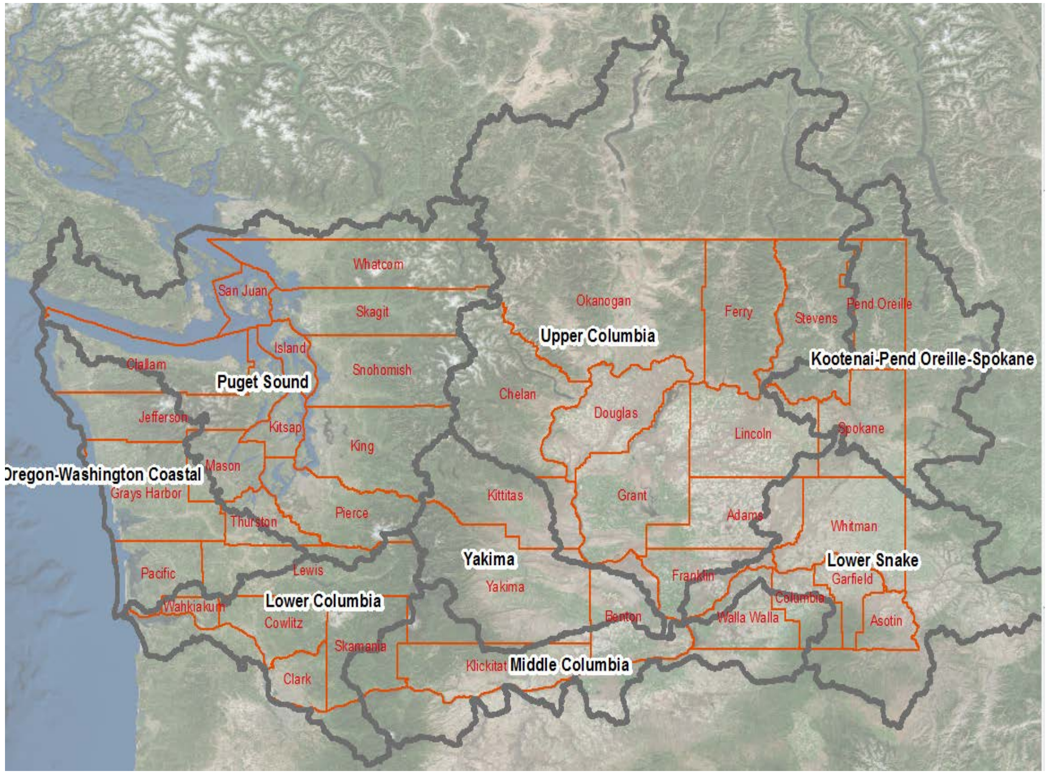
- Flood Protection
- Restoration and Protection of Naturally Functioning Areas

Water Quality and Storm Water Runoff

- Retrofits
- Point or Nonpoint Source Pollution Control
- Green/Low Impact Infrastructure
- Combined Sewer Overflow

FRAMEWORK – AREA OF ANALYSIS

- For the final economic analysis, we will be grouping the information we collect into eight basins based on Hydraulic Unit Codes (HUCs)
- We will aggregate information at the HUC 4 level as depicted in the picture to the right
- The Matrix on the next slide displays the relationships between the buckets and cups and the HUC Basins



FRAMEWORK – BUCKETS AND BASINS

Basin - Based on Level 4 Hydrologic Unit Boundaries	Water Supply & Management				Flood Risk Reduction		Water Quality & Storm Water Runoff			
	Water Storage	Fish Passage	Water Needs	Drought Mitigation	Flood Protection	Floodplain Preservation	Retrofits	Source Control	Green Infrastructure	Combined Sewer Overflow
Puget Sound										
Yakima										
Washington Coastal (Including Chehalis)										
Upper Columbia										
Middle Columbia										
Lower Columbia										
Lower Snake										
Kootenai-Pend Oreille-Spokane										

ECONOMIC ANALYSIS

- Different Kinds of Economic Analysis
  - Benefits and Costs
  - Ecosystem Services
  - Effects on Different Industries
  - Other Supply Chain Impacts
  - Stimulus to Economy
  - Quality of Life
- Many Tools
- Need Guidance on Priorities

- **Not a State Water Plan**
- **Fish are in Each Bucket**
- **All Kinds of Funding**

WHAT DO WE NEED FROM YOU

Input on Two Fundamental Topics:

1. Have We Captured All the Major Water Infrastructure and Fisheries Habitat Restoration Projects that are:
   - Known to be Proposed over the Next 20 Years
   - ***Likely to be Needed in the Next 20 years?***
2. How Do You Interpret:
   - The Economic Opportunities of these Investments?
   - The Economic Consequences of Failing to Invest in Specific Projects?

- **WAYS TO PARTICIPATE**

Communicate about Infrastructure Projects and Needs

Add to the Spreadsheet lists on the Tables at Stations

Add to the Flip Charts

Please Provide URLs and/or Contact Information with
Any Project Information

Express Your Thoughts on Economics of Investing/Not Investing

On the Comment Sheets

On 3 X 5 Cards provided during Focus Group

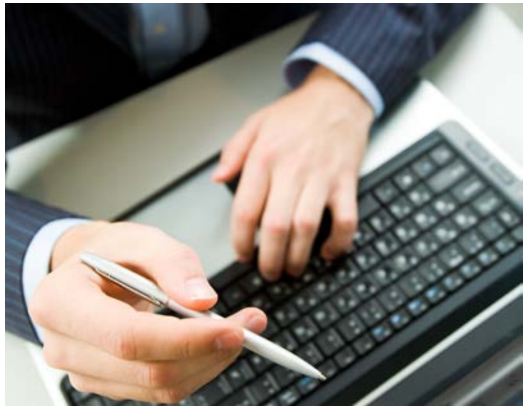
Via Email after the Workshop!

OTHER WAYS TO PARTICIPATE

- Email Written Comments
- Talk to One of Us on the Phone
- Meet with One or More of Us
- Spread the Word

Deadline for Providing Input:

October 10



QUESTIONS?

Contact:

Gretchen Greene

D +1 360 608 1975

ggreene@ramboll.com

Ramboll Environ
400 E Evergreen Blvd.
Suite 304
Vancouver WA 98660
USA
www.ramboll-environ.com

THANK YOU!

RAMBOLL ENVIRON

Workshops to Obtain Input on the Economic Analysis of Water Infrastructure Investment in WA
List of Attendees

Name	Title/Position	Organization	Workshop Attended
Amanda Cronin	Project Manager	Washington Water Trust	Lynnwood
John Phillips	President-Elect	King County	Lynnwood
Joe Scordino	Consultant		Lynnwood
Ann Soule	Resource Manager	Public Works City of Sequim	Lynnwood
Steve Nelson		RH2	Lynnwood
Mike Wert	Senior Associate	David Evans and Associates, Inc	Lynnwood
Sarah Brandt	Senior Associate	enviroissues	Lynnwood
Jason Mulvihill-Kuntz	Salmon Recovery Manager	Lake Washington / Cedar / Sammamish Watershed (WRIA 8)	Lynnwood
Tom Fitzhugh	Supervising Water Resources Scientist	MWH	Lynnwood
Abbi Dorn	Principal Engineer	Brown and Caldwell	Lynnwood
Katherine Minsch	Regional Liaison	Seattle Public Utilities	Lynnwood
Doug Levy	Owner	Outcomes by Levy, LLC	Lynnwood
Jesse DeNike		Plauche & Carr	Lynnwood
Wesley Chin	Supervising Engineer	King County Stormwater Services	Lynnwood
Shelly Wilkins	Policy Analyst	Washington State Senate	Lynnwood
Morgan Torres		Ross Strategic	Lynnwood
Ron Shultz	Policy Director	Washington State Conservation Commission	Lynnwood
Mark Maurer	Water Resources and Stormwater Utility Planner	Thurston County	Lynnwood
Nona Snell	Senior Budget Assistant to the Governor	Washington State	Lynnwood
Morgan Mak	Mitigation & Recovery Strategist	Washington Military Department Emergency Management Division	Lynnwood
Diane Buckshnis	Council Member Position 4	City of Edmonds	Lynnwood
Michael Larrity	Col. Basin Manager	WDFW	Lynnwood
Brynne Walker	Annual Programs Manager	WA EMD	Lynnwood
Andy Rheaume	Planner	City of Redmond	Lynnwood
Jon Hutchings	Public Works Director	Whatcom County	Lynnwood
Karen Stewart	Everett Planner	City of Edmonds	Lynnwood
Jeremy Pratt	VP	GEI	Lynnwood
Perry Falcove	Project Coordinator	Snoqualmie Watershed Forum	Lynnwood
Damian Skenbech	Senior Engineer	Kiewit Infrastructure	Lynnwood
Rob G.		Ross Strategic	Lynnwood
Laura Butler	Policy Assistant	WSDA	Lynnwood
Chris Butlerminor	Professor		Lynnwood
C. Roberts	President	Urban Tech Systems	Lynnwood
Janakis Scevery		Pure Blue	Lynnwood
Kiza Gates	Water Science Team Lead	WDFW	Lynnwood
Don Robinett	Stormwater Manager	City of SEATAC	Lynnwood
Paula Harris	River & Flood Manager	Whatcom County	Lynnwood
Bill Clarke	Attorney		Lynnwood
Jessica Knickerbocker	PE	City of Tacoma	Lynnwood
Janne Kaje	Salmon Recovery King County Manager	King County	Lynnwood
Kevin Buckley		Settle Pulic Utilities	Lynnwood
Dave Cox	Hydrogeologist	Tetra Tech	Lynnwood
Luke Kelly	Restoration Project Manager	Trout Unlimited	Lynnwood

Name	Title/Position	Organization	Workshop Attended
Alex Mitchell	Perf. Analyst	Puget Sound Partnership	Lynnwood
Curt Crawford	Stormwater Services Manager	King County	Lynnwood
Michele Riggs	Project Manager technical services	Cedar Grove Composting	Lynnwood
Carolyn Carlstrom	Civil Engineer Technician	Landau Associates	Lynnwood
Will Hall	Director	Snohomish County SWM	Lynnwood
Greg McCaughlin	Project Manager	WWT	Lynnwood
Dustin Atchison	Project Manager	CH2M	Lynnwood
Allison Bergseng	Project Engineer	Landau Associates	Lynnwood
Santtu Winter	Project Manager	CH2M	Lynnwood
Guillaume Manger	Res. Scientist	UW Climate Impacts Group	Lynnwood
Gary Stoyka	Natural Resource Manager	Whatcom County	Lynnwood
Rachel Berryessa	Project Manager	King County	Lynnwood
David Radabaugh	NFIP Coordinator	Department of Ecology	Lynnwood
Matt Fontaine	Senior Engineer	Herrera Environmental Consultants	Lynnwood
Dawn Pucai	Lead Entity Coordinator for Salmon Recovery		Lynnwood
Danielle Shaw	Puget Sound Team		Lynnwood
Susan Saffrey	Policy Advisor	Seattle Public Utilities	Lynnwood
Mike Schwisow		WSWRA	Lynnwood
Tyler Schroeder	Deputy Exec.	Whatcom County	Lynnwood
Pat Brommer	WQ Prog.	Ecology	Lynnwood
Jim Bucknell	Project Manager	RH2 Engineering	Lynnwood
Kasia Patora	Rules & Accounting Gov. Relations	Ecology	Lynnwood
Gary Schimek	Natural Resource Manager	City of Redmond	Lynnwood
Amy Water	GS Manager	Seattle 2030 District	Lynnwood
Melissa Downes	Hydrogeologist	Office of the Columbia River, Washington State Department of Ecology	Yakima
Kristen Bettridge	Finance & Operations Manager	Office of Drinking Water, Washington State Department of Health	Yakima
Lisa Pelly	Director	Trout Unlimited	Yakima
David Ortman			Yakima
David Haire	Program Manager	Department of Natural Resources Water Resources Program	Yakima
Dave Brown	Water/Irrigation Manager	City of Yakima	Yakima
Michael Tobin	District Manager	North Yakima Conservation District	Yakima
John Foltz	Lead Entity Coordinator	Snake River Salmon Recovery	Yakima
Cory Kamphaus	Project Fisheries Biologist	Yakama Nation Fisheries	Yakima
Darryll Olsen		Columbia-Snake River Irrigators Association	Yakima
Justin Bezold	Yakima Project Manager	Trout Unlimited	Yakima
Robert Calvert		WID	Yakima
A.F. Miller		WID	Yakima
Jason Shira	Hydrogeologist	Aspect Consulting, LLC	Yakima
Donald Gotchalian	Assistant Director of Public Services	Yakima County	Yakima
Jon Culp	Program Manager	WSCC	Yakima
Eric Olson		AG	Yakima
Joel Purdy	Hydrogeologist	GeoEngineers	Yakima
Berry Harvester		WDFW	Yakima
Miles McPhee		Bumping Basin Conservation	Yakima
Saundra McPhee		Bumping Basin Conservation	Yakima

Name	Title/Position	Organization	Workshop Attended
Jerry Louthain	Engineer	HDR	Yakima
Terry Keenhan	Engineer Water Resources Manager	Yakima County	Yakima
Tom Dent	Representative	Washington State House of Representatives	Yakima
Brian Miller	RCD-YAHP	RCD	Yakima
Eleaine Packard			Yakima
Sue Ollson			Yakima
Joel Freudenthal	Sr Nat Res Spec	Yakima County	Yakima
Steve Jones	President	Colossal Or	Yakima
David Wilson	Engineer III	Snohomish County	Yakima
Rick Dieker	Manager	Yakima Tieton ID	Yakima
Henry Hu	Vice President	West Consultants	Yakima
Steve Matloch	Principal	Western Water	Yakima
Ranie Haas	Director of Regulatory & Industry Affairs	WSTFA	Yakima
Frank Lyall	President	Yakima County Farm Bureau	Yakima
Ronie Efflead		Retired WDOE	Yakima
Mike Battle	President	HLA Engineering	Yakima
Mike Livingston	Regional Director	WDFW	Yakima
Sarah Gage	Program Manager	GSRO/RCO	Yakima
Peter Dikstra	Partner	Plauche & Carr	Yakima
Judy Warnick	Senator	Washington State	Yakima
Naydene Maykot	Board Member	Friends of Bumping Lake	Yakima
David Haire	Water Resources Program Manager	CTVIR	Yakima
Jaclyn Hancock	Hydrogeologist	WSPA	Yakima
Alex Conlley		YBFWRB	Yakima
Sage Park	Regional Director	Washington State Department of Ecology	Yakima
Diana Carter	Lobbyist	Tacoma Public Utilities Cascade Water	Yakima
Jean Mendoza	Ex Director	Friends of Toppenish Creek (FOTC)	Yakima
Sandy Braden	Member	FOTC	Yakima
Mark Ewbank	Consultant Engineer	Herrera Environmental Consultants	Yakima
Ryan		Pure Blue	

APPENDIX C
PROJECT DATABASE

APPENDIX D
REGIONAL ECONOMIC IMPACT ANALYSIS

REGIONAL ECONOMIC IMPACT ANALYSIS

For the economic impact analysis IMPLAN data is the primary source of economic activity. IMPLAN data comes from various sources. Employment and wage and salary income at the state and county levels is from the Bureau of Labor Statistics (BLS). National, state and county level proprietors, proprietor income, and the relationship between employee compensation and wage and salary income (to infer benefits) are from the Bureau of Economic Analysis (BEA). Data from the U.S. Census Bureau includes the number of firms by size at the national, state, county and zip-code levels. This Appendix Cescribes the IMPLAN background and methodology.

Background on IMPLAN

IMPLAN was chosen because it requires regional data which has been compiled from multiple sources and includes hundreds of industrial sectors. In addition to being widely used in regional economic analysis, the model and its methodology has been extensively reviewed in professional and economic journals. IMPLAN was developed by the US Forest Service in cooperation with the Federal Emergency Management Agency and the Bureau of Land Management (BLM) for the purpose of land and resource management planning. For the specified region, the IMPLAN approach accounts for all of the dollar flows between the different sectors within the economy and emulates the way income injected into one sector is then spent and re-spent in other sectors of the economy, generating economic multipliers.

Using IMPLAN software and data, transaction tables are estimated for each HUC basin and the state as a whole. Each transaction table contains 526 economic sectors and provides for estimation of a variety of economic statistics including:

- Total sales - total production measured by sales revenues;
- Intermediate sales - sales to other businesses and industries within a given region;
- Final sales - sales to end users in a region and exports out of a region;
- Employment - number of full and part-time jobs (annual average) required by a given industry including self-employment;
- Regional income - total payroll costs (wages and salaries plus benefits) paid by industries, corporate income, rental income and interest payments; and
- Business taxes - sales, excise, fees, licenses and other taxes paid during normal operation of an industry (does not include income taxes).

In a regional economic impact analysis, employment, income and business taxes are the most useful variables when comparing the relative contribution of an economic sector to a regional economy. Total sales are less useful and they can be misleading because they include sales to other industries in the study area for use in the production of other goods. Thus, they tend to overstate the true economic value of goods and services produced in any economy. This makes them inconsistent with other commonly used measures of output such as Gross National Product (GNP) or GDP, which counts final sales only.

Another important distinction relates to terminology. Throughout this report, the term sector refers to economic subdivisions used in the IMPLAN database and resultant input-output models (526 individual sectors based on North American Industry Classification System Codes). Further, the term water dependent sectors refers to specific IMPLAN sectors that have been combined into three water dependent categories, Agriculture and Mining, Manufacturing, and Commercial, All IMPLAN sectors that are not included in water dependent sectors are termed all other (less water intensive) industries.

Measuring Impacts

Direct impacts indicate the initial change in economic activity due to water infrastructure development. Direct impacts capture both water industry construction activities and activities in other industries that directly support the infrastructure and water industry. Direct impacts measure the total amount of economic activity in terms of the value and employment that is injected into the local economy directly from the water infrastructure development. All eight HUC basin analyses identify and assess the impacts of the infrastructure development to the Washington regional economy.

Indirect impacts measure the response of local industries to increased demand from inter-industry transactions. The indirect impacts trace the ripple effect through the local economy as local industries increase supply due to the increase in demand generated from the water infrastructure development.

Induced impacts measure the response of local industries to the increased expenditures resulting from new household income generated from direct and indirect effects.

Direct impacts accrue to immediate businesses and industries that rely on water, and could decline without water infrastructure investments. However, output responses may vary depending upon the specific infrastructure investment needs of each basin. A small need relative to total water infrastructure investment would likely have a minimal impact, but larger needs could be critical.

Another important distinction relates to terminology. Throughout this report, the term sector refers to economic subdivisions used in the IMPLAN database and resultant input-output models (526 individual sectors based on North American Industry Classification System Codes). Further, the term water dependent sectors refers to specific IMPLAN sectors that have been combined into three water dependent categories, Agriculture and Mining, Manufacturing, and Commercial, All IMPLAN sectors that are not included in water dependent sectors are termed all other (less water intensive) industries.

Direct impacts to total sales, employment, regional income and business taxes are derived using regional level economic multipliers estimating using IMPLAN models. The formula for a given IMPLAN sector is:

$$D_{i,t} = Q_{i,t} *. S_{i,t} * EQ* RFD_i * OM_i(Q, L, 1, T)$$

where:

$D_{i,t}$ = direct economic impact to sector i in period t

$Q_{i,t}$ = total sales for sector i in period t in an affected county

RFD i,= ratio of final demand to total sales for sector i for a given region S i,t = water shortage as percentage of total water use in period t

EQ = elasticity of output and water use

OM i(L, i,r 1 = direct output multiplier coefficients for labor (L), income (I) and taxes (T) for sector i.

Indirect and induced impacts are calculated using the same formula used to estimate direct impacts, except indirect and induced multiplier coefficients are used. This study focuses on the impact to employment and output in the results section. The impacts to the water dependent sectors are presented by basin as a discussion at the industry level for water supply projects. The impacts to the economy through the physical construction of all types of water infrastructure projects is presented for all basins based on the actual identified water infrastructure needs for the 20-year period 2017-2036.